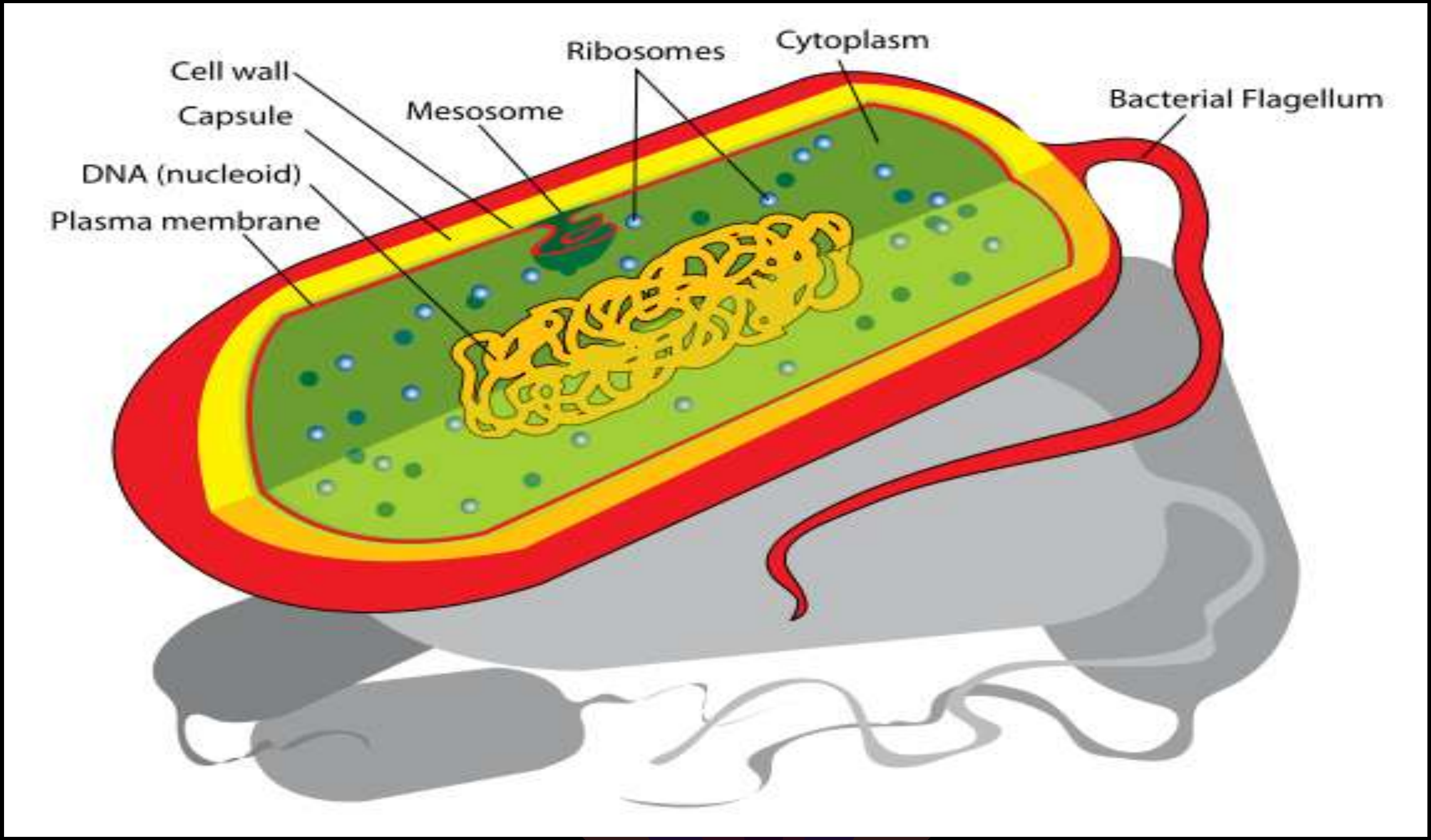
Functional and Anatomy of Bacteria



Lecture 3 Bacterial Cell Structure & Function

Cell Diagram: Mariana Ruiz, pub domain

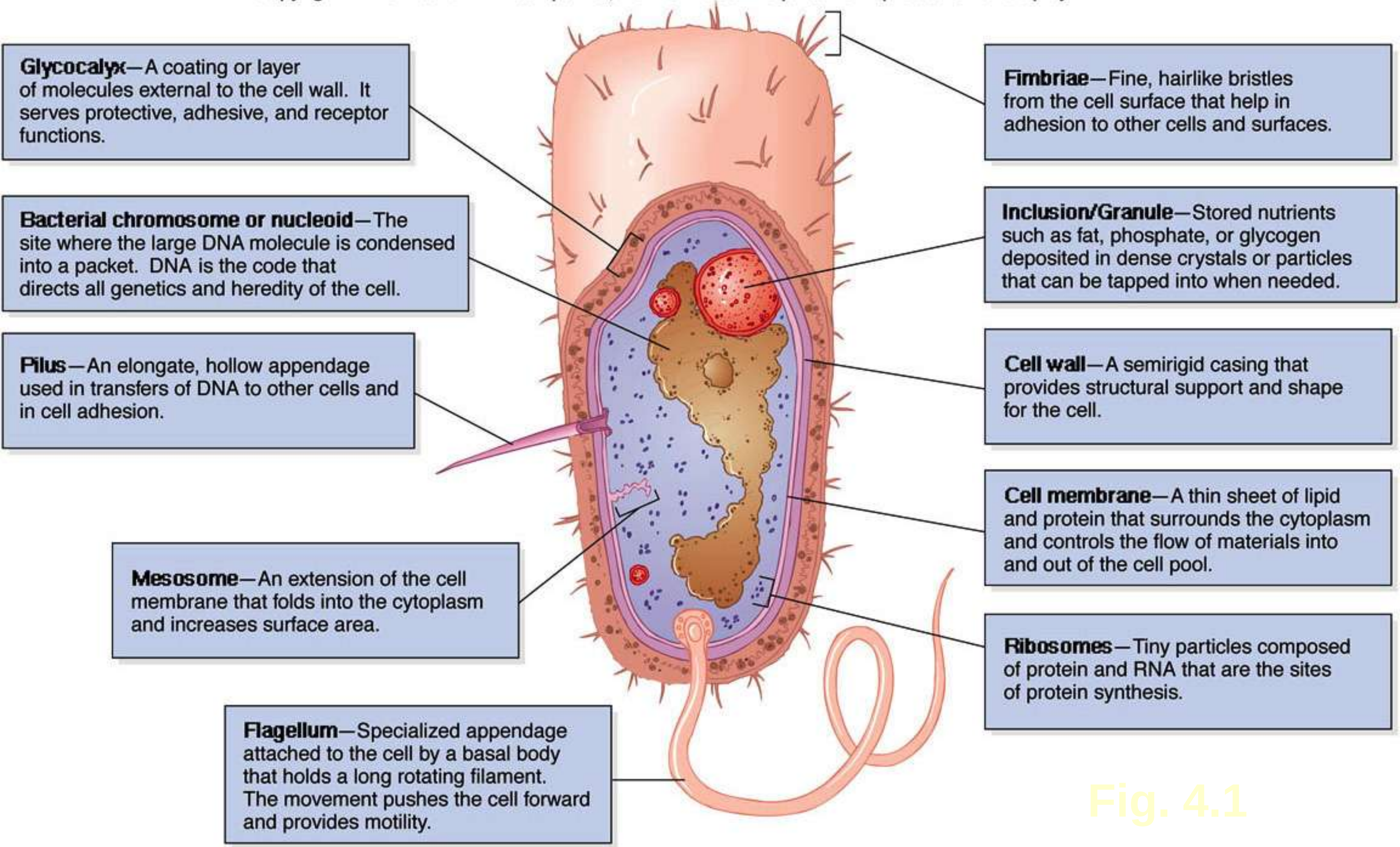

Glycocalyx—A coating or layer of molecules external to the cell wall. It serves protective, adhesive, and receptor functions.
Bacterial chromosome or nucleoid—The site where the large DNA molecule is condensed into a packet. DNA is the code that directs all genetics and heredity of the cell.
Pilus—An elongate, hollow appendage used in transfers of DNA to other cells and in cell adhesion.
Mesosome—An extension of the cell membrane that folds into the cytoplasm and increases surface area.
Flagellum—Specialized appendage attached to the cell by a basal body that holds a long rotating filament. The movement pushes the cell forward and provides motility.
Fimbriae—Fine, hairlike bristles from the cell surface that help in adhesion to other cells and surfaces.
Inclusion/Granule—Stored nutrients such as fat, phosphate, or glycogen deposited in dense crystals or particles that can be tapped into when needed.
Cell wall—A semirigid casing that provides structural support and shape for the cell.
Cell membrane—A thin sheet of lipid and protein that surrounds the cytoplasm and controls the flow of materials into and out of the cell pool.
Ribosomes—Tiny particles composed of protein and RNA that are the sites of protein synthesis.

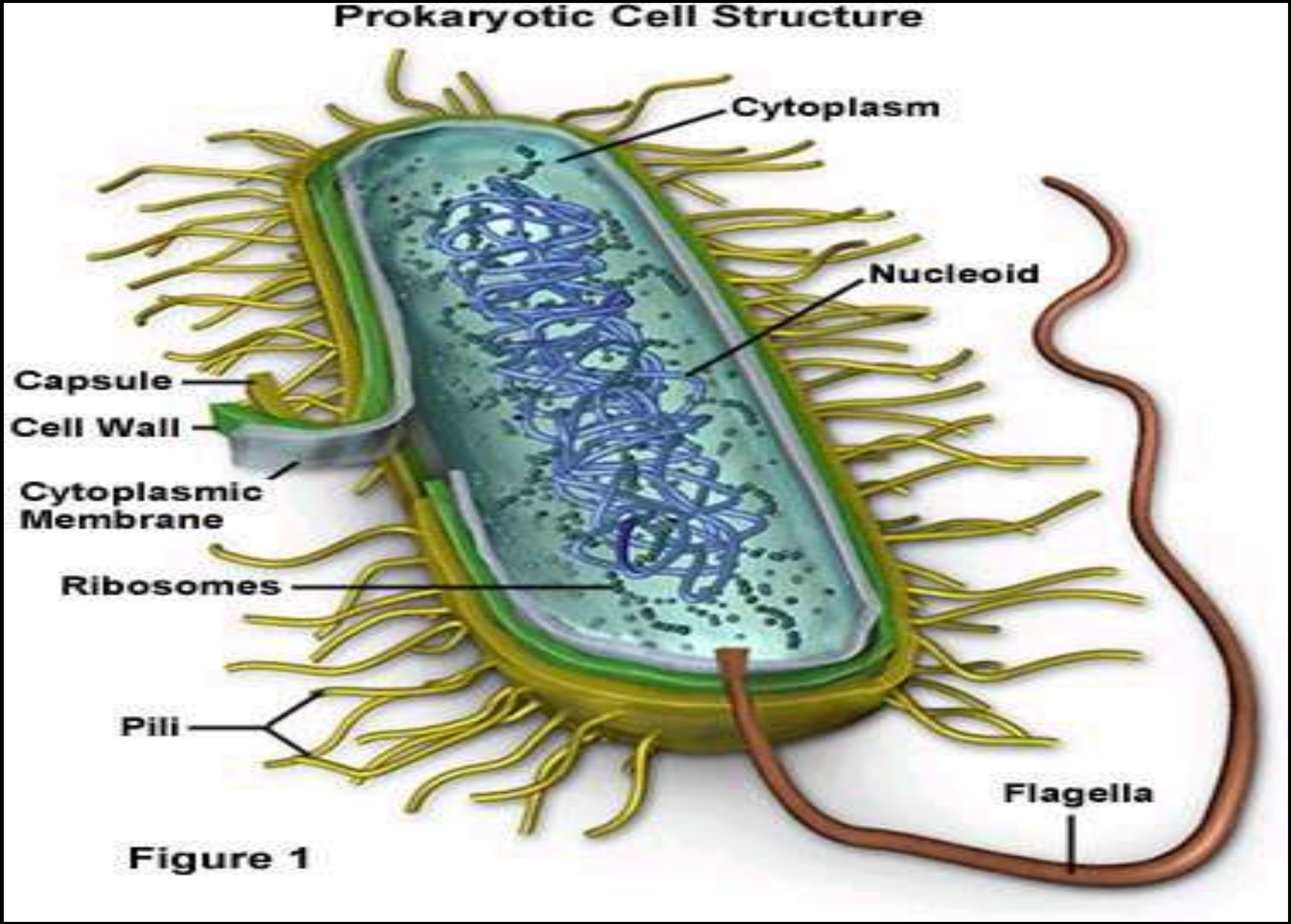
Fig. 4.1

Prokaryotic vs. Eukaryotic Cells

- Prokaryotic cells
  - No Nucleus
  - No Organelles
  - Cell Wall of peptidoglycan
  - Binary Fission
  - 1 circular chromosome

- Eukaryotic Cells
  - Nucleus
  - Organelles
  - If cell wall, Cellulose or chitin
  - Mitosis
  - Linear chromosomes

BACTERIA: Cell Structure



Prokaryotic Cell Structure

- Glycocalyx - term to describe substances that surround bacterial cells
- 1. Capsule
  - if substance is organized and firmly attached to cell wall (   )
- 2. Slime Layer
  - if substance is unorganized and loosely attached to cell wall

glycocalyx

- Coating of molecules external to the cell wall, made of sugars and/or proteins
- 2 types
    1. capsule - highly organized, tightly attached
    2. slime layer - loosely organized and attached
- functions
    - attachment
    - inhibits killing by white blood cells
    - receptor

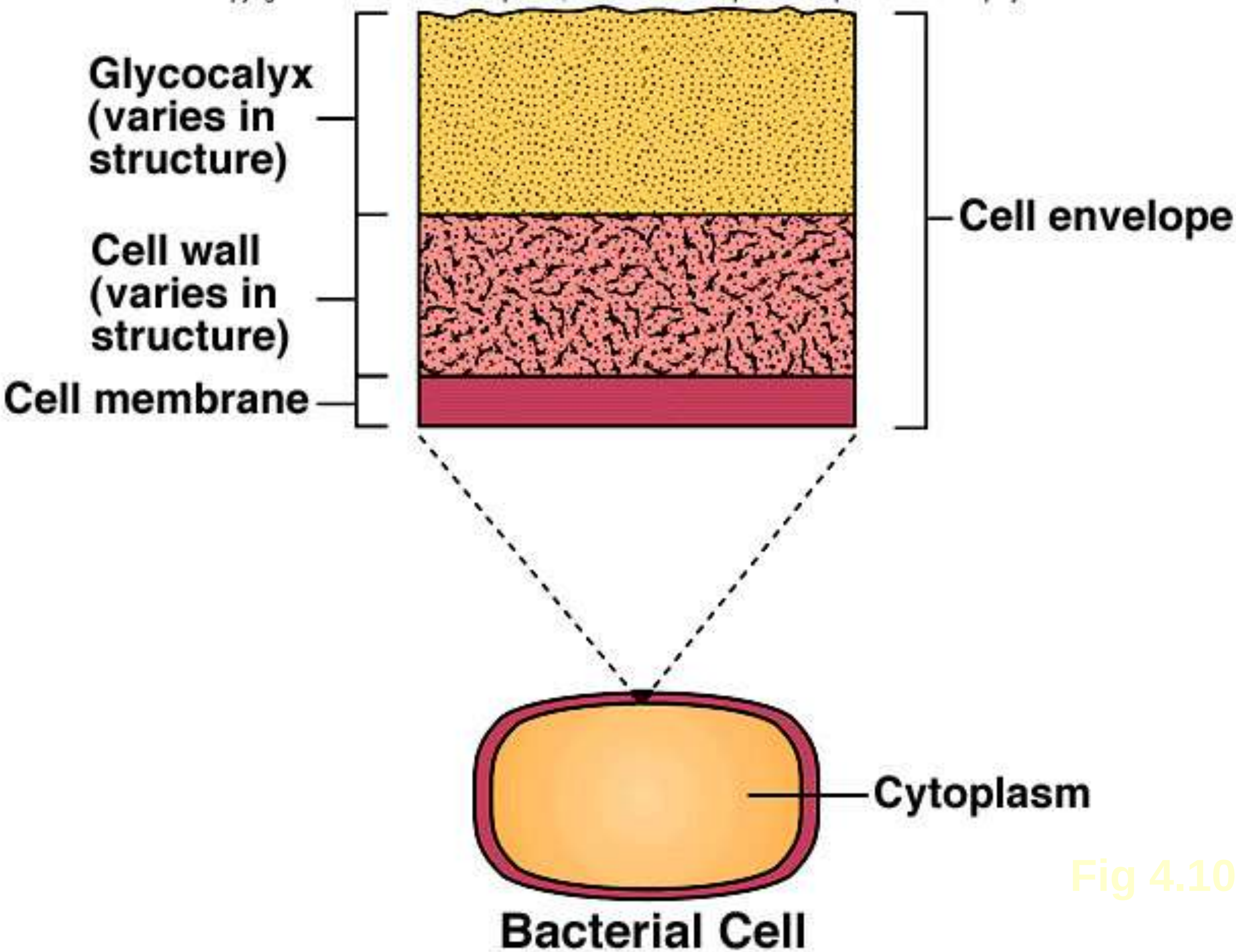
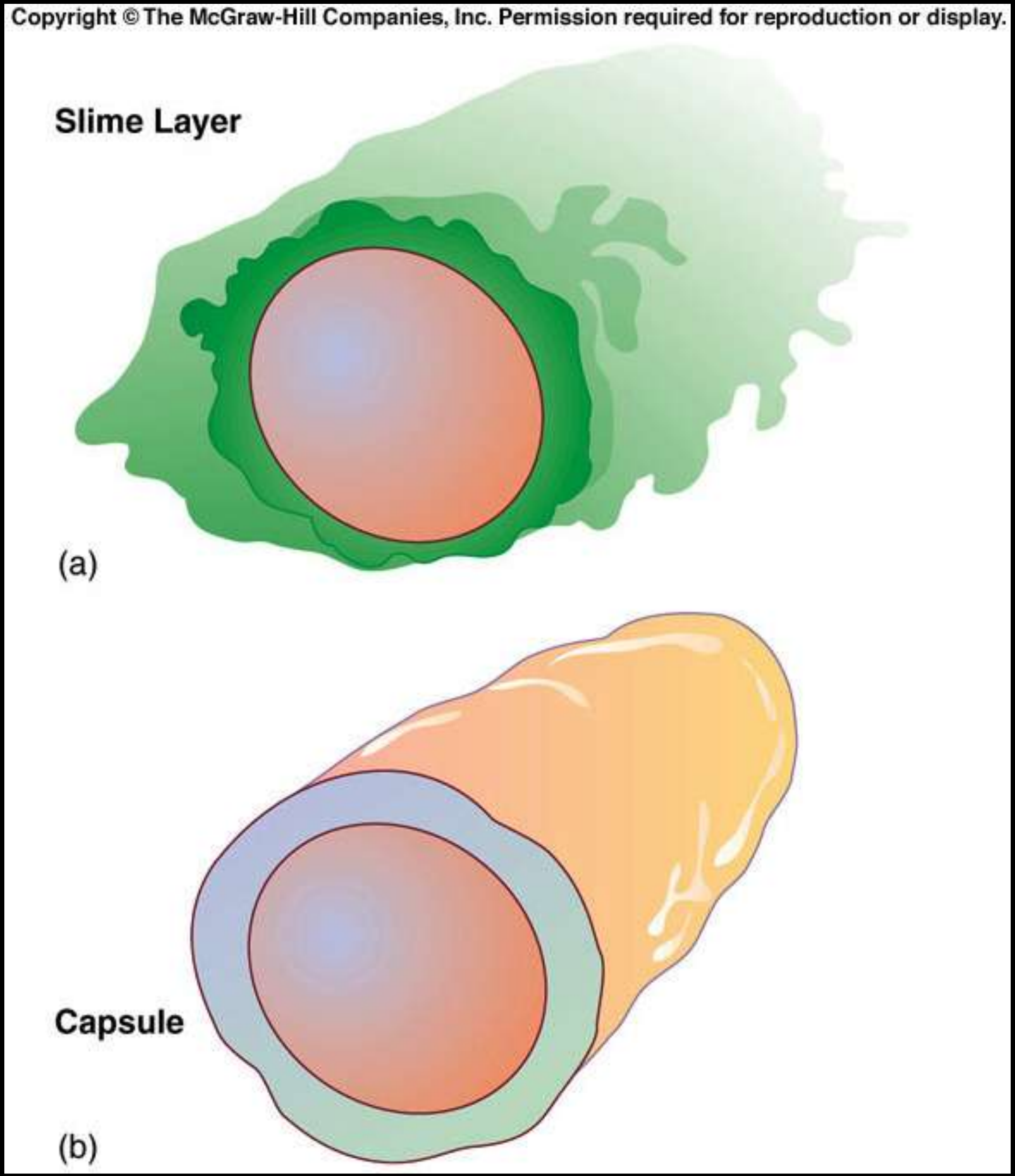
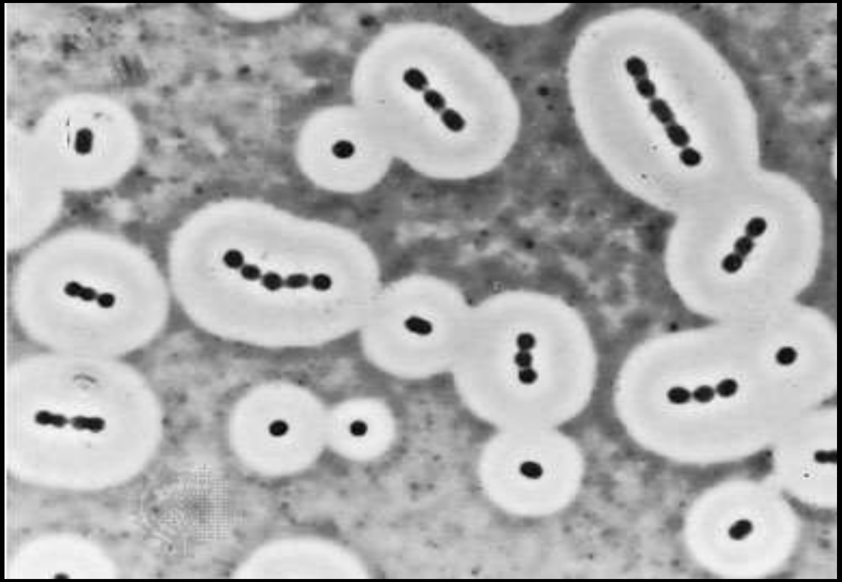

Glycocalyx (varies in structure)
Cell wall (varies in structure)
Cell membrane
Cell envelope
Cytoplasm
Bacterial Cell

Fig 4.10

2 Types of Glycocalyx



1- Capsule



Function of Capsule

1. Contribute to Virulence of bacteria by preventing phagocytosis by WBC's

A. *Streptococcus pneumoniae*

B. *Bacillus anthracis*

Functions of Capsules

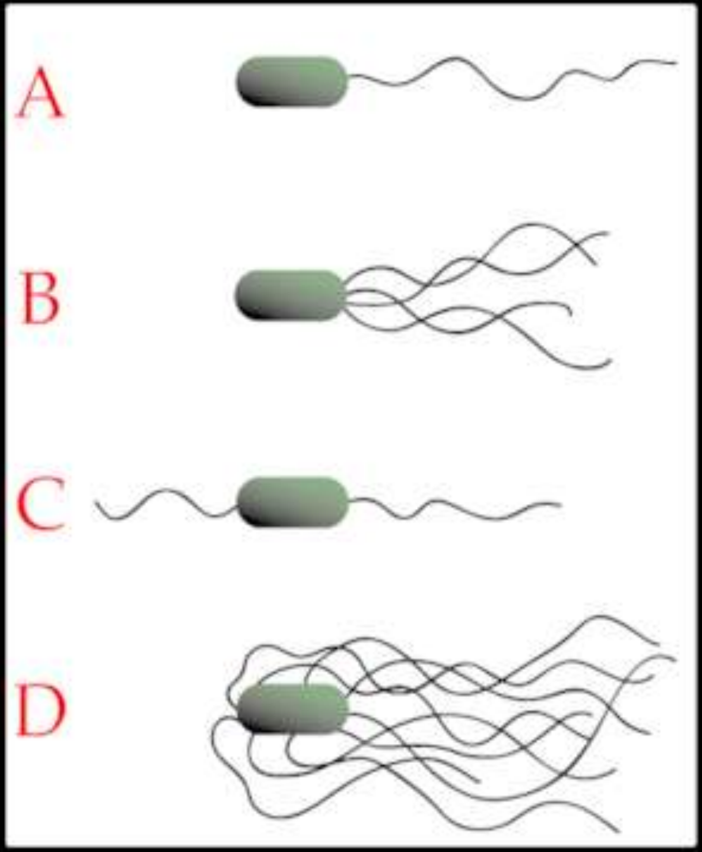
- 2. Prevents drying out or dessication
- 3. Allows bacteria to adhere to various surfaces
  - *Streptococcus mutans* - enamel on teeth to cause dental carries
  - *Klebseilla pneumoniae* - attaches to respiratory tract

Motility

- Almost all **Spiral** bacteria are **motile**
- About 1/2 of **Bacilli** are **motile**
- Almost all **Cocci** are **non-motile**

2- Flagella

- A. Monotrichous
- B. Lophotrichous
- C. Amphitrichous
- D. Peritrichous

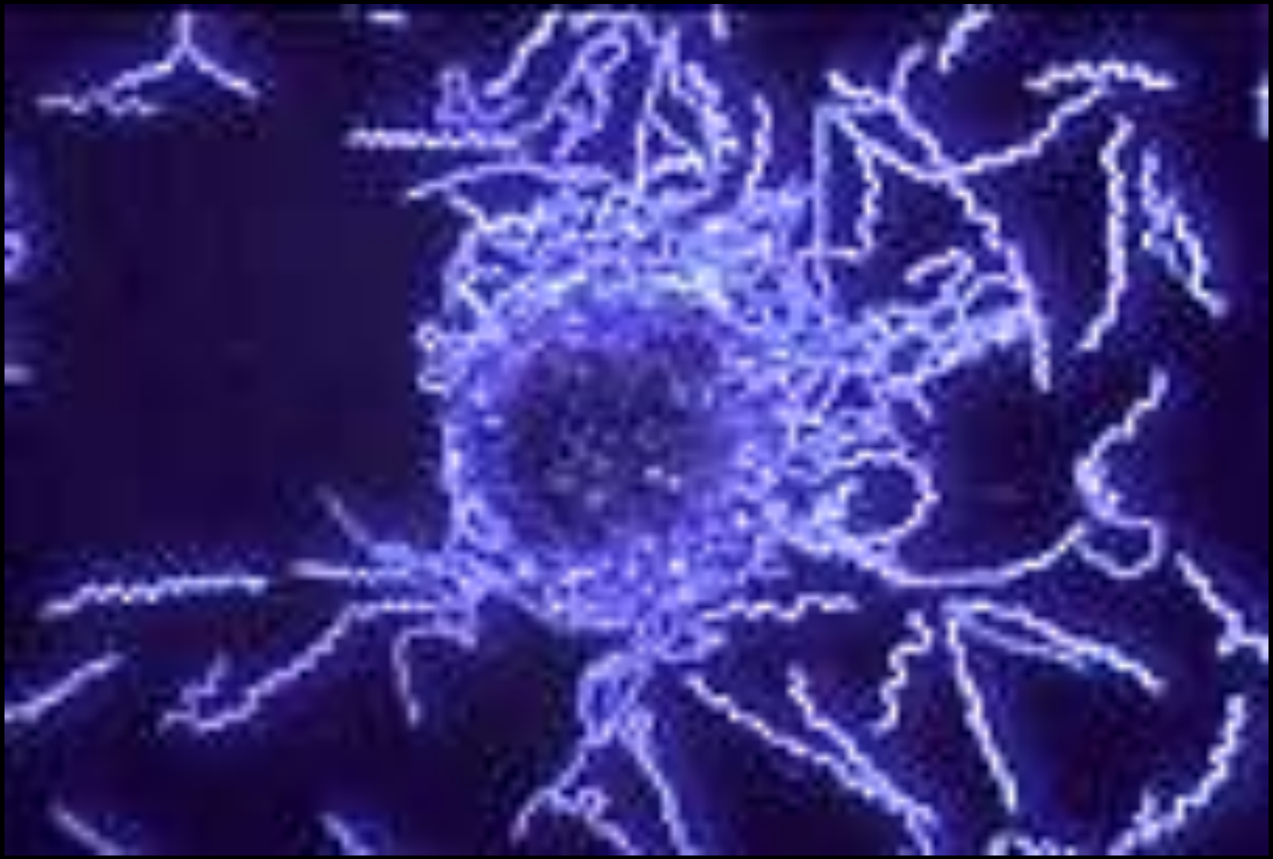


Flagellar arrangements

1. monotrichous – single flagellum at one end
2. lophotrichous – small bunches arising from one end of cell
3. amphitrichous – flagella at both ends of cell
4. peritrichous – flagella dispersed over surface of cell, slowest

Axial Filament - found only in spirochetes (flexible spirals)

Treponema pallidum

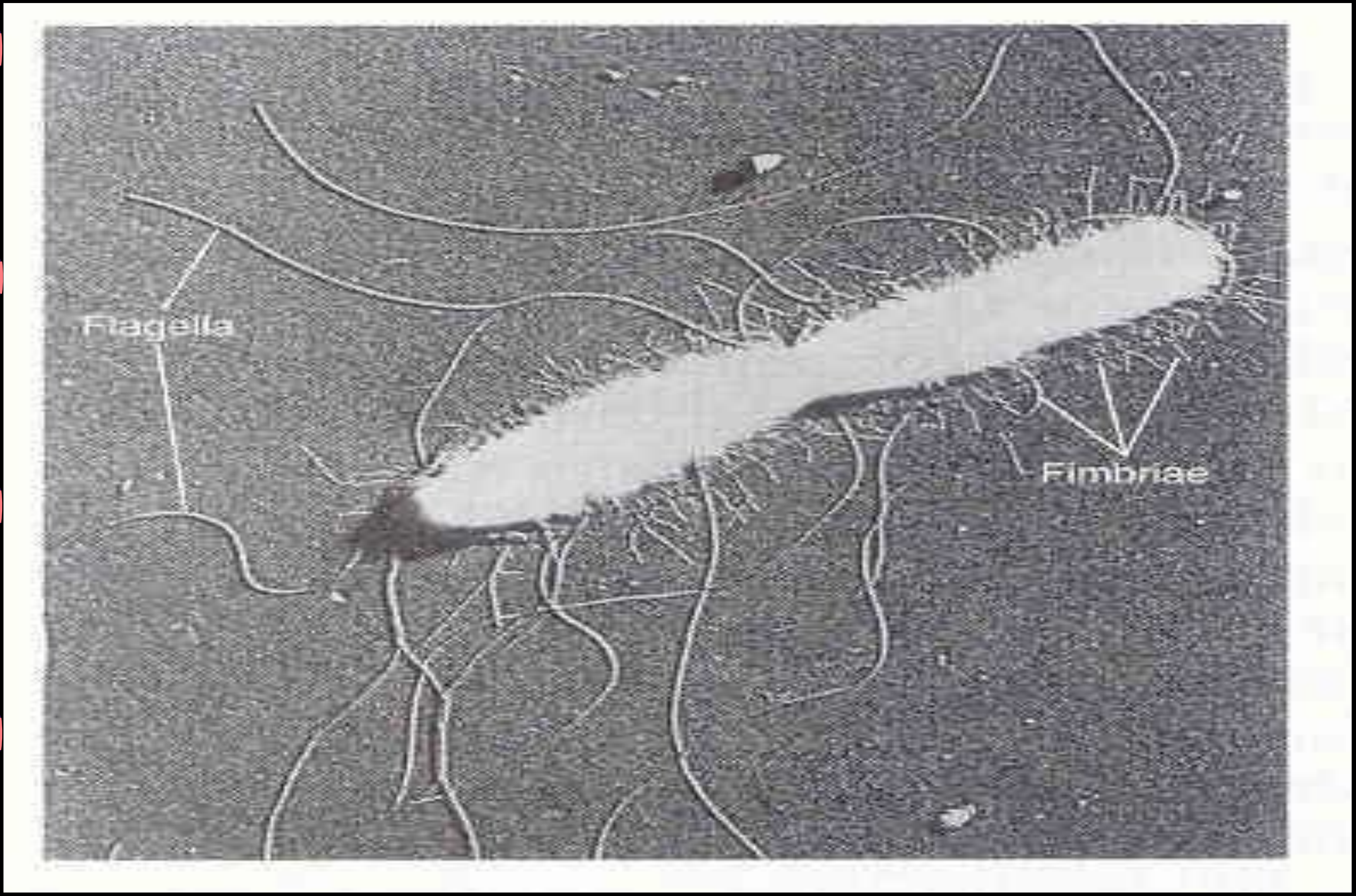


Borrelia burgdorferi

3- Fimbriae

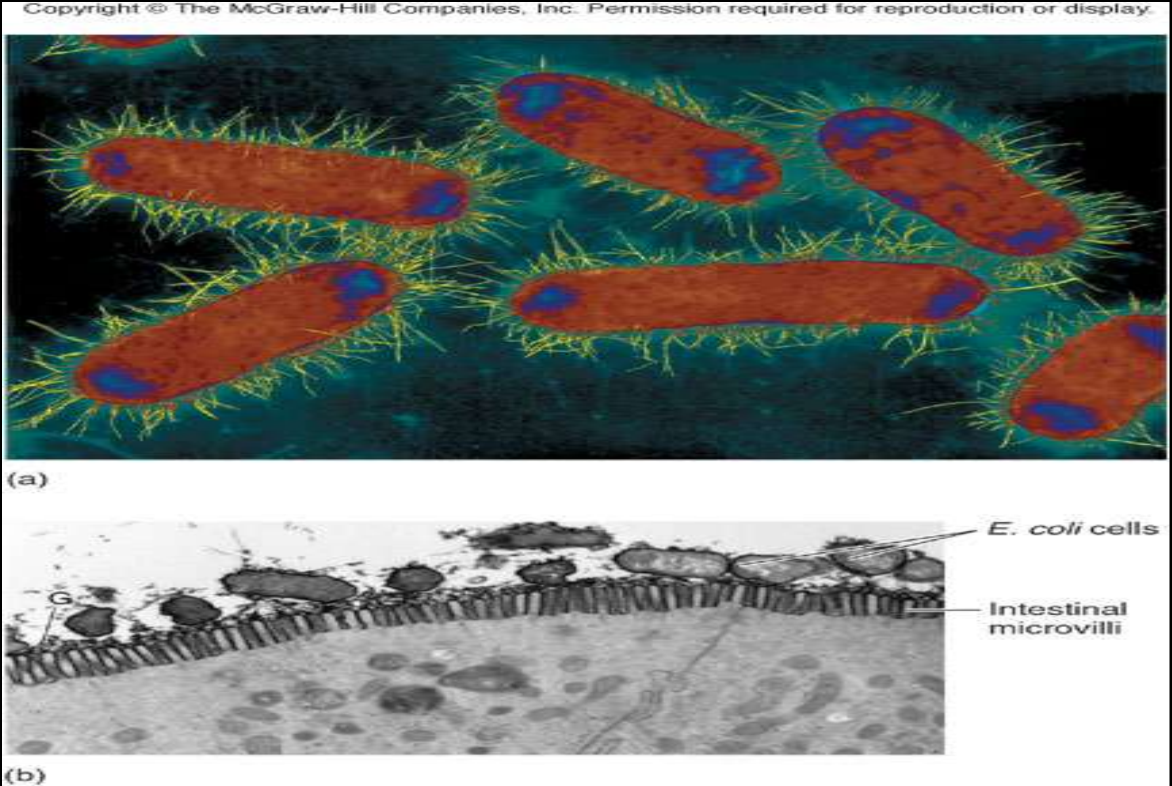
- Filamentous appendages that are shorter, straighter and more numerous that flagella
- found mostly in Gram (-) Bacteria
- used for attachment not motility

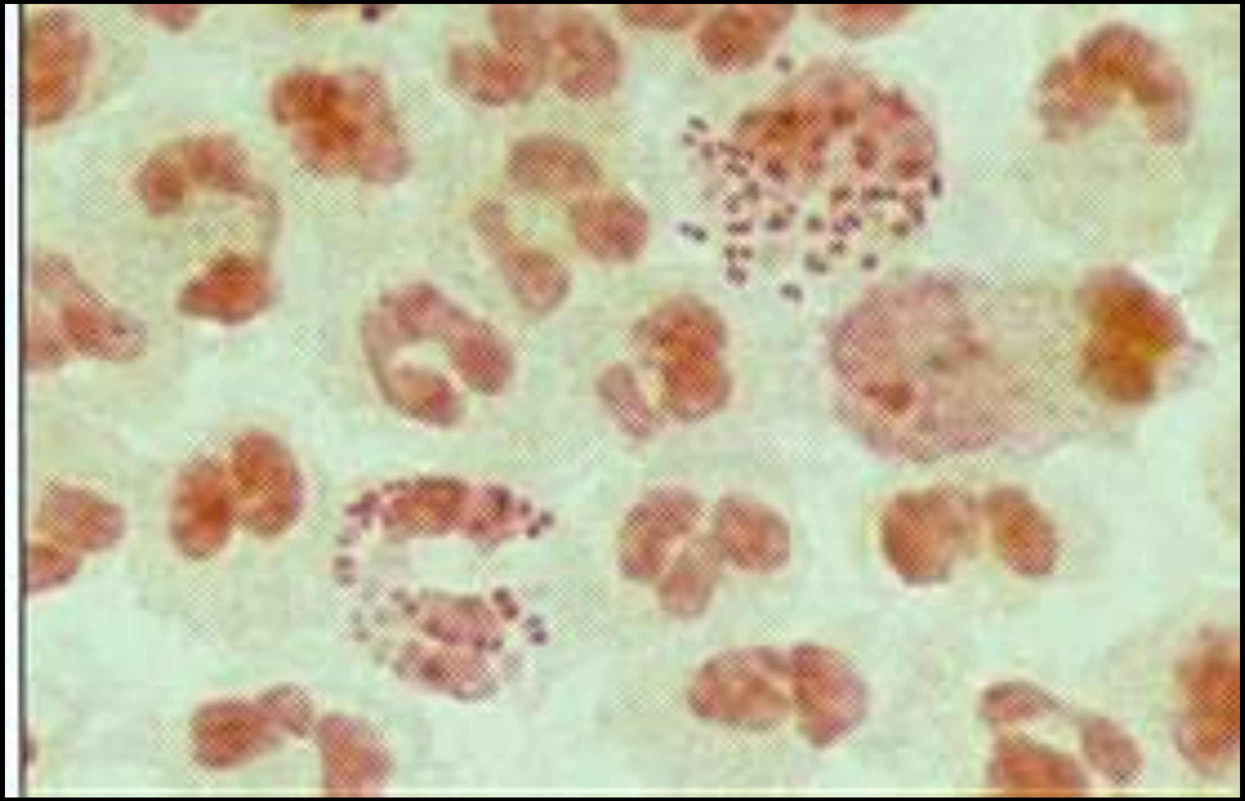
3- Fimbriae



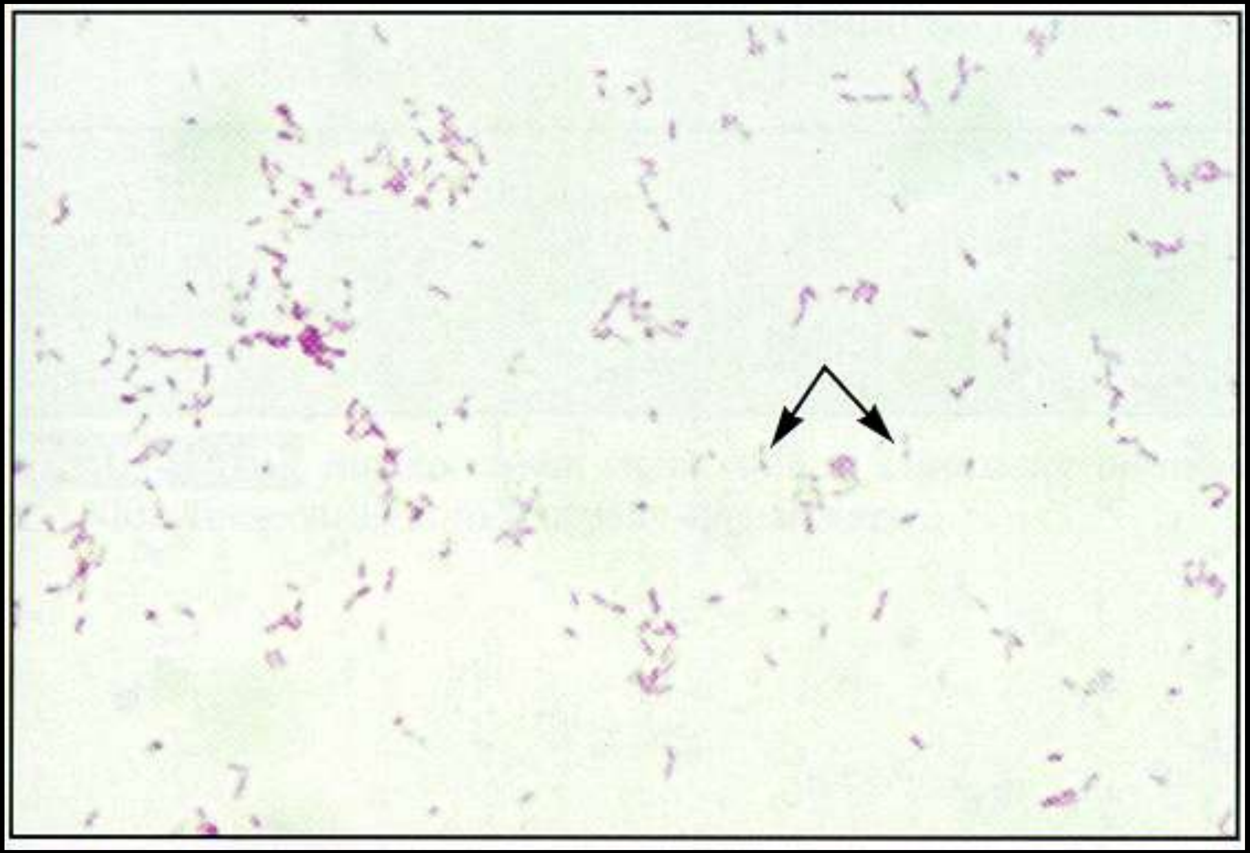
fimbrae

- fine hairlike bristles from the cell surface
- function in adhesion to other cells and surfaces

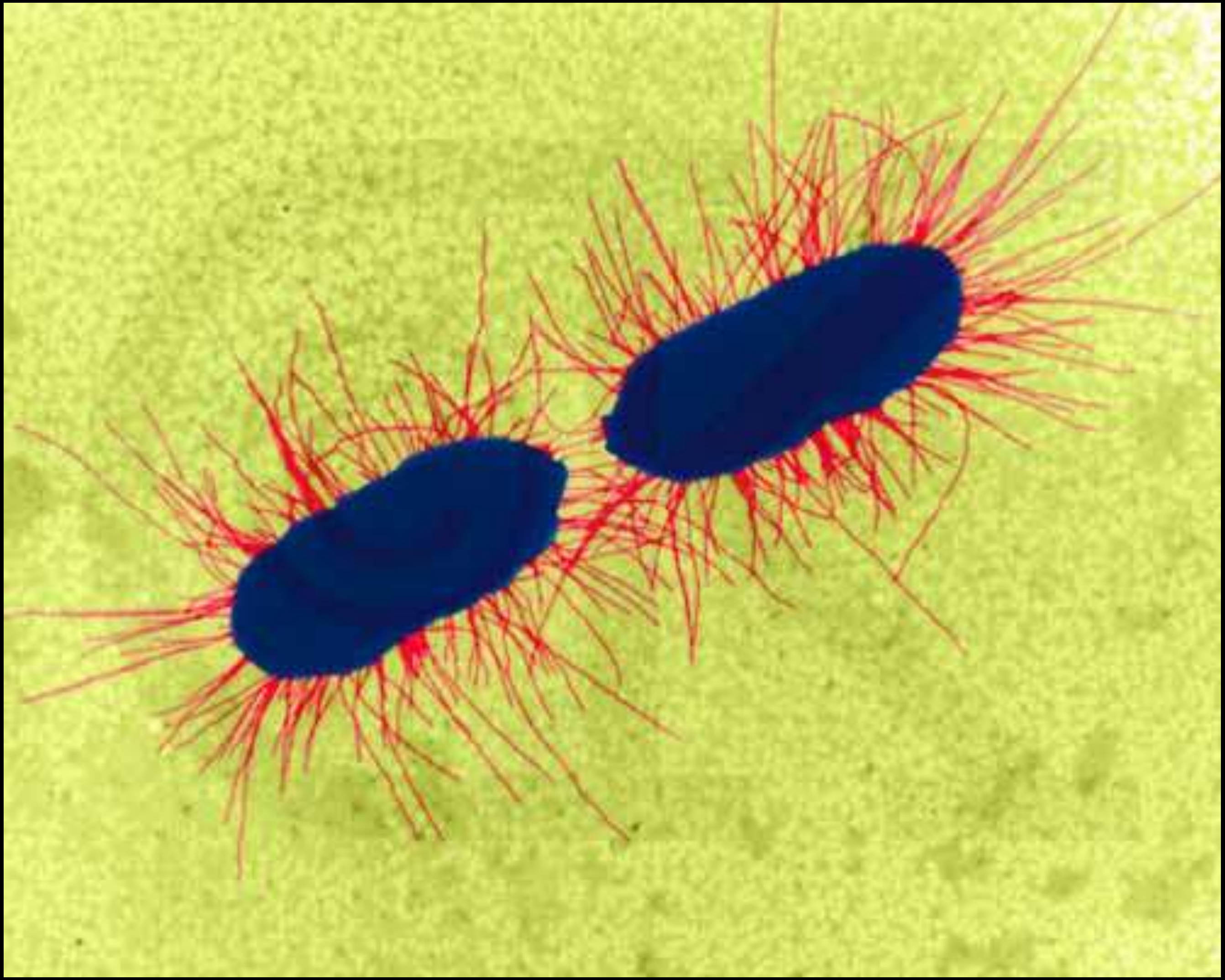




Neisseria gonorrhoeae



Bordetello pertussis



E. coli (pathogenic)

Pili

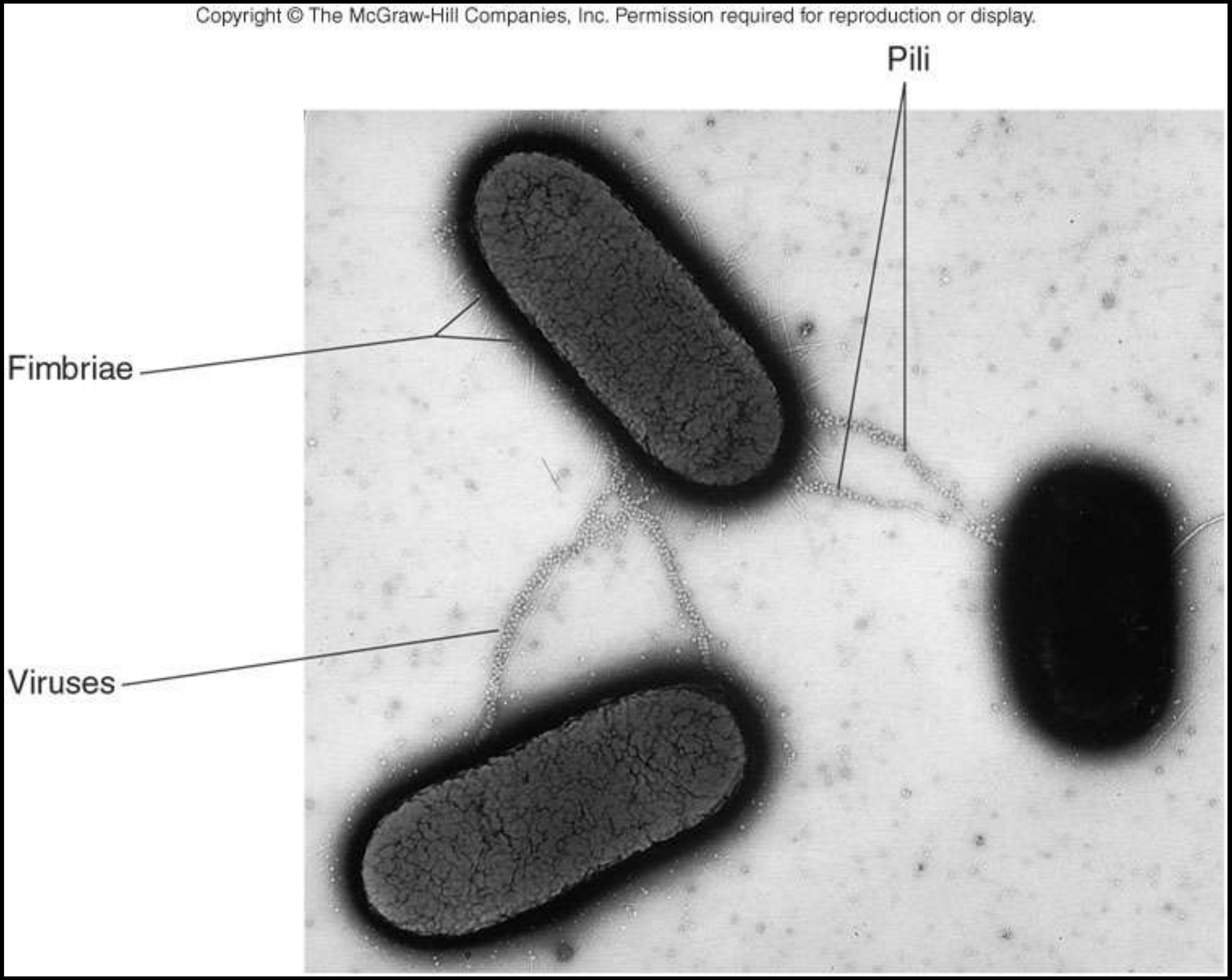
rigid tubular structure made of pilin protein

found only in Gram negative cells

Functions

- joins bacterial cells for DNA transfer (conjugation)
- adhesion

Conjugation



4- Cell Wall

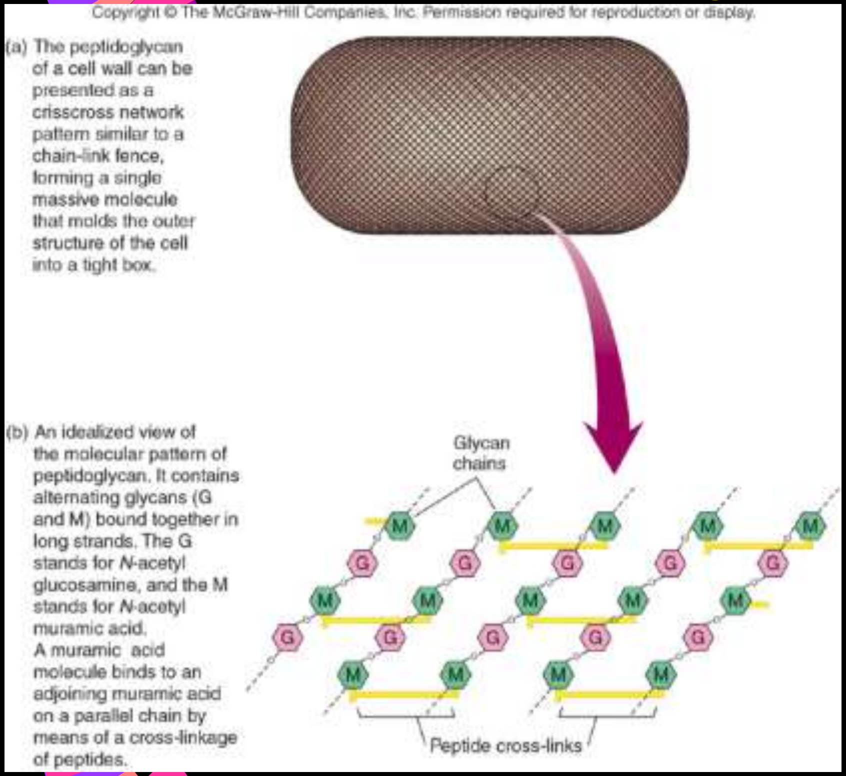
- Main structural component - Peptidoglycan

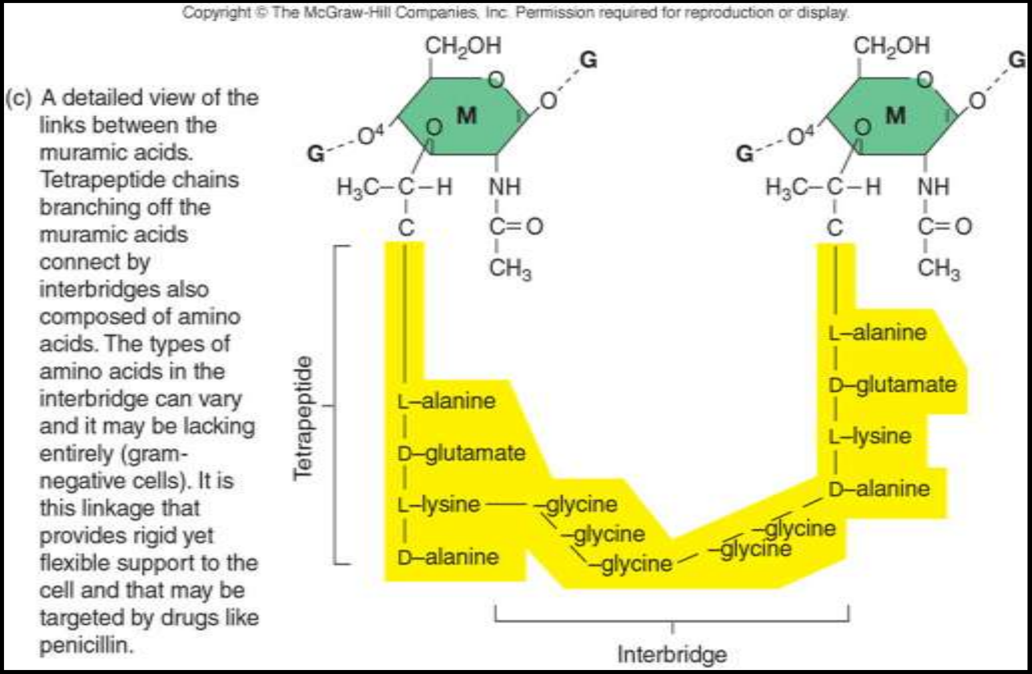
- Peptidoglycan
  - repeating dissacharide units
  - polypeptides

Peptidoglycan

- Unique macromolecule composed of a repeating framework of long glycan chains cross-linked by short peptide fragments
- Provides strong, flexible support to keep bacteria from bursting or collapsing because of changes in osmotic pressure

Peptidoglycan





4 groups based on cell wall composition

1. Gram positive cells
2. Gram negative cells
3. Bacteria without cell walls
4. Bacteria with chemically unique cell walls

Gram positive Gram negative

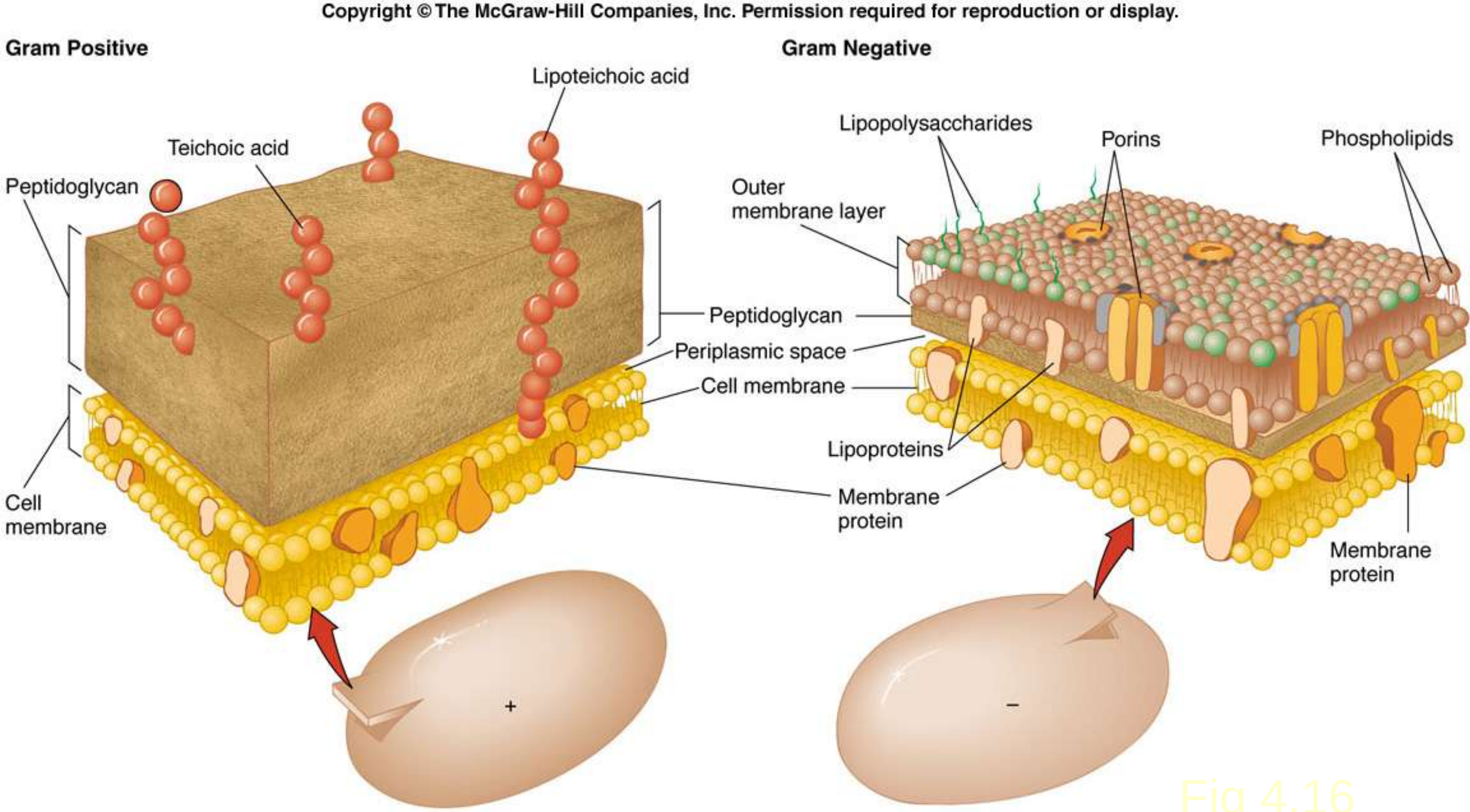
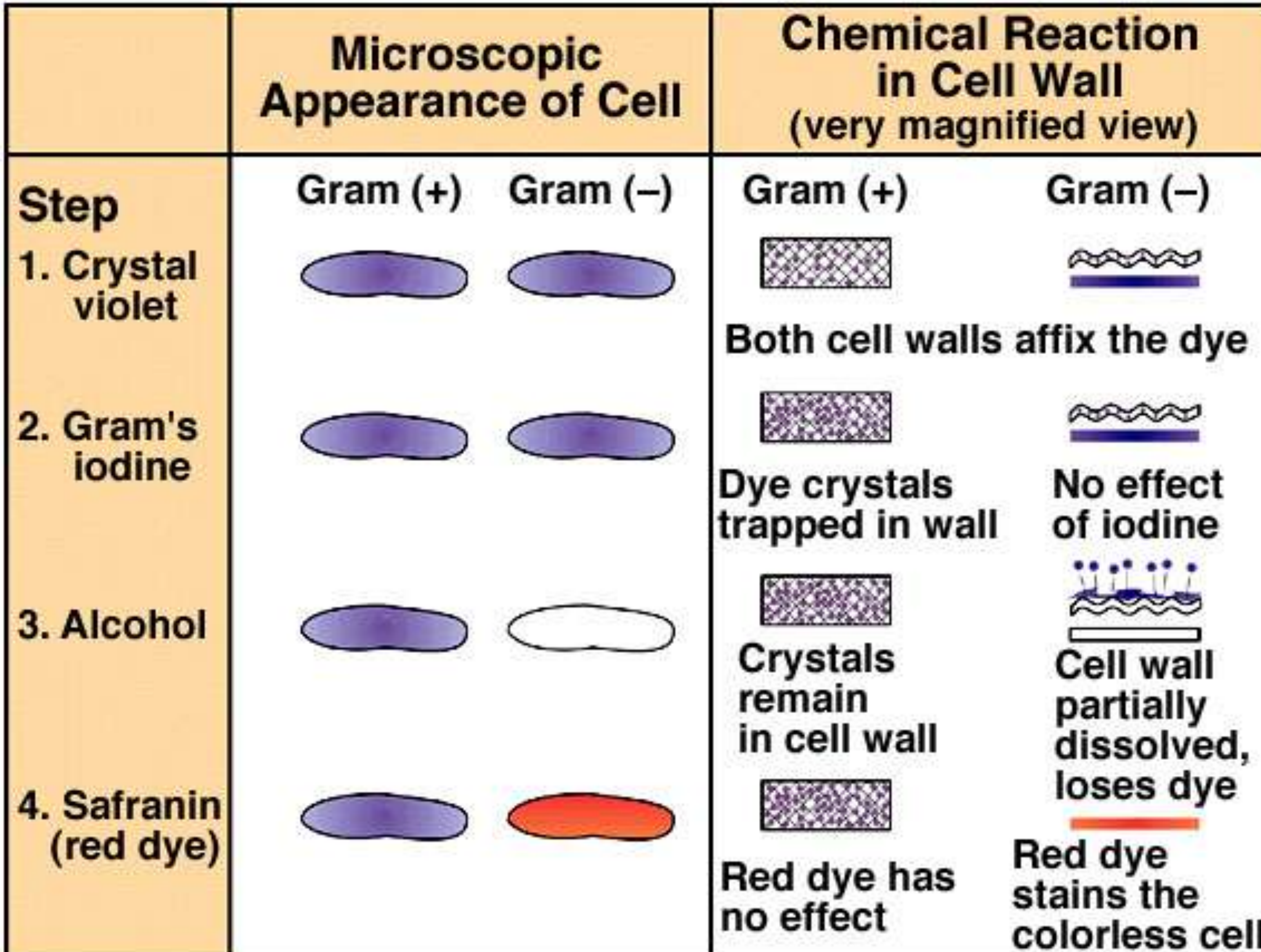


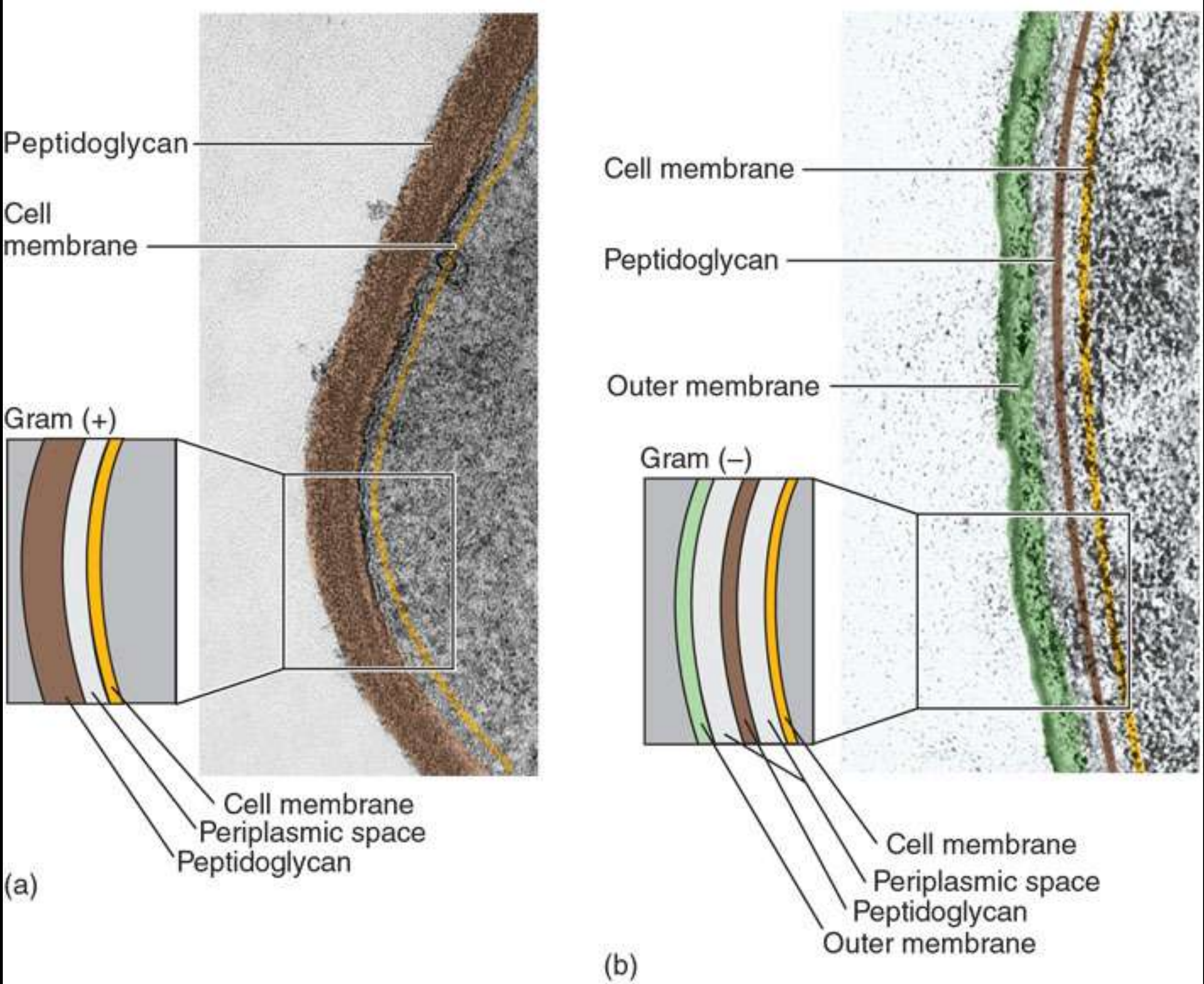
Fig 4.16


Microscopic Appearance of Cell
Chemical Reaction in Cell Wall (very magnified view)
Step
Gram (+)
Gram (–)
Gram (+)
Gram (–)
1. Crystal violet
Both cell walls affix the dye
2. Gram's iodine
Dye crystals trapped in wall
No effect of iodine
3. Alcohol
Crystals remain in cell wall
Cell wall partially dissolved, loses dye
4. Safranin (red dye)
Red dye has no effect
Red dye stains the colorless cell

Gram positive cell wall

- Consists of
  - a thick, homogenous sheath of peptidoglycan 20-80 nm thick
  - tightly bound acidic polysaccharides, including teichoic acid and lipoteichoic acid
  - Cell membrane
- Retain crystal violet and stain purple

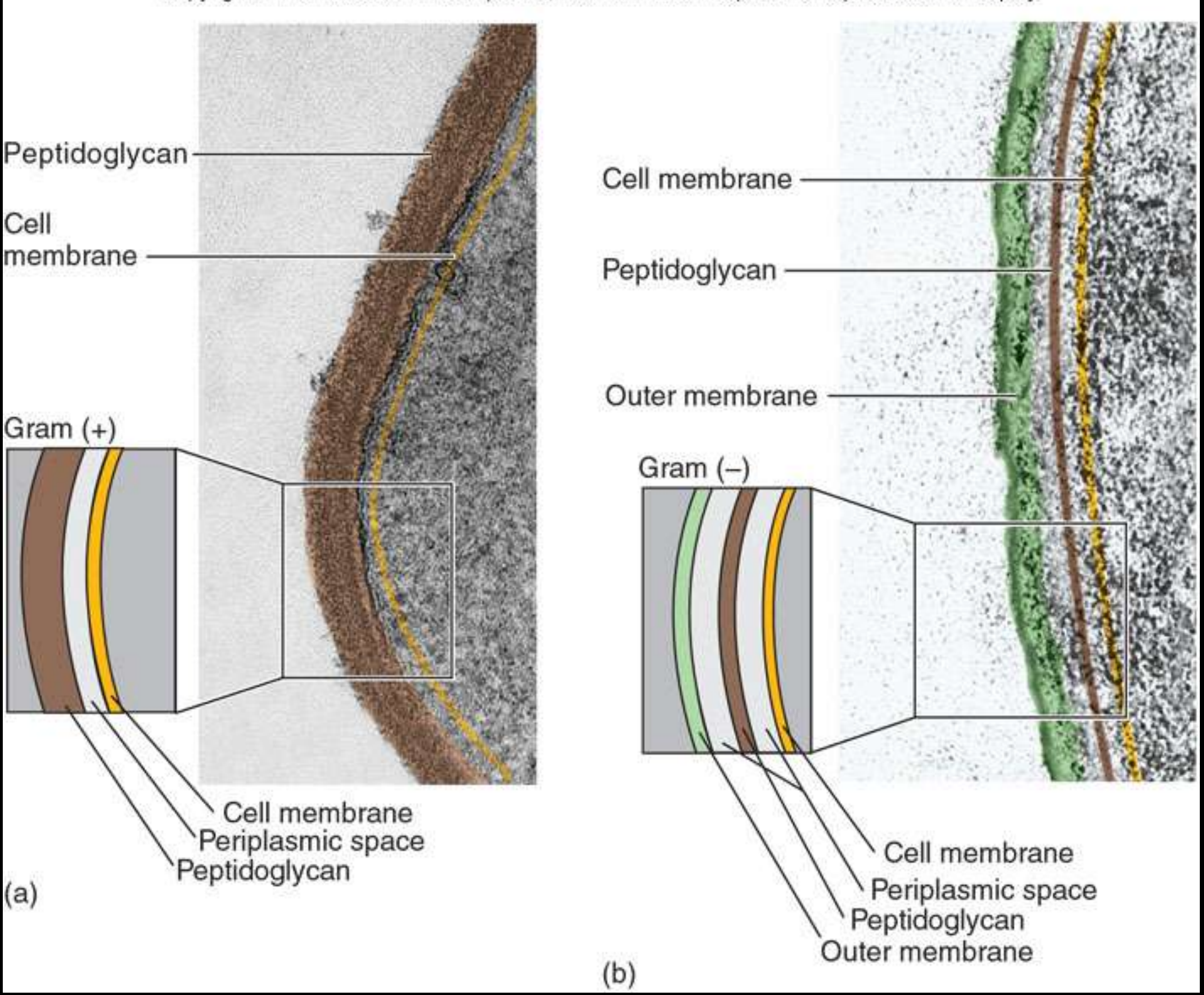
Gram positive wall

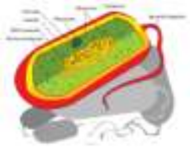


Gram negative cell wall

- Consists of
  - an outer membrane containing lipopolysaccharide (LPS)
  - thin shell of peptidoglycan
  - periplasmic space
  - inner membrane
- Lose crystal violet and stain red from safranin counterstain

Gram negative cell wall

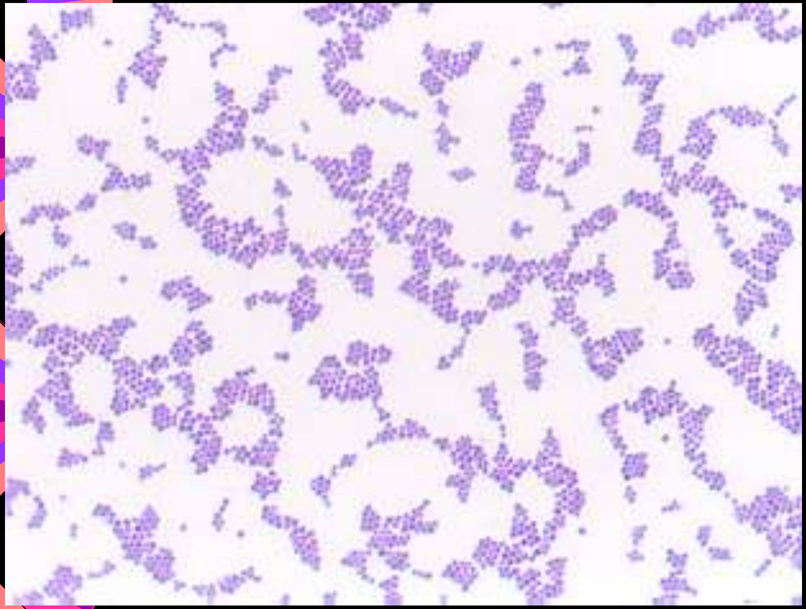




Prokaryotes - **Cell Wall**

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:

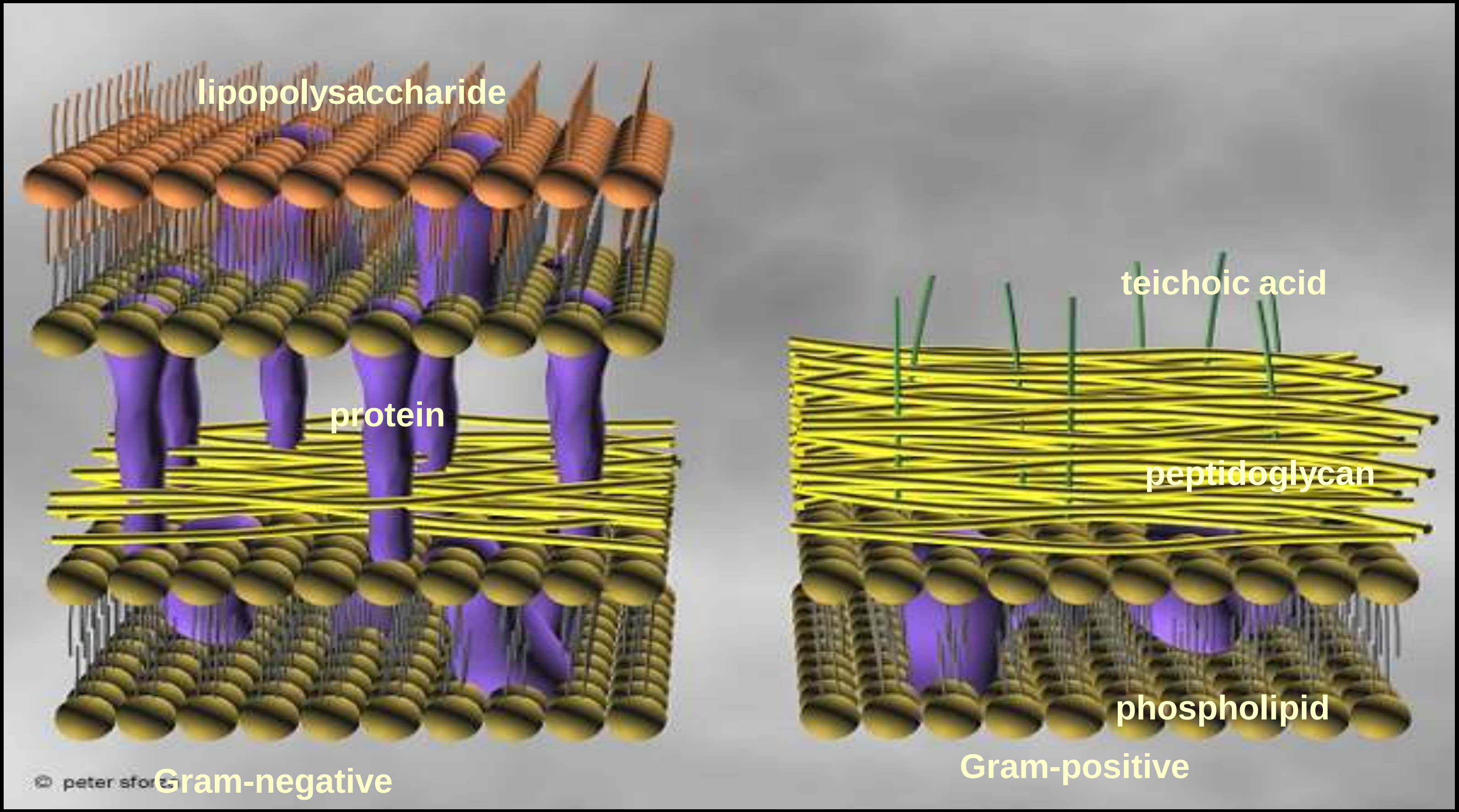
Gram-positive



Gram-negative

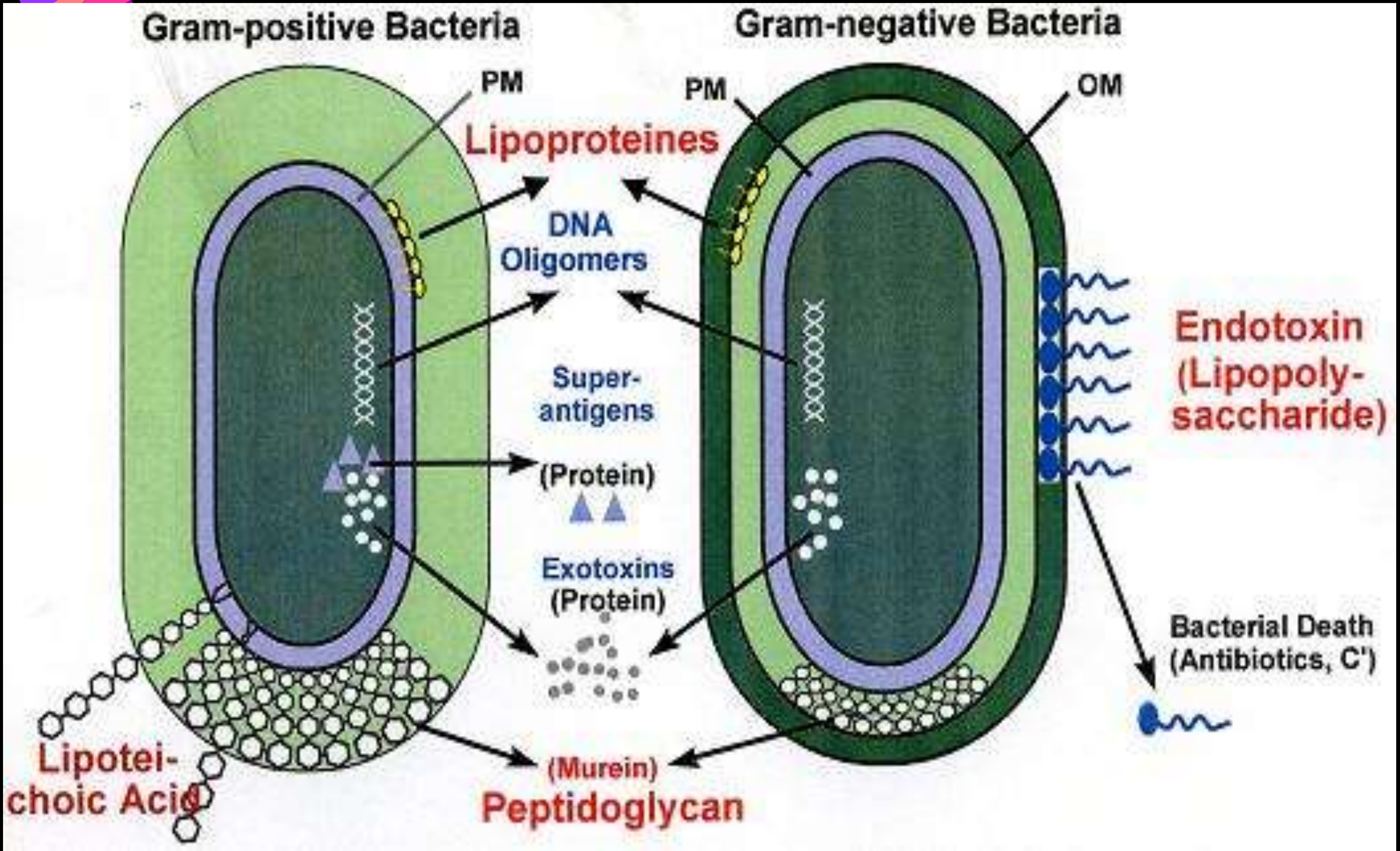
Images: PHIL Public Health Image Library

Cell Wall



Diagrams of the cell wall structure of Gram-negative (left) and Gram-positive bacteria. Key: peptidoglycan layer (yellow); protein (purple); teichoic acid (green); phospholipid (brown); lipopolysaccharide (orange). (Used by permission of *P. Sforza*)

Cell Wall


Gram-positive Bacteria
Gram-negative Bacteria
PM
PM
OM
Lipoproteines
DNA
Oligomers
Super-
antigens
(Protein)
Endotoxin
(Lipopoly-
saccharide)
Exotoxins
(Protein)
Bacterial Death
(Antibiotics, C')
Lipotei-
choic Acid
(Murein)
Peptidoglycan

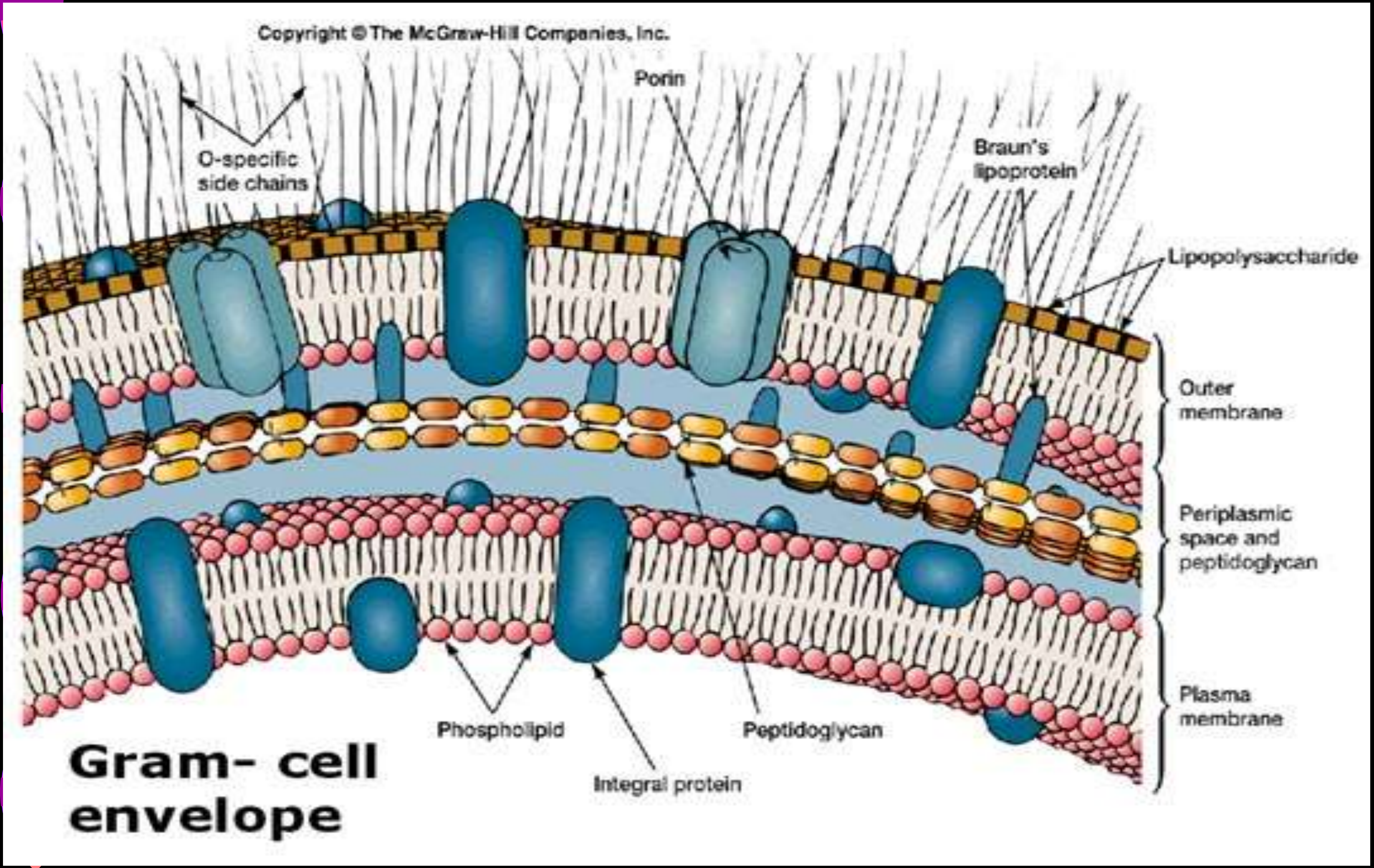
Gram (+) Cell Wall

- NAM N-acetylmuramic acid
- NAG N- acetylglucosamine
- tetrapeptide side chains
- pentaglycine crossbridges
- teichoic acid

Gram (-) Cell Wall

- NAM
- NAG
- Tetrapeptide side chains
- pentaglycine
- 2nd Outer membrane
  - Lipopolysaccharides (LPS)
    - Lipid A
    - O Antigen

Cell Wall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Porin
O-specific side chains
Braun's lipoprotein
Lipopolysaccharide
Outer membrane
Periplasmic space and peptidoglycan
Plasma membrane
Phospholipid
Peptidoglycan
Integral protein
Gram- cell envelope

Bacterial cell wall - chemically unlike any other structure in Animal cells

- Target for drugs that can attack and kill bacteria without harming the host cell

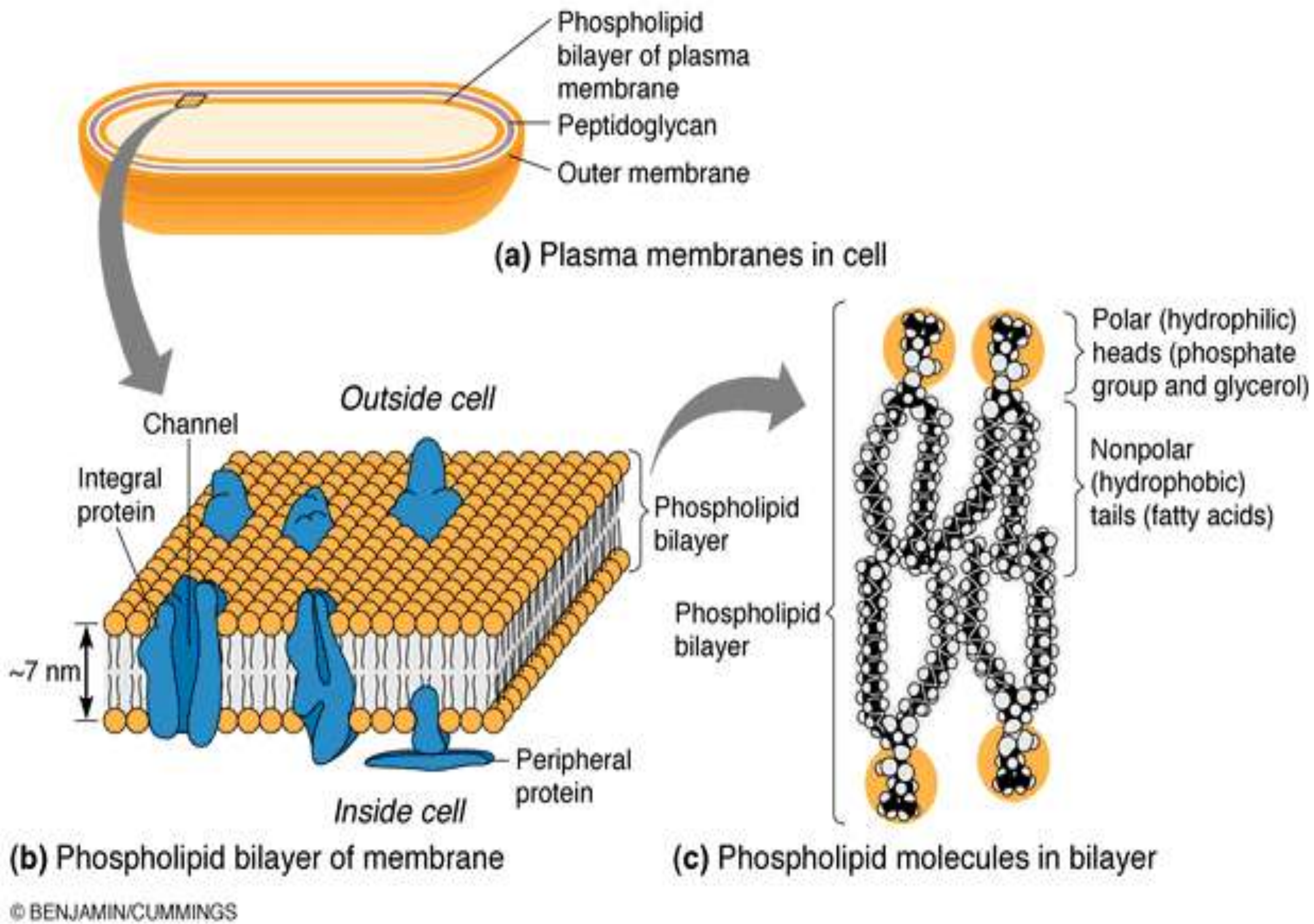
- MANY ANTIBIOTICS are specifically directed at Cell Wall Synthesis
  - Penicillin
    - Works by damaging the pentaglycine crossbridges of the peptidogylcan layer
    - Works best against Gram (+) bacteria

Lysozyme

- Digestive enzyme that damages bacterial cell walls
- Found in tears, saliva & mucus
- Attacks the bond between NAM & NAG
- Works best on Gram (+) bacteria

5- Cell Membrane (Plasma Membrane)

- 2 structural component
  - double layer of phospholipids
  - proteins
- Fluid Mosaic Model



Phospholipid bilayer of plasma membrane
Peptidoglycan
Outer membrane
(a) Plasma membranes in cell
Outside cell
Channel
Integral protein
~7 nm
Phospholipid bilayer
Peripheral protein
Inside cell
(b) Phospholipid bilayer of membrane
Polar (hydrophilic) heads (phosphate group and glycerol)
Nonpolar (hydrophobic) tails (fatty acids)
Phospholipid bilayer
(c) Phospholipid molecules in bilayer
© BENJAMIN/CUMMINGS

Functions of Cell Membrane

- 1. Selective barrier (selectively permeable)
- 2. Secretes exoenzymes
  - amylases
  - lipases
  - peptidases
  - CAN NOT UNDERGO PHAGOCYTOSIS

Functions of Cell Membrane

- 3. E.T.S. is located here
- 4. Enzymes for cell wall synthesis
- 5. If photosynthesis, enzymes are located on membranous structures called thylakoids
- 6. Mesosomes - invagination of cell membrane attached to DNA (Binary Fission)?

Cytoplasm

- dense gelatinous solution of sugars, amino acids, & salts
- 70-80% water
- serves as solvent for materials used in all cell functions

6- Nuclear area (nucleoid)

- 1 circular chromosome (ccDNA)
- attached to a mesosome
  - segragation of DNA during Binary Fission

Chromosome

- single, circular, double-stranded DNA molecule that contains all the genetic information required by a cell
- DNA is tightly coiled around a protein, aggregated in a dense area called the **nucleoid**

plasmids

- small circular, double-stranded DNA
- free or integrated into the chromosome
- duplicated and passed on to offspring
- not essential to bacterial growth & metabolism
- may encode antibiotic resistance, tolerance to toxic metals, enzymes & toxins
- used in genetic engineering- readily manipulated & transferred from cell to cell

Plasmids

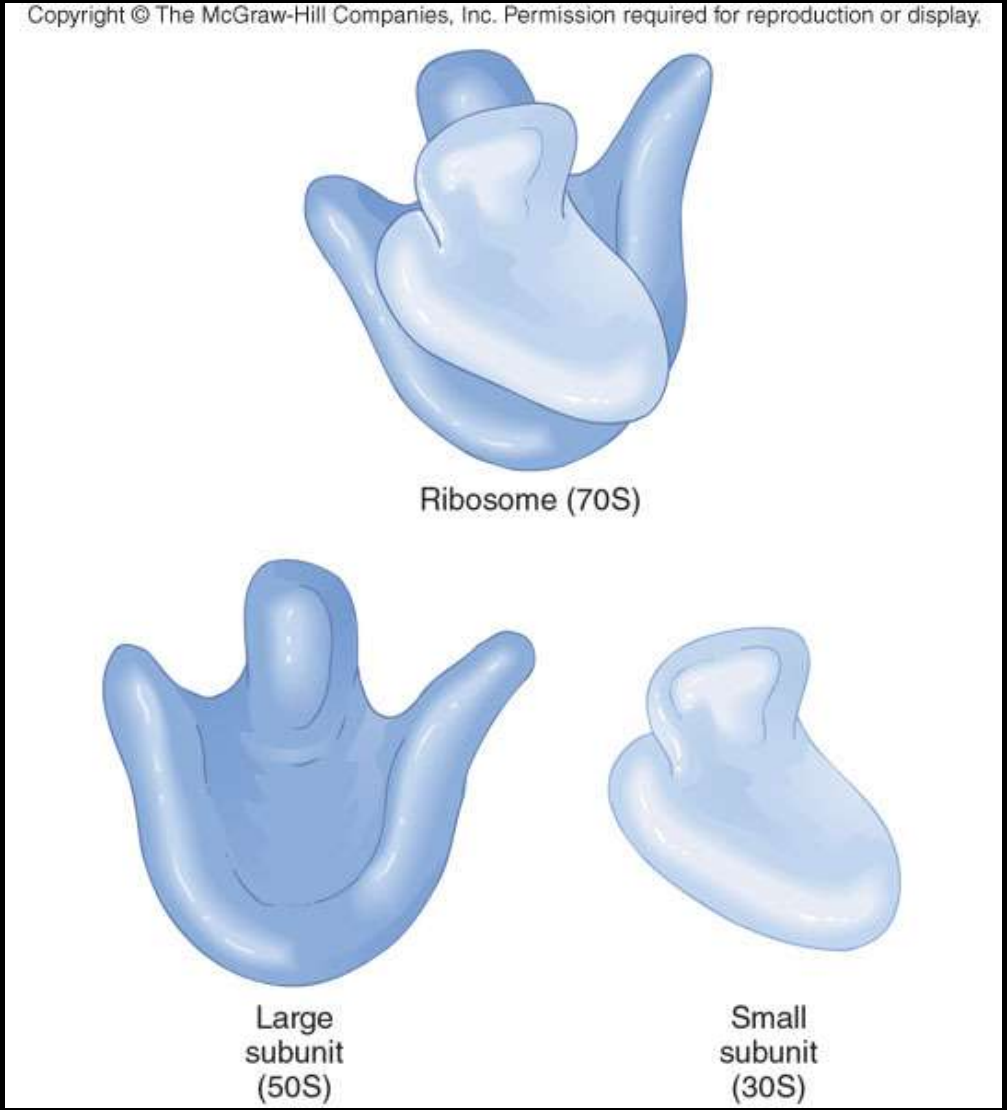
- 5 to 100 genes
- Code for auxiliary metabolic functions:
  - antibiotic resistance
    - penicillase
  - production of toxins
    - *E. coli* 0157:H7

Ribosomes - protein synthesis

- Prokaryotic Ribosome
- 70 S
  - 50 S
  - 30 S

- Eukaryotic Ribosomes
- 80 S
  - 60 S
  - 40 S

Ribosomes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Ribosome (70S)
Large subunit (50S)
Small subunit (30S)

Inclusions, granules

- intracellular storage bodies
- vary in size, number & content
- bacterial cell can use them when environmental sources are depleted
- Examples: glycogen, poly-β-hydroxybutyrate, gas vesicles for floating, sulfur and polyphosphate granules

Inclusions

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Selective Toxicity

- Some antibiotics are aimed at the 70 S ribosomes of bacterial cells
- Streptomycin, Neomycin, Erythromycin and Tetracycline work by inhibiting protein synthesis by disrupting the 70 S ribosome

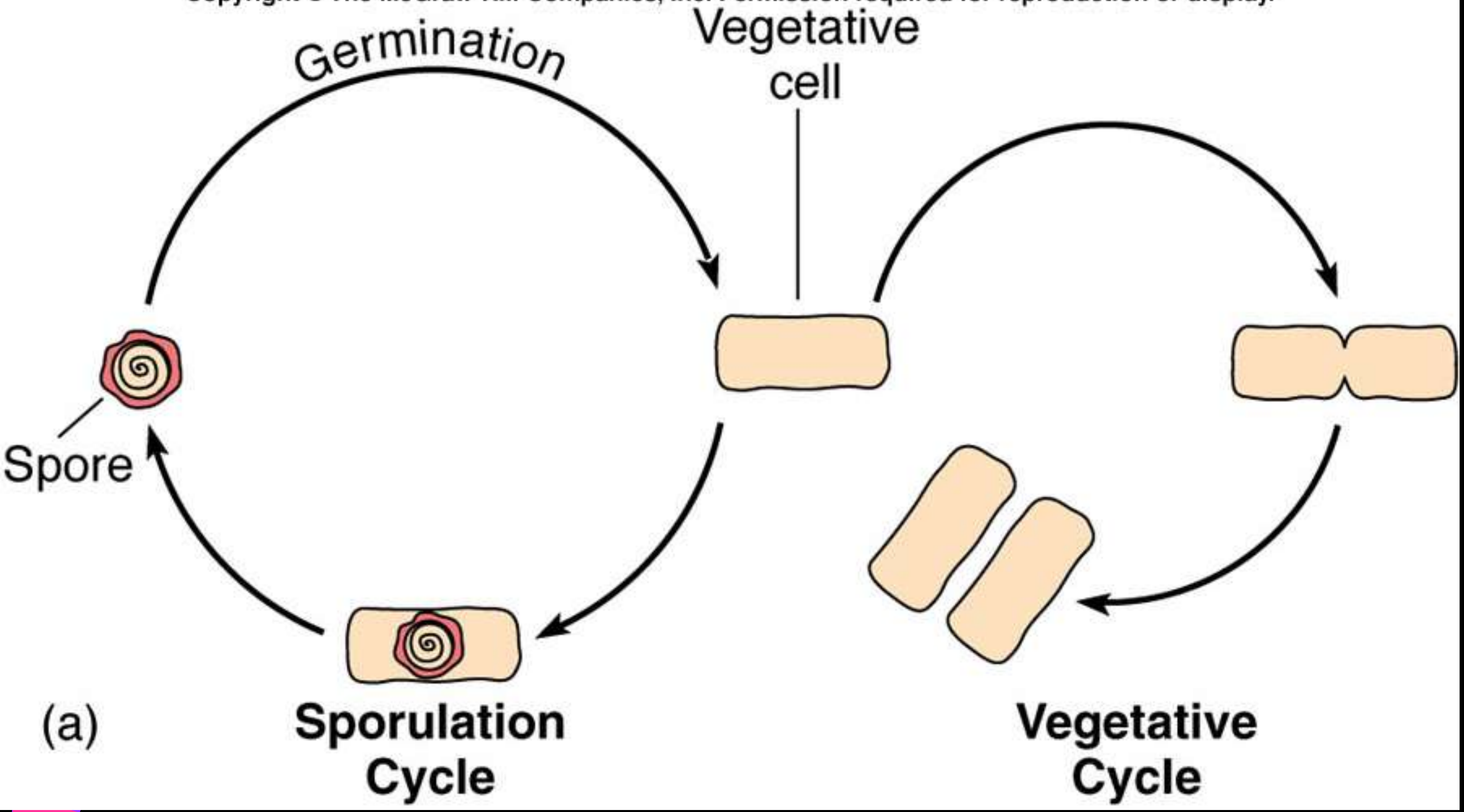
endospores

- Resting, dormant cells
- produced by some G+ genera: *Clostridium*, *Bacillus & Sporosarcina*
- Have a 2-phase life cycle – vegetative cell & an endospore
- **sporulation** -formation of endospores
- **germination**- return to vegetative growth
- hardiest of all life forms
- withstand extremes in heat, drying, freezing, radiation & chemicals not a means of reproduction

endospores

- resistance linked to high levels of calcium & dipicolinic acid
- dehydrated, metabolically inactive
- thick coat
- longevity verges on immortality 25, 250 million years.
- pressurized steam at 120ºC for 20-30 minutes will destroy.

endospores


Germination
Vegetative
cell
Spore
(a)
Sporulation
Cycle
Vegetative
Cycle

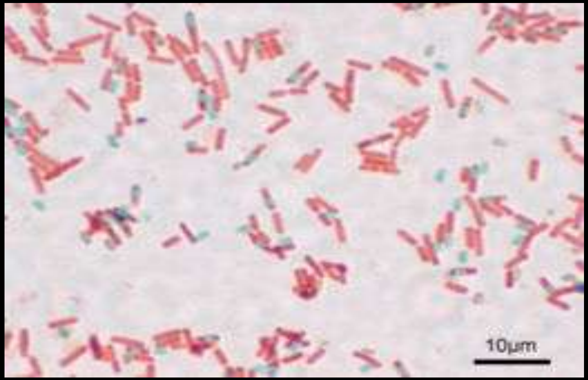
Endospores - formed under periods of environmental stress

- Only found in Gram (+) Bacteria
- *Bacillus*
  - *Bacillus cereus*
  - *Bacillus anthracis*
- *Clostridium*
  - *Clostridium tetani*
  - *Clostridium botulinum*
  - *Clostridium perfringens*

7- *Endospores*

- Extremely resistant to heat, cold, chemicals, lack of water, etc.
- Most vegetative bacterial cells are killed at temps. above 70 C (160 F)
  - Endospores can survive boiling water for several hours (some for as long as 20 hours)

Endospores



A stained preparation of Bacillus subtilis showing endospores as green and the vegetative cell as red

- Dormant, tough, non-reproductive structure produced by small number of bacteria.
- Primary function of most endospores:

  ____

  ____

- Resistant to radiation, desiccation, lysozyme, temperature, starvation, and chemical disinfectants.
- Endospores commonly found in soil and water, where they may survive for long periods of time

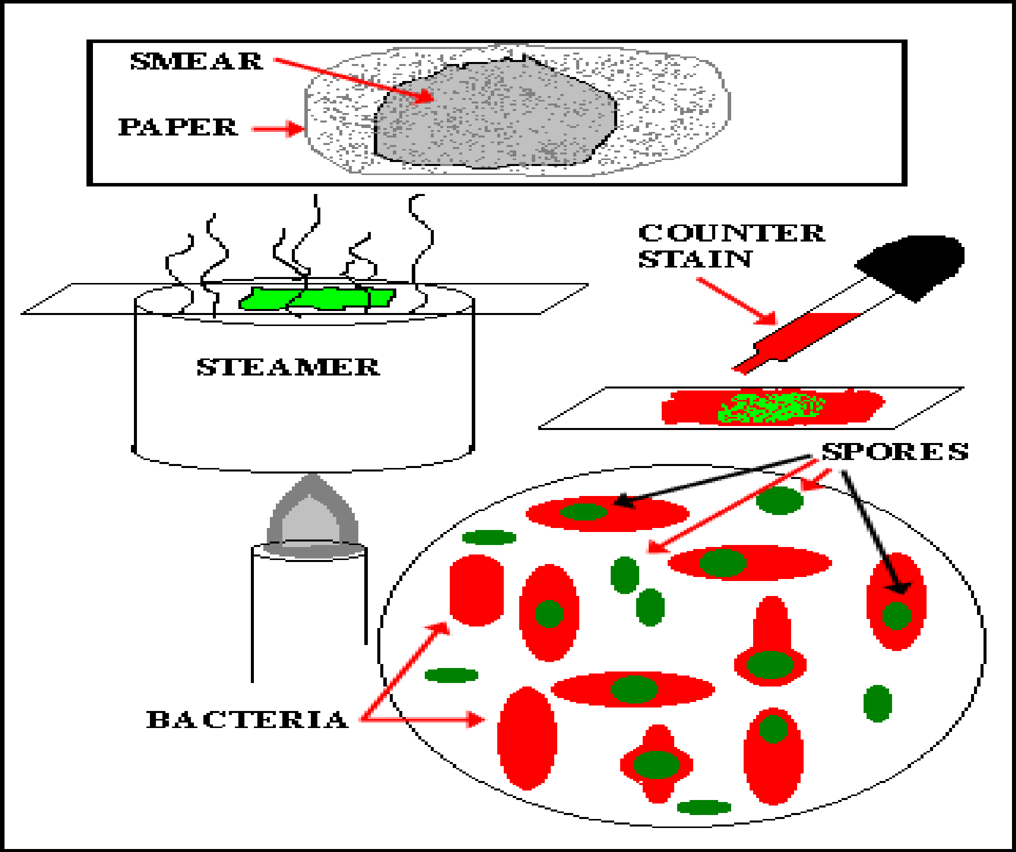


Image:

Stain: Jerry Keplinger, James H. Quillen College of Medicine

Procedure: Source link no longer works

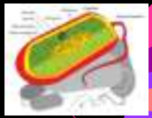
Endospores

- Spores can remain viable for weeks, months, years
- *Thermoactinomyces vulgaris*
  - spores found in Minnesota were 7,500 years old and still germinated

Examples of bacteria

- *Staphylococcus aureus*
- *Staphylococcus epidermidis*
- *Streptococcus pneumoniae*
- *Vibrio cholerae*
- *Rhodospirillium rubrum*
- *Bacillus subtilis*
- *Micrococcus luteus*
- *Escherichia coli*
- *Bacillus anthrasis*
- *Salmonella enteridis*
- *Streptococcus pyogenes*
- *Steptococcus lactis*
- *Streptococcus faecalis*
- *Erlichia canis*
- *Campylobacter jujuni*
- *Helicobacter pylori*
- *Enterobacter aerogenes*

THE END



*Prokaryotes – **Shapes***

Most bacteria are classifies according to shape:

1. _________ *(pl. bacilli)* = rod-shaped

2. _________ *(pl. cocci … sounds like cox-eye)* = spherical

3. _________ *(pl. spirilla)* = spiral

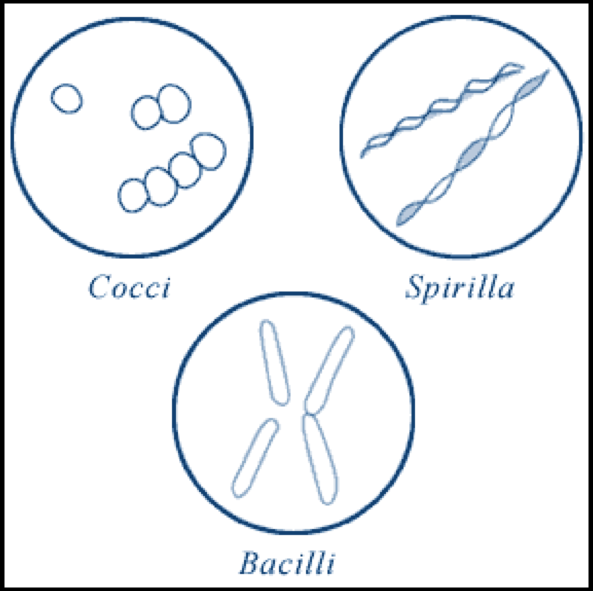
Some bacteria have quite different shapes:

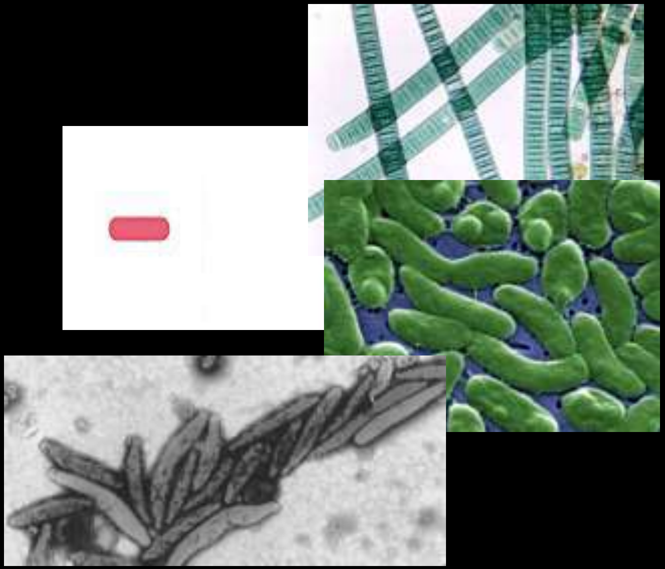
a. Coccobacilli = elongated coccal form

b. Filamentous = bacilli that occur in long threads

c. Vibrios = short, slightly curved rods

d. Fusiform = bacilli with tapered ends





Images:

Bacterial Shapes: fda gov