A study material for M.Sc. Biochemistry (Semester: IV) Students
on the topic (EC-1; Unit II)

Cell Wall of Bacteria

The Boundary which makes the Difference

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Bacteria: Bacteria are prokaryotic cells, the simplest of microbial cells. In essence, they consist of cell protoplasm contained within a retaining structure or cell envelope.

Basic Characteristics:

- Prokaryotic
- Simplest of all microbial cells
- Single-celled organisms
- Distinctive cell walls, or unique cell envelopes, which contain a peptidoglycan layer
- Lack a true nucleus; instead, have a region called the 'nucleoid region' (i.e., DNA) DNA is free floating ,
- May have additional DNA which is not associated with this nucleoid region (called a plasmid)

Other Characteristics:

- Rapid growth and cell division (binary fission) under favorable conditions
- Mutants that arise from bacteria can become extremely resilient organisms because bacteria can:
  - Grow and reproduce cells quickly
  - Adapt quickly to changing environments
- Plasmids impart additional resistant characteristics to bacteria via cell-to-cell transfer of this extra DNA material
- Capable of colonizing in almost any environment
- Extremely diverse and numerous in soils or waters

Bacteria

- **Bacteria** are a large domain of prokaryotic microorganism.
- **Bacteria were first observed by Antonie van Leeuwenhoek in 1676. He called them "animalcules“**
- The name Bacterium was introduced much later, by Christian Gottfried Ehrenberg in 1828.
- Bacterial cells are about one tenth the size of eukaryotic cells and are typically 0.5–5.0 micrometres in length. However, a few species — for example, *Thiomargarita namibiensis* and *Epulopiscium fishelsoni* — are up to half a millimeter long and *E. fishelsoni* reaches 0.7 mm
  - ***Thiomargarita namibiensis*** is a gram-negative coccoid Proteobacterium, found in the ocean sediments of the continental shelf of Namibia. It is the largest bacterium ever discovered, in general, 0.1–0.3 mm (100–300 µm) wide, but sometimes up to 0.75 mm (750 µm). Its size is large enough to be seen by the naked eye.
  - ***Epulopiscium fishelsoni*** ("Fishelson's guest at a fish's banquet") is a Gram-positive bacterium that has a symbiotic relationship with the surgeonfish. It is most well known for its large size, ranging from 200-700 µm in length, and about 80 µm in diameter. Until the discovery of *Thiomargarita namibiensis* in 1999, it was the largest bacterium known.
- Among the smallest bacteria are members of the genus Mycoplasma, which measure only 0.3 micrometres, as small as the largest viruses

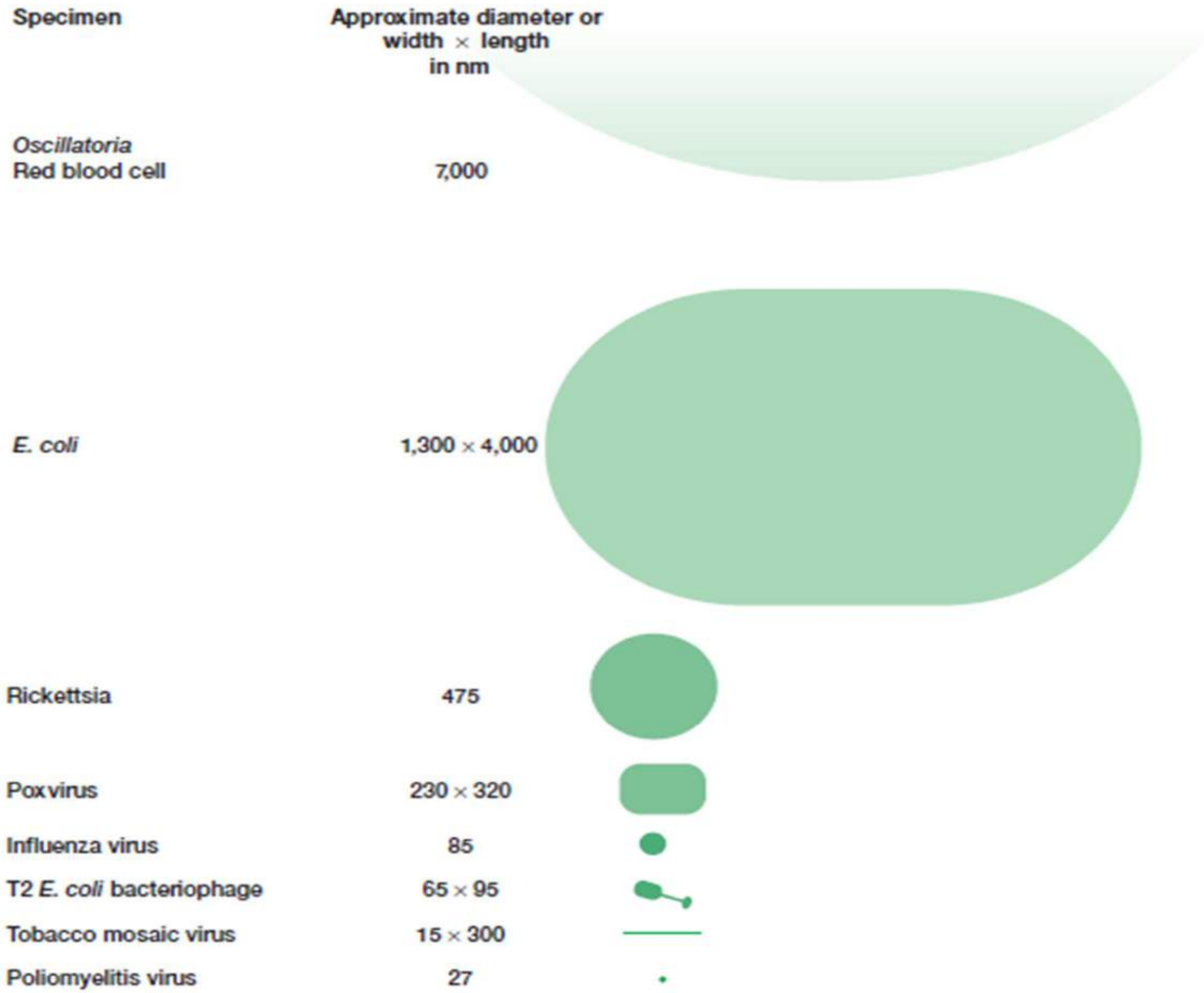


Figure 3.3 **Sizes of Bacteria and Viruses.** The sizes of selected bacteria relative to the red blood cell and viruses.

Shapes of Bacteria

Cocci: Spherical

Streptococcus: in chain

Tetrad

Sarcinae: cubical

Staphylococcus: in bunch

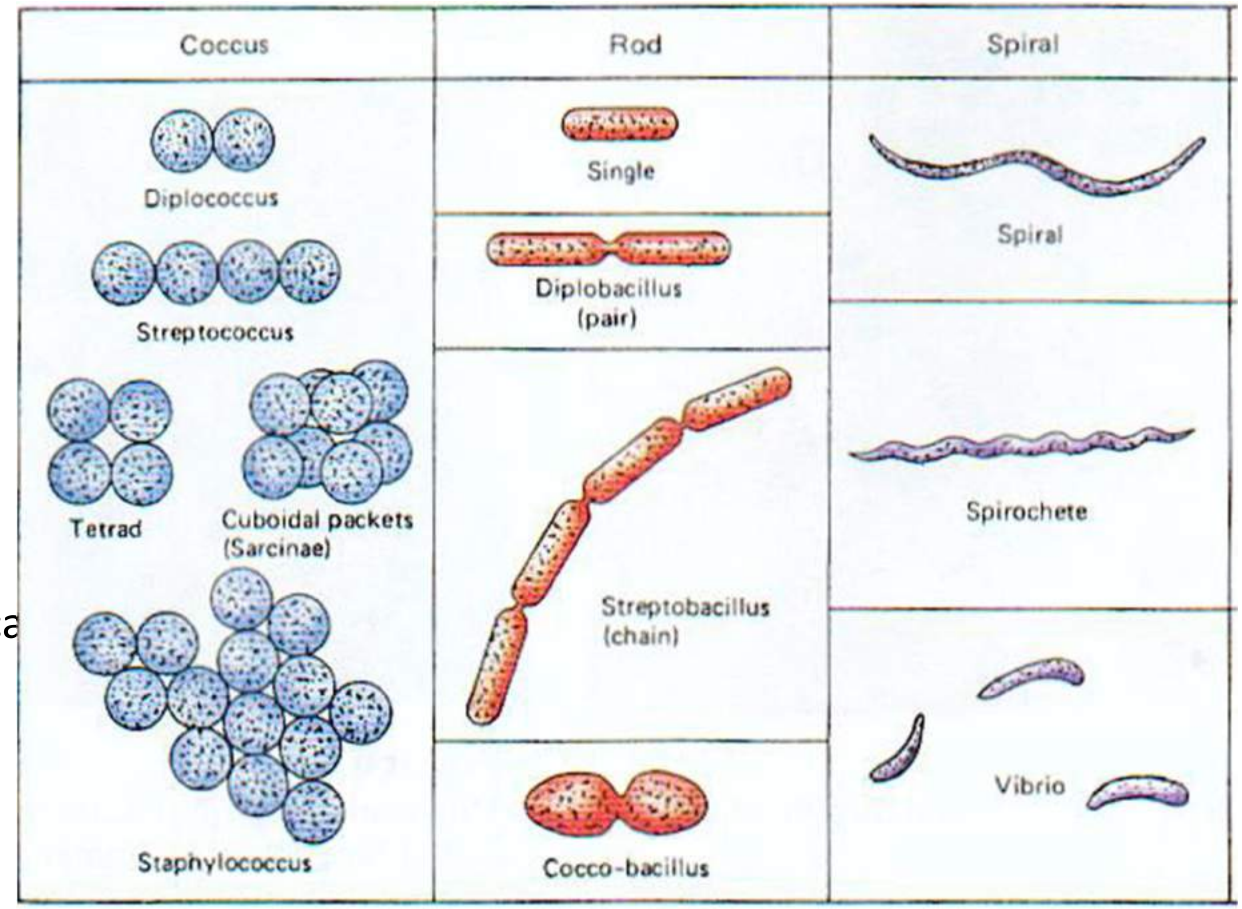
Bacilli: Rod

Spirilla: Helical-Rigid

Spirochetes: Helical –Flexible

(Due to absence of peptidoglyca

No shape: Pleomorphic



Structure of Bacteria

- **Essential structures**
  Cell wall
  Cell membrane
  Cytoplasm
  Nuclear material
- **Particular structures**
  Capsule
  Flagella
  Pili
  Spore

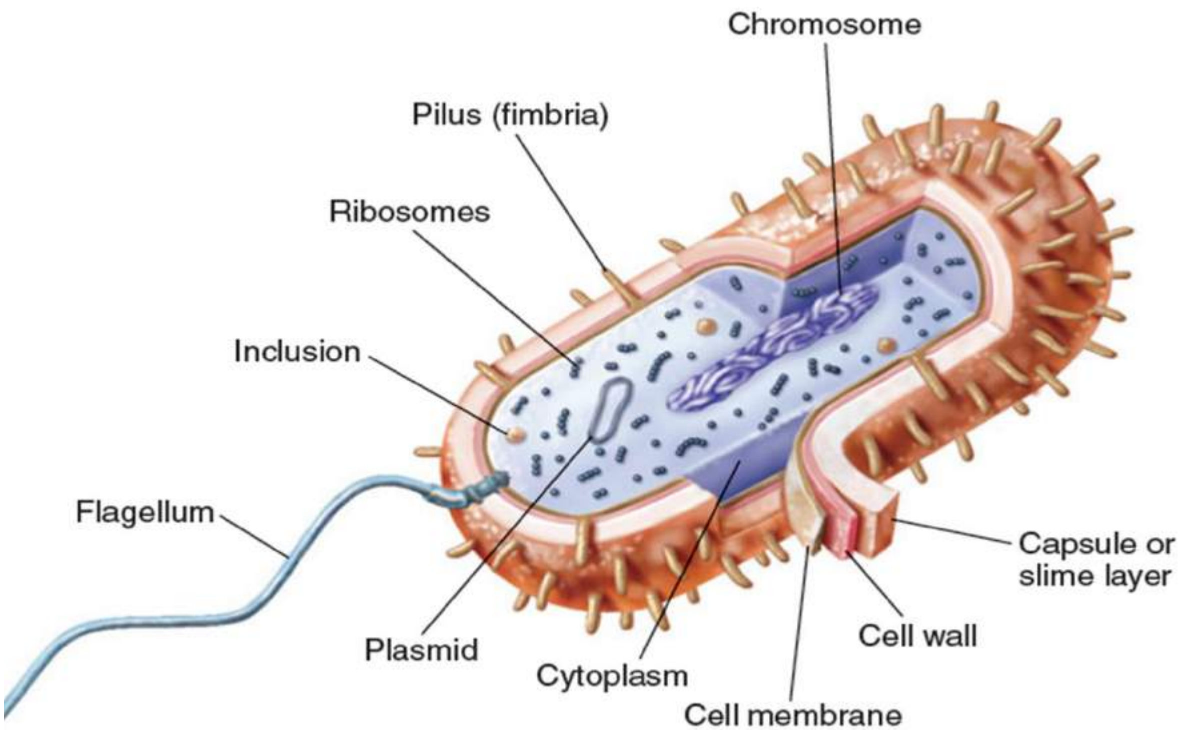


FIGURE 4.3 **A typical prokaryotic cell.** The cell depicted is a bacillus with a polar flagellum (a flagellum at one end).

Cell Wall:

It is the layer lies just out side the Plasma membrane.

15-30nm in thickness,
10%-25% of dry weight.

- **Role**
  - Help in protection, Rigidity and shape
  - Countering the effects of **osmotic pressure**
  - Providing **attachment sites** for bacteriophages
  - Providing a rigid platform for surface appendages- **flagella**, **fimbriae**, and **pili** all emanate from the wall and extend beyond it
  - Play an essential role in cell division
  - Be the sites of major **antigenic determinants** of the cell surface。

Cell wall:

- Main components of bacterial cell wall is Peptidogycan and Lipopolysaccharide
- On the basis of staining of bacterial cell wall bacteria are Gram Positive or Gram negative.

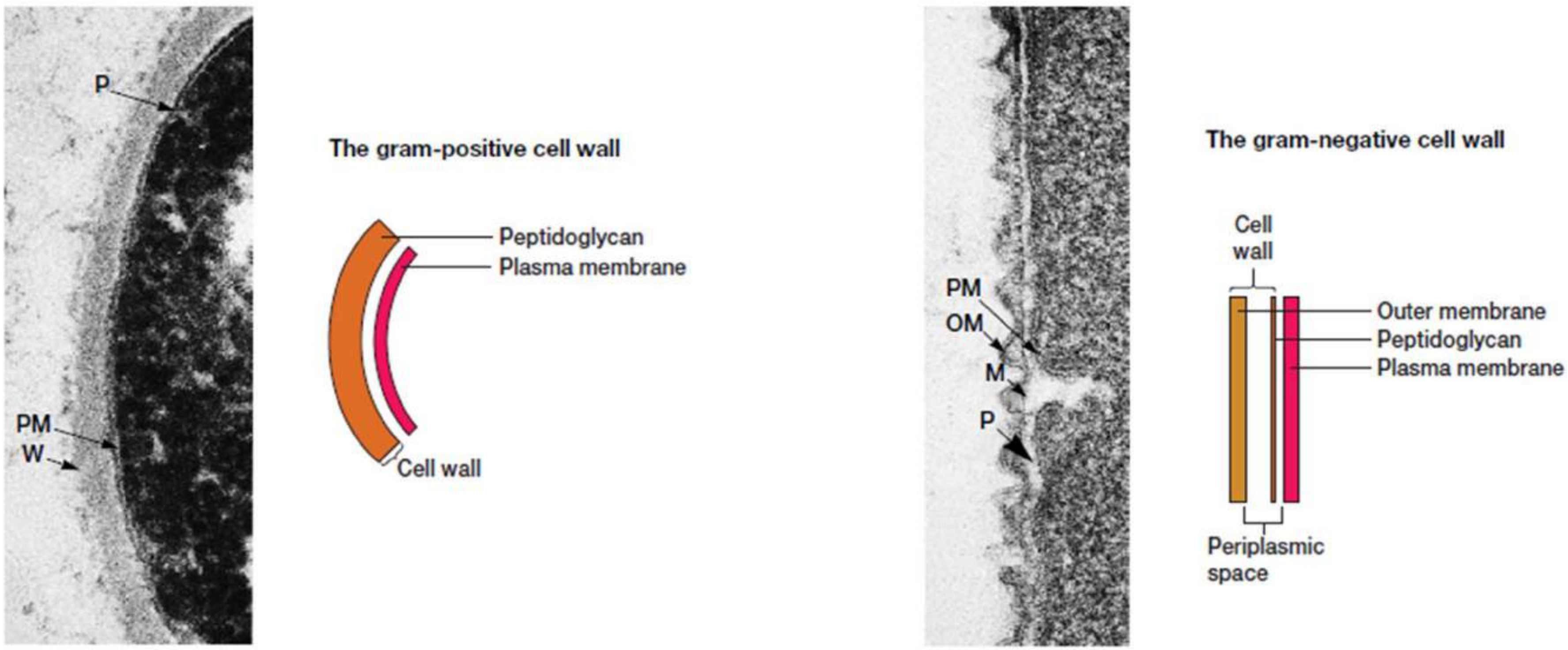


Figure 3.15 Gram-Positive and Gram-Negative Cell Walls. The gram-positive envelope is from *Bacillus licheniformis* (left), and the gram-negative micrograph is of *Aquaspirillum serpens* (right). M; peptidoglycan or murein layer; OM, outer membrane; PM, plasma membrane; P, periplasmic space; W, gram-positive peptidoglycan wall.

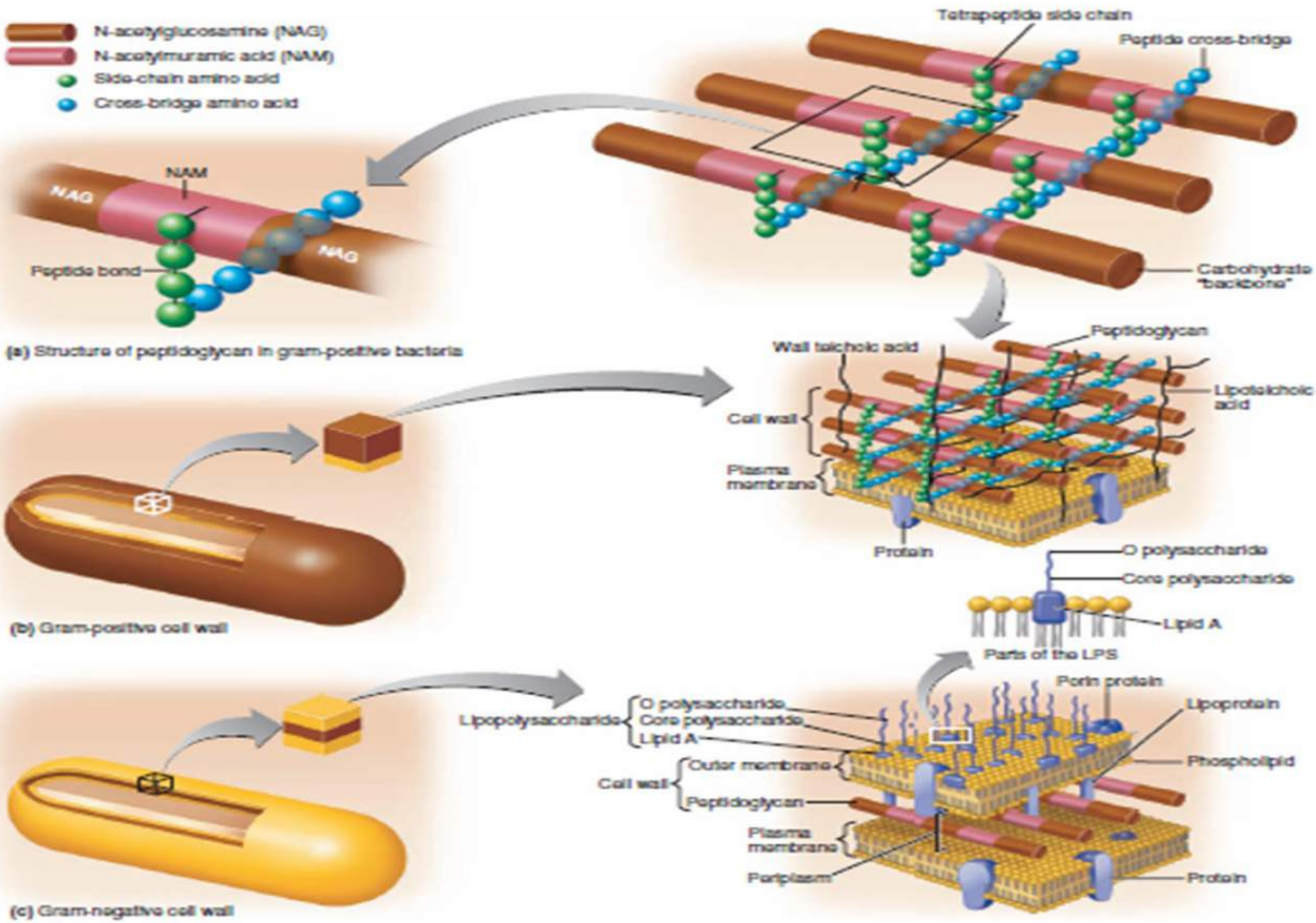


Figure 4.13 Bacterial cell walls. (a) The structure of peptidoglycan in gram-positive bacteria. Together the carbohydrate backbone (glycan portion) and tetrapeptide side chains (peptide portion) make up peptidoglycan. The frequency of peptide cross-bridges and the number of amino acids in these bridges vary with species of bacteria. The small arrows indicate where penicillin interferes with the linkage of peptidoglycan rows by peptide cross-bridges. (b) A gram-positive cell wall. (c) A gram-negative cell wall.

Q What are the major structural differences between gram-positive and gram-negative cell walls?

Peptidoglycan structure

Peptidoglycan or murein is an enormous mesh-like polymer . Polymer consist of two sugar derivatives ***N-acetyl glucosamine and N-acetylmuramic acid*** **and several different amino acids like Alanine, meso-Diaminopimelic acid or L- Lysine and D – Glutamic acid or Glutamine**

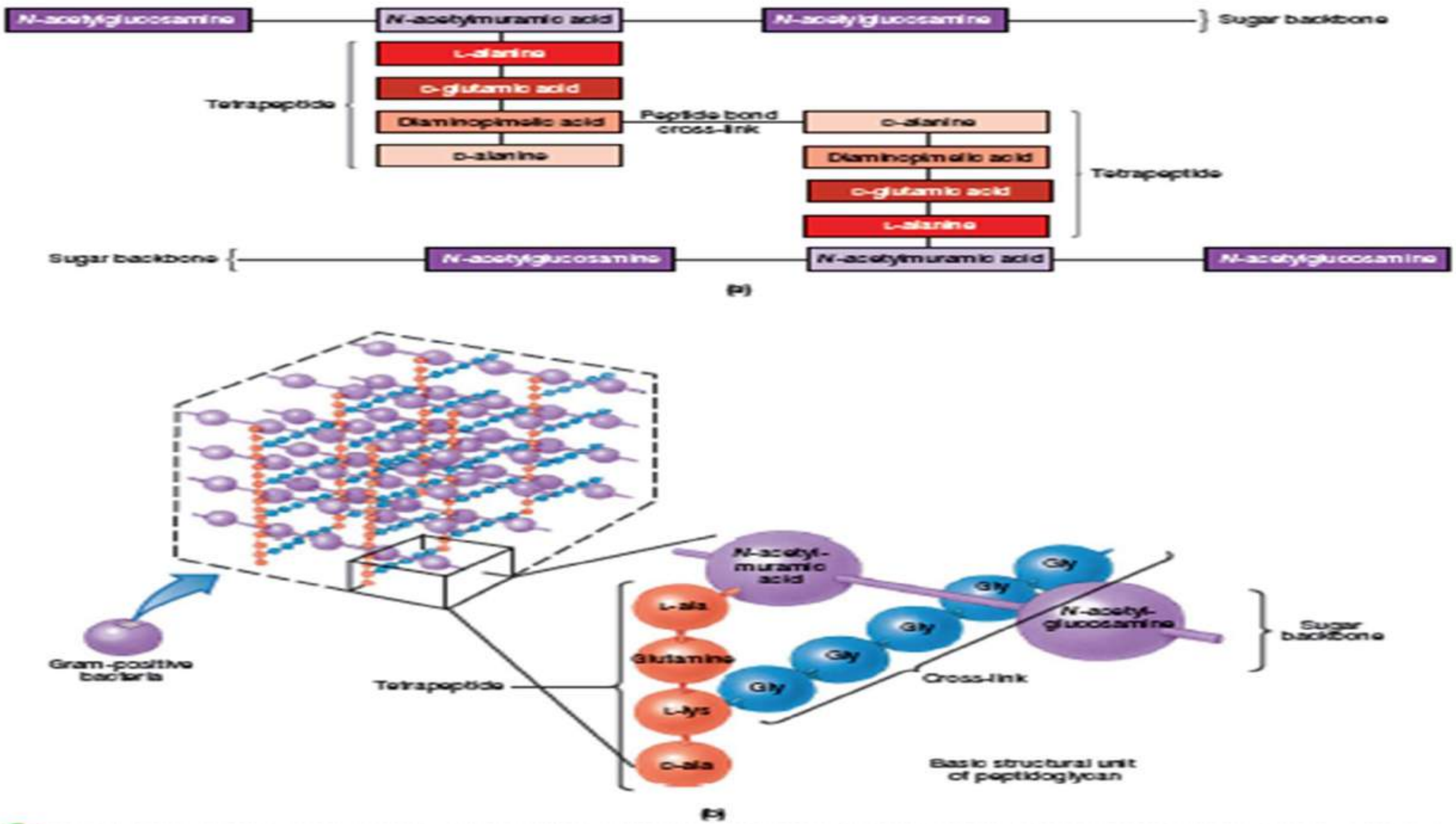
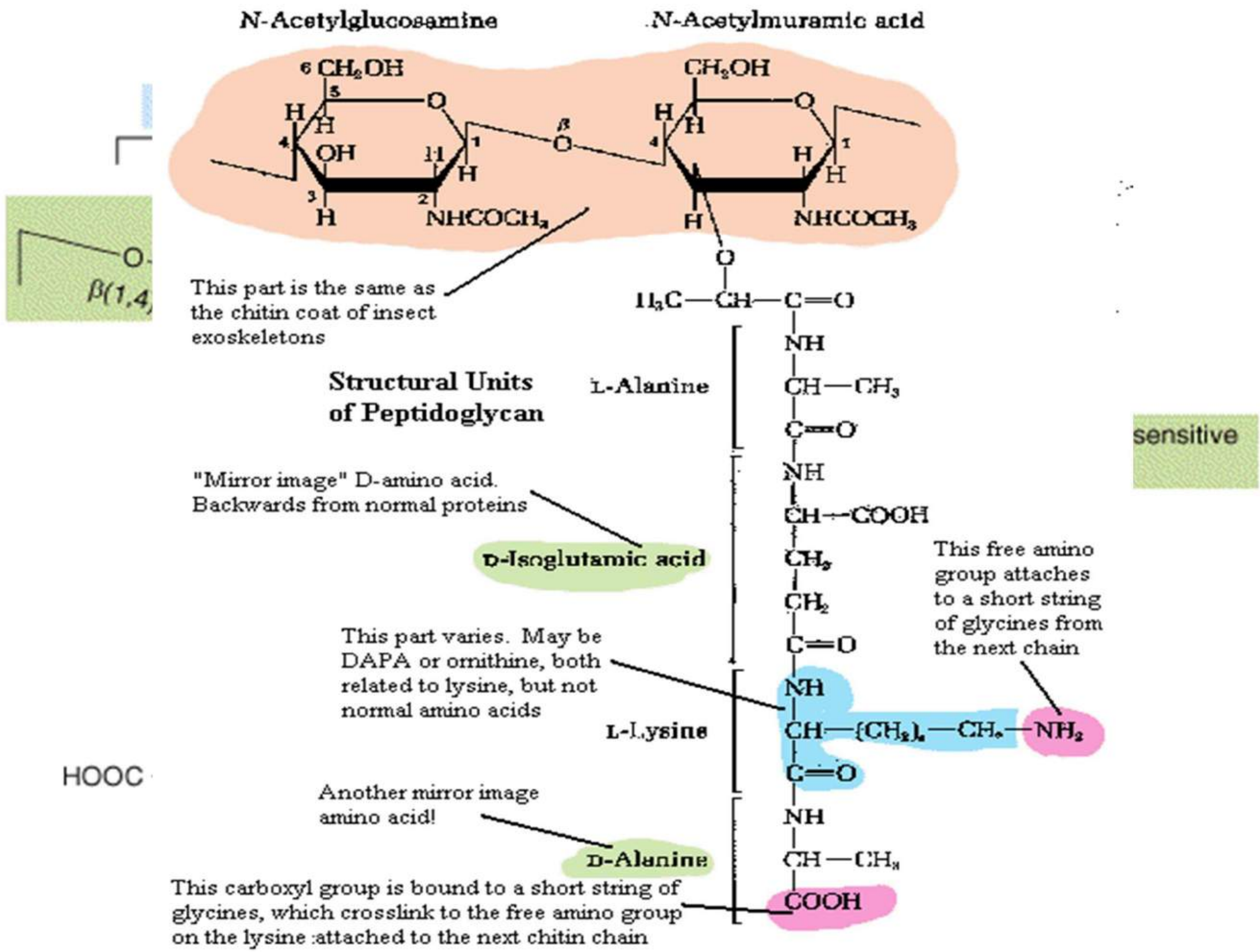


FIGURE 4.4 Peptidoglycan. (a) A two-dimensional view of the peptidoglycan of the Gram-negative bacterium *Escherichia coli*; a polymer of two alternating sugar units (purple), *N*-acetylglucosamine and *N*-acetylmuramic acid, both of which are derivatives of glucose. The sugars are joined by short peptide chains (tetrapeptides) that consist of four amino acids (red). The sugars and tetrapeptides are cross-linked by a simple peptide bond. (b) A three-dimensional view of peptidoglycan for the Gram-positive bacterium *Staphylococcus aureus*. Amino acids are shown in red. Compare the components with those in (a). Different organisms can have different amino acids in the tetrapeptide chain, as well as different cross-links.



N-Acetylglucosamine
N-Acetylmuramic acid
This part is the same as the chitin coat of insect exoskeletons
Structural Units of Peptidoglycan
L-Alanine
"Mirror image" D-amino acid. Backwards from normal proteins
D-Isoglutamic acid
This part varies. May be DAPA or ornithine, both related to lysine, but not normal amino acids
L-Lysine
This free amino group attaches to a short string of glycines from the next chain
Another mirror image amino acid!
D-Alanine
This carboxyl group is bound to a short string of glycines, which crosslink to the free amino group on the lysine :attached to the next chitin chain
β(1,4)
HOOC
sensitive

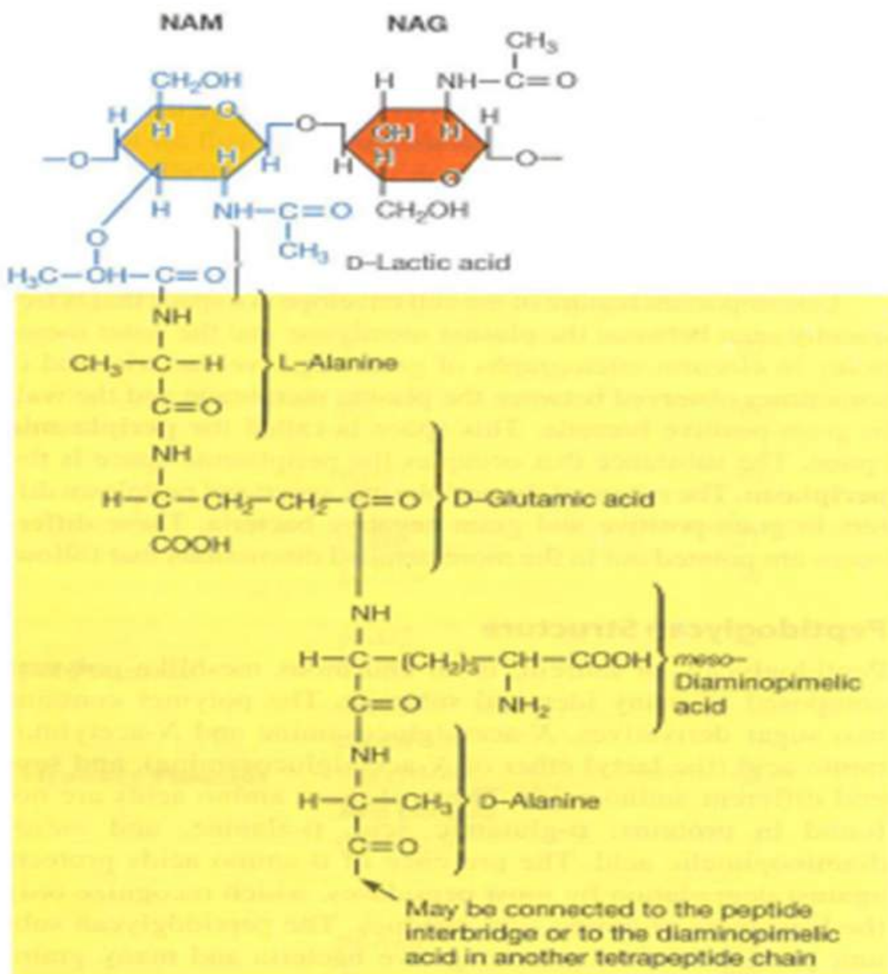


Figure 3.18 Peptidoglycan Subunit Composition. The peptidoglycan subunit of *E. coli*, most other gram-negative bacteria, and many gram-positive bacteria. NAG is *N*-acetylglucosamine. NAM is *N*-acetylmuramic acid (NAG with lactic acid attached by an ether linkage). The tetrapeptide side chain is composed of alternating D- and L-amino acids since *meso*-diaminopimelic acid is connected through its L-carbon. NAM and the tetrapeptide chain attached to it are shown in different shades of color for clarity.

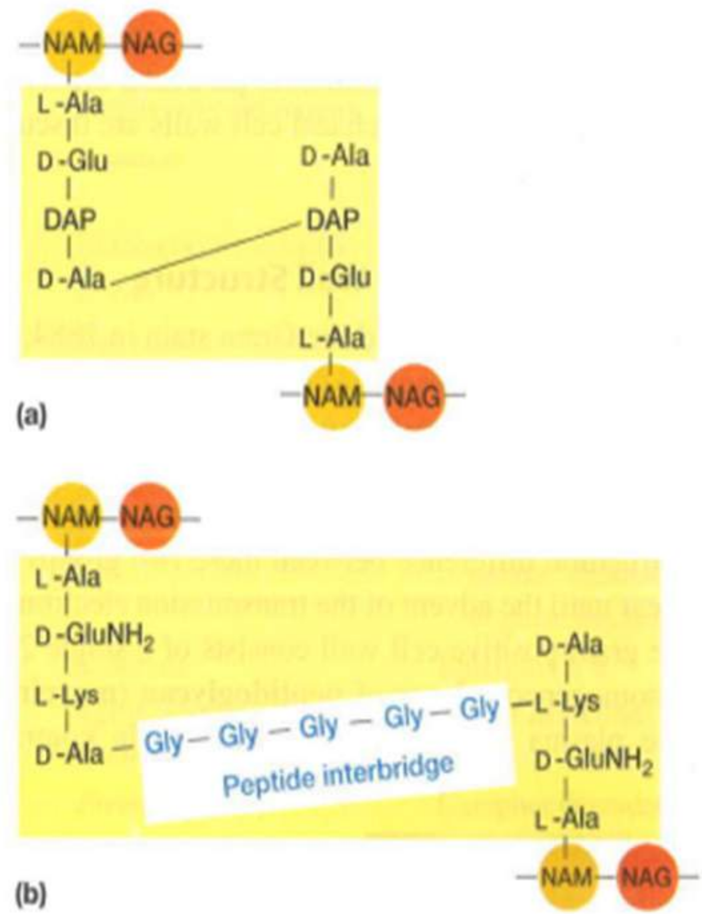
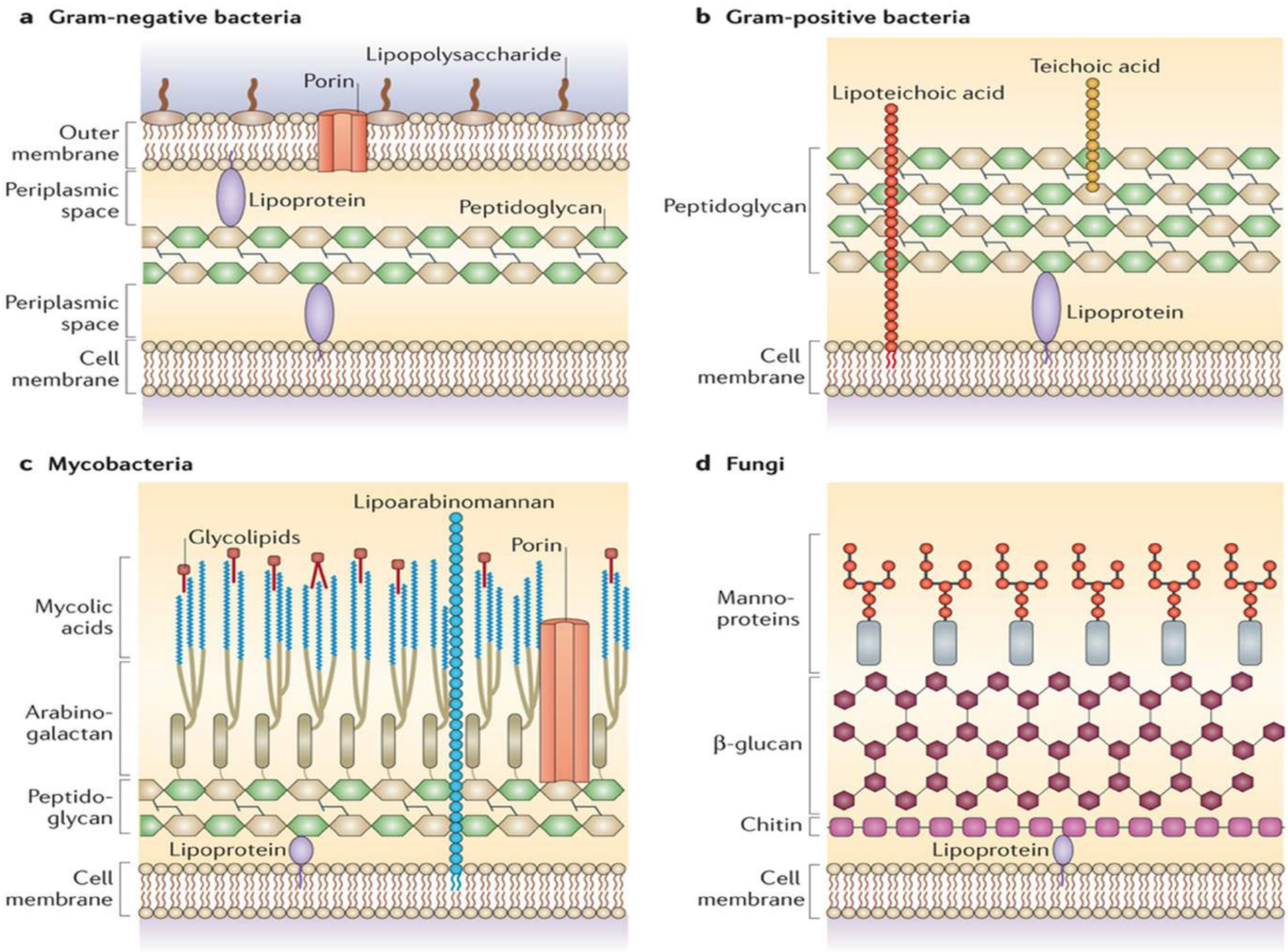


Figure 3.20 Peptidoglycan Cross-Links. (**a**) *E. coli* peptidoglycan with direct cross-linking, typical of many gram-negative bacteria. (**b**) *Staphylococcus aureus* peptidoglycan. *S. aureus* is a gram-positive bacterium. NAM is *N*-acetylmuramic acid. NAG is *N*-acetylglucosamine. Gly is glycine. Although the polysaccharide chains are drawn opposite each other for the sake of clarity, two chains lying side-by-side may be linked together (see figure 3.21).



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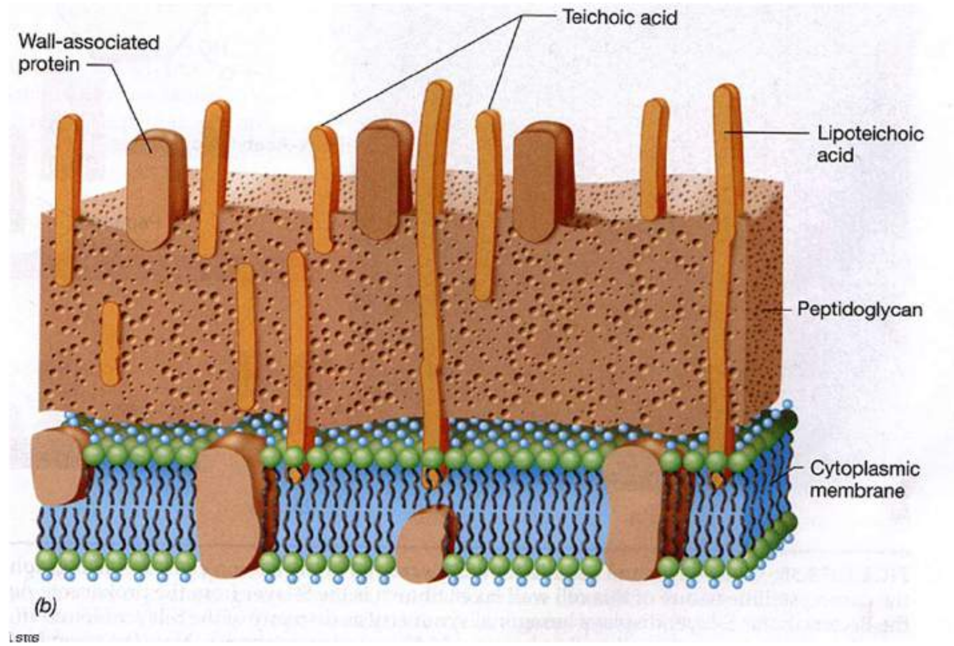
Gram positive bacterial cell wall

- Gram positive bacteria normally have cell walls that are thick and composed primarily of peptidoglycan
- Peptidoglycan in gram positive bacteria contains a peptide interbridge.
- The periplasmic space (space between cell wall and cell membrane) of gram positive bacteria is less than gram negative bacteria. Several proteins (M protein) present in periplasm which help in pathogenesis and virulance.
- In addition, gram positive cell walls usually contain large amount of Teichoic acid,

Teichoic acid

- polymer of glycerol or ribitol joined by phosphate groups.
- Amino acids such as D- alanine or sugars like glucose are attached to the glycerol and ribitol groups.
- The teichoic acids are covalently connected to either the peptidoglycan itself or to plasma membrane lipids; in the latter case they are called lipoteichoic acid.



- Teichoic acid is negatively charged help give the gram positive cell wall its negative charge.
- Teichoic acids also act as antigenic determinants, so they are important for the serologic identification of many Gram positive bacteria.
- It maintain the integrity of cell wall.

Gram Negative bacterial cell wall

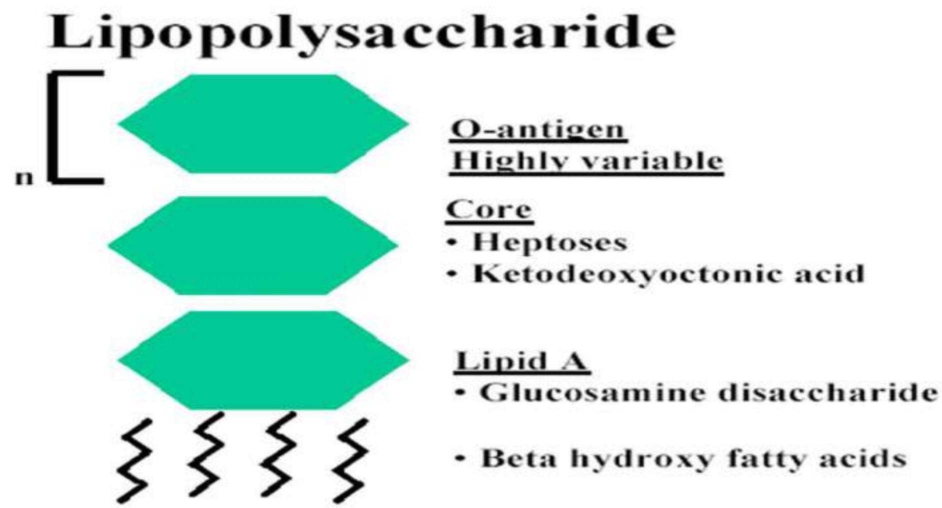
- It has thin peptidoglycan layer next to the plasma membrane.
- The periplasmic space (space between cell wall and cell membrane) of gram negative bacteria is more than gram positive bacteria.

Periplasmic Proteins

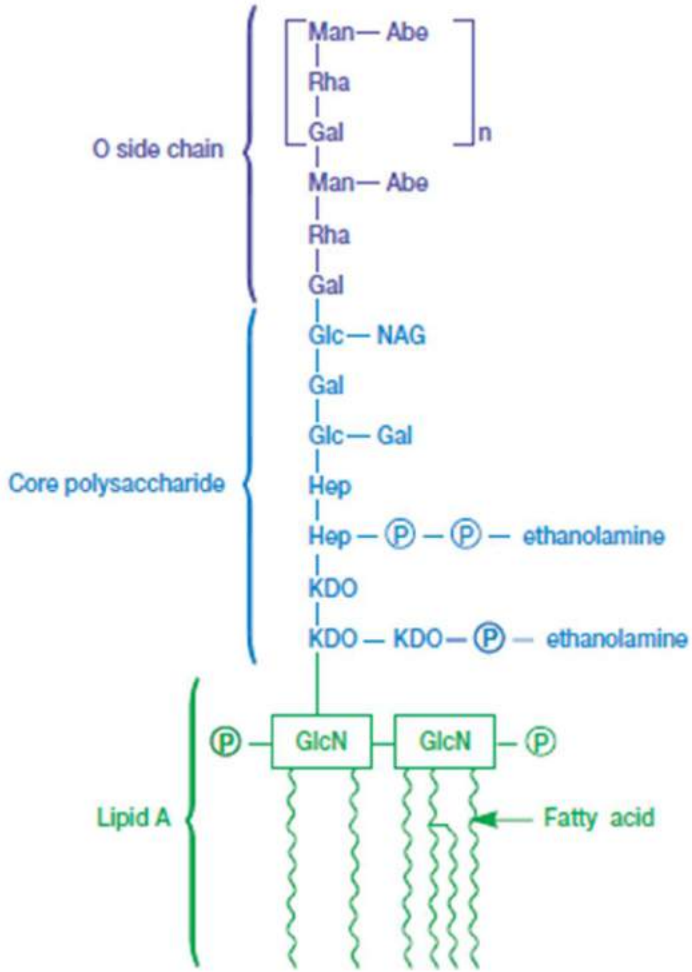
- Some periplasmic proteins participate in nutreint acquisition – for example, the denitrifying bacteria, which convert nitrate to nitrogen gas, bacteria that that use inorganic molecules as energy sources (Chemolithotrophs) have electron transport proteins in their periplasm.
- Other proteins are involved in peptidoglycan synthesis and the modification of toxic compound that could harm the cell
- The most unusual constituents of outer membrane are its Lipopolysaccharides (LPSs).

LPSs

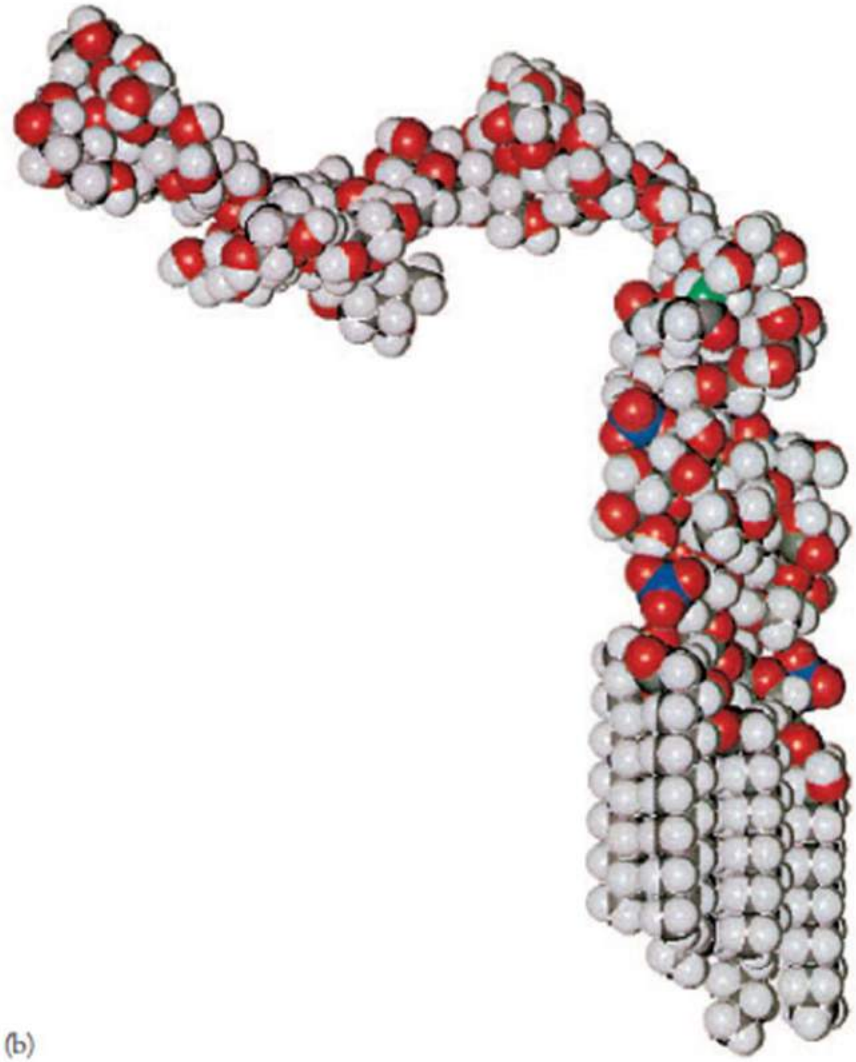
- It contains both lipid and carbohydrate and consist of three parts
  - Lipid A
  - The core polysaccharide
  - The O side chains



- The lipid A region contains two glucosamine sugar derivatives, each with three fatty acids and phosphate or pyrophosphate attached.
- The core polysaccharide is joined to lipid A
- The O side chain or O antigen is a polysaccharide chain extending outward from the core .



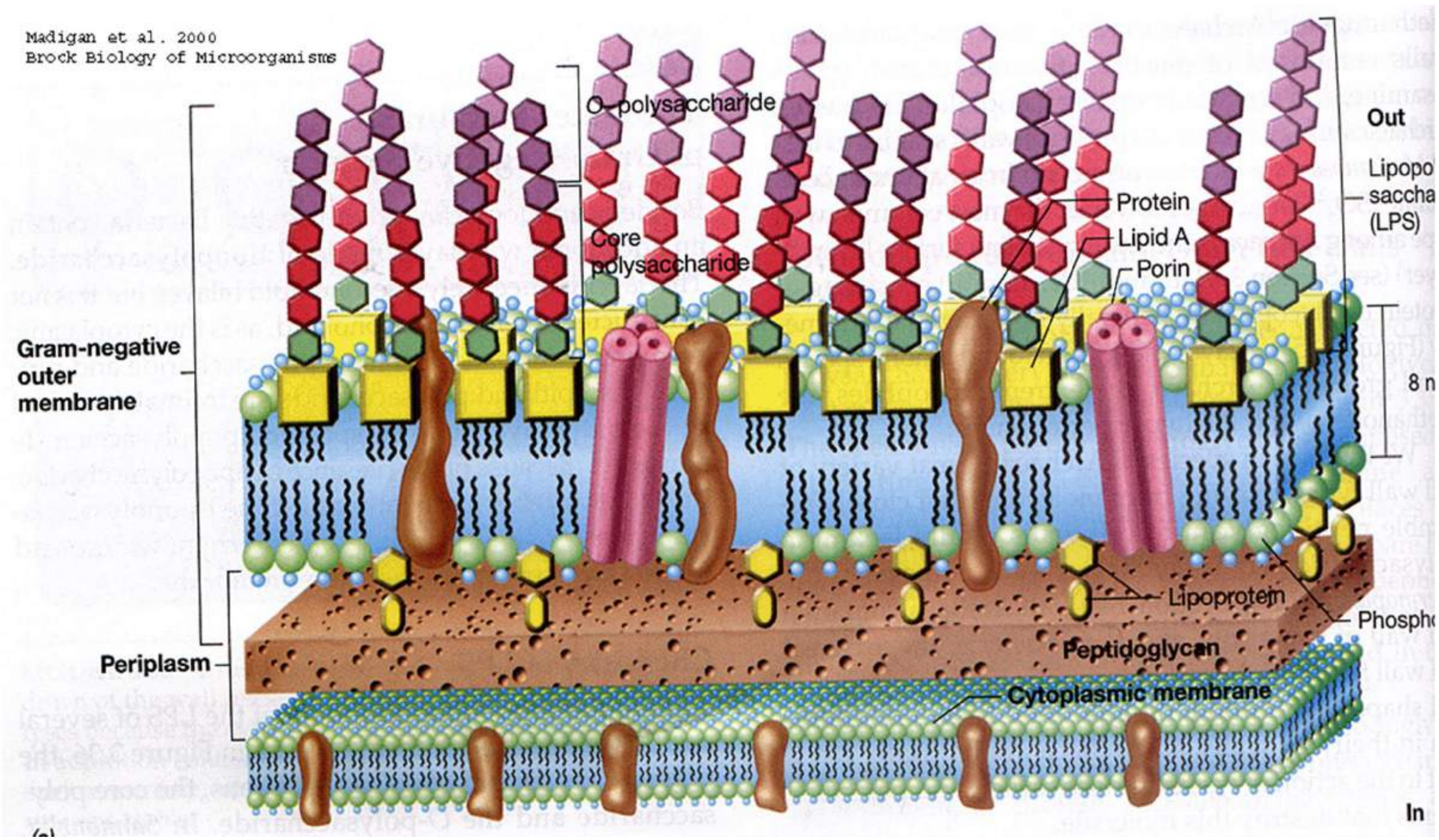
(a)



(b)

Figure 3.25 Lipopolysaccharide Structure. (**a**) The lipopolysaccharide from *Salmonella.* This slightly simplified diagram illustrates one form of the LPS. Abbreviations: Abe, abequose; Gal, galactose; Glc, glucose; GlcN, glucosamine; Hep, heptulose; KDO, 2-keto-3-deoxyoctonate; Man, mannose; NAG, *N*-acetylglucosamine; P, phosphate; Rha, L-rhamnose. Lipid A is buried in the outer membrane. (**b**) Molecular model of an *Escherichia coli* lipopolysaccharide. The lipid A and core polysaccharide are straight; the O side chain is bent at an angle in this model.

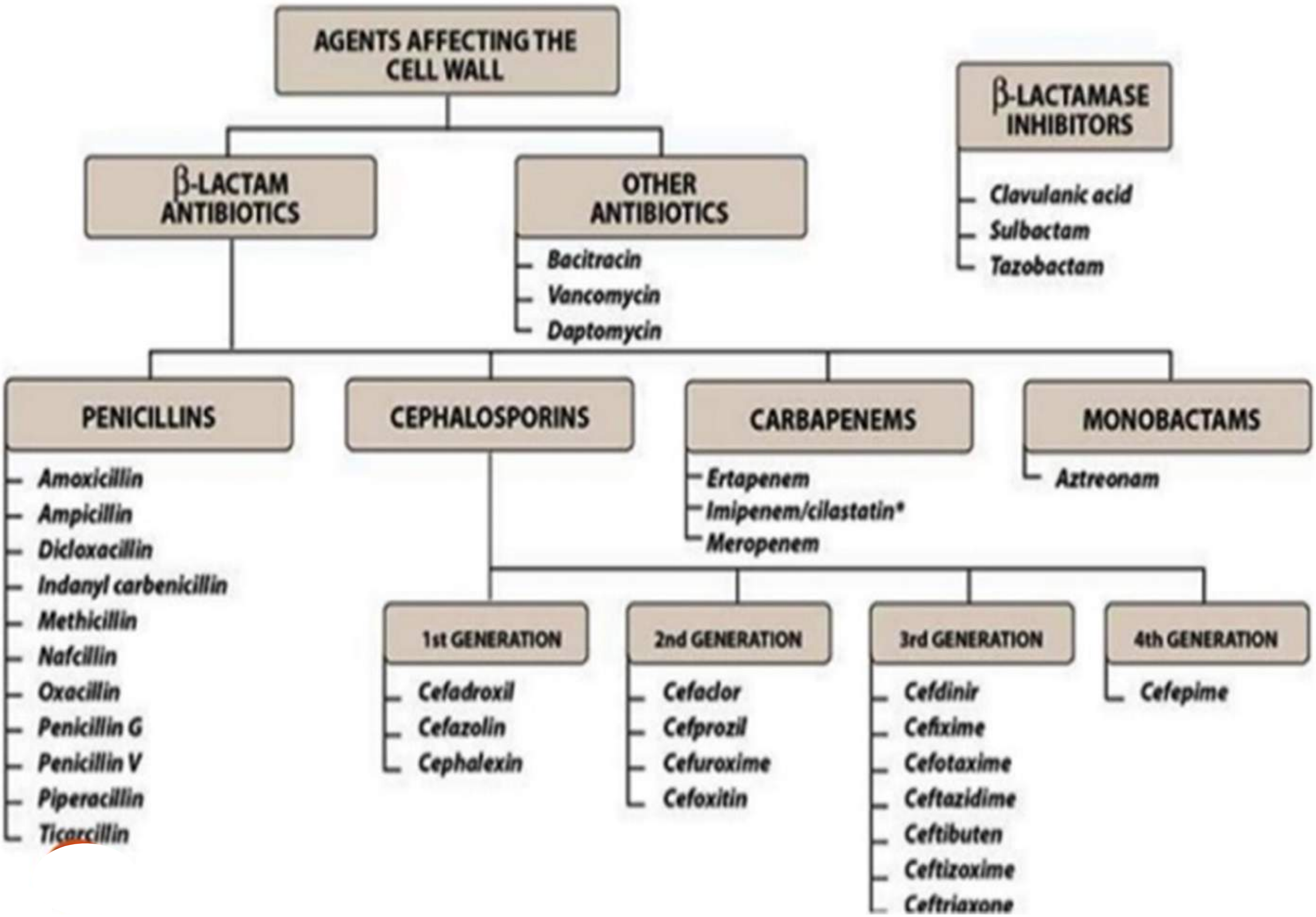
Special components of Gram negative cell wall



Functions of LPSs

- LPSs contribute negative charge on the bacterial surface due to lipid A
- Lipid A also help s stabilize outer structure
- LPSs may also contribute to bacterial attachment to surface and biofilm formation.
- The major function of LPSs is that it aids in creating a permeability barrier.
- Lipid A portion LPS often is toxic; as a result, the LPS can act as an endotoxin and cause some of the symptoms that arise in gram negative bacterial infection.
- The O side chain of LPS is also called the O antigen because it elicits an immune system. This response involves the production of antibodies that bind the starin specific form of LPS that elicited the response.

CLASSIFICATION OF CELL WALL INHIBITORS



Acknowledgement and Suggested Readings:

1. Microbiology, An Introduction; Tortora, Funke and Case; Pearson Publication
2. Microbiology; Prescott, Harley and Klein; The MacGraw-Hill Companies
3. Microbiology: Principles and Explorations; Jacquelyn G Black; John Wiley and Sons Inc.
4. Brock Biology of Microorganisms; Madigan, Martinko, Stahl and Clark; Benjamin Cummings (Pearson Publication)

Thanks