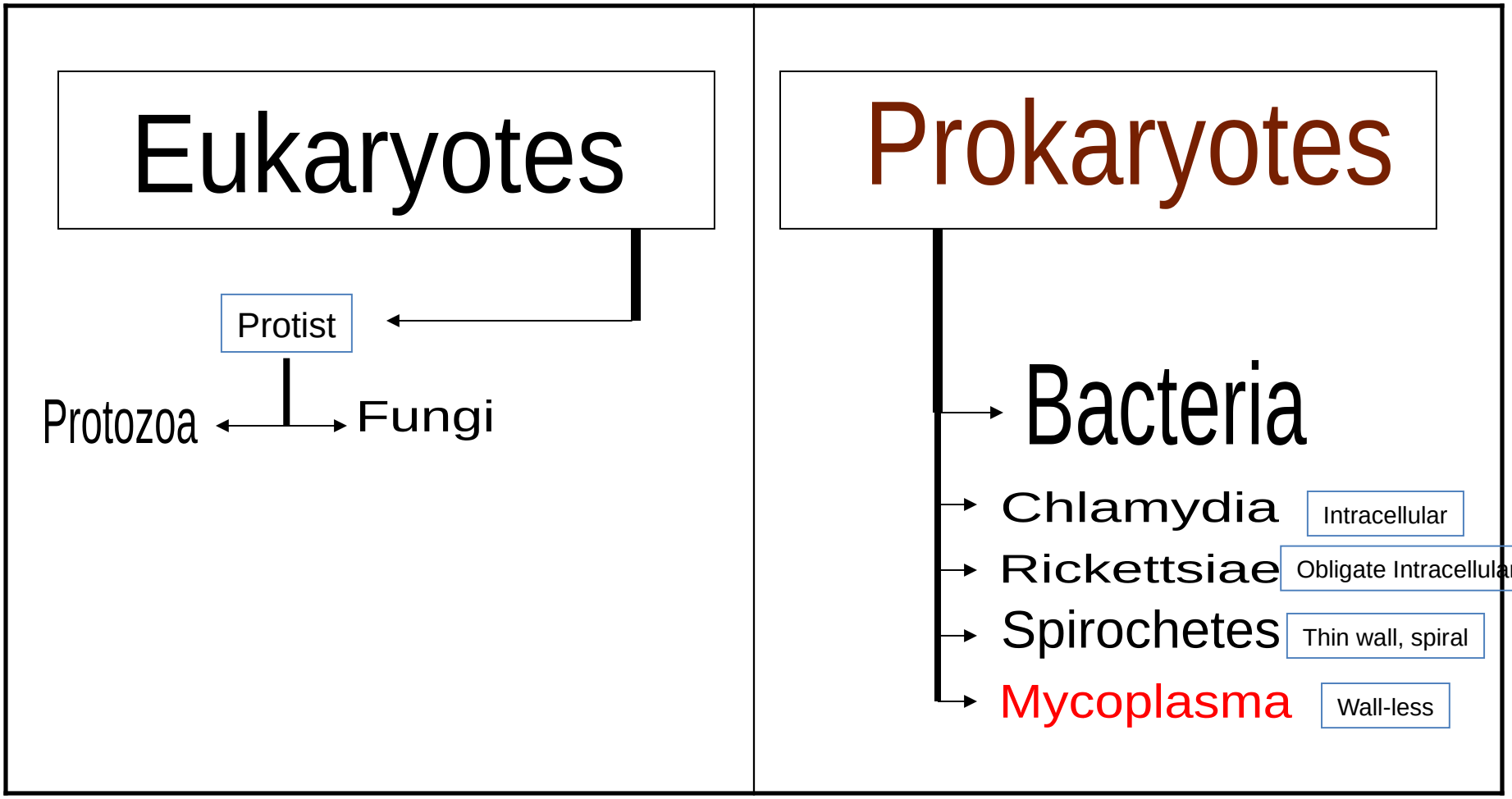

بسم الله الرحمن الرحيم

Structure of Bacterial Cell

Aims & Objectives

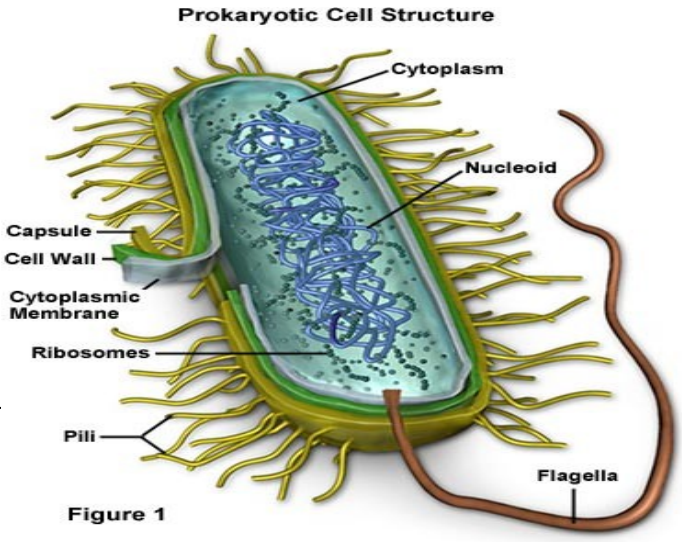
At the end of the lecture, students of 3rd Year MBBS should be able to

1. Describe structure and function of each of various parts of the bacterial cell including cell wall, cytoplasmic membrane, mesosomes, ribosomes, granules and nucleoid. #85
2. Describe specialized structures outside the cell wall including capsule, flagella, pili and glycocalyx. #86
3. List the differences between cell wall characteristics of Gram Positive and Gram Negative Bacteria. #87
4. Describe classification and important functions of plasmids. #88
5. Describe functions and arrangement of transposons. #89
6. Describe structure, functions and medical importance of bacterial spores with examples. #90

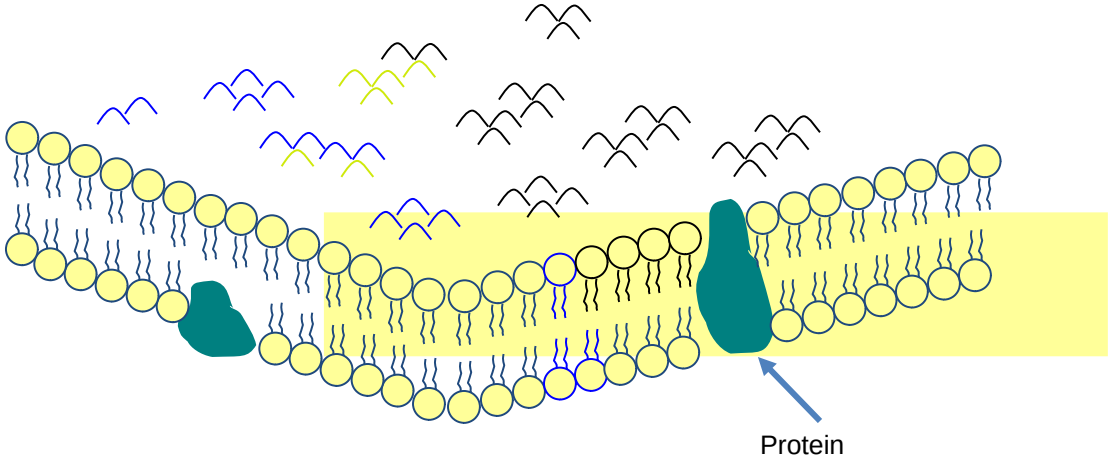

Eukaryotes
Protist
Protozoa
Fungi
Prokaryotes
Bacteria
Chlamydia
Intracellular
Rickettsiae
Obligate Intracellular
Spirochetes
Thin wall, spiral
Mycoplasma
Wall-less

Viruses

Structure of Bacterial Cell



- Prokaryotes simple one cell structure.
- **no nucleus** , the genetic material is present in the form of a spiral.
- Cell contents are enclosed in a **cell membrane**.
- It is surrounded by **cell wall** which is composed of lipids and proteins.
- **Flagellum** for locomotion.
- Some contain **fimbriae** for attachment.
- Contain **Plasmid** extrachromosomal packets of genetic material.



Plasma membrane

- It is a unit membrane composed of phospholipids and proteins (lipid bilayer).
- Transport proteins responsible for active transport of ions, nutrients and waste across the membrane *selective permeability*
- also contains membrane enzymes, i.e. permeases (for uptake of nutrients), respiratory enzymes & pigments and cytochrome enzymes,

Functions of cell membrane

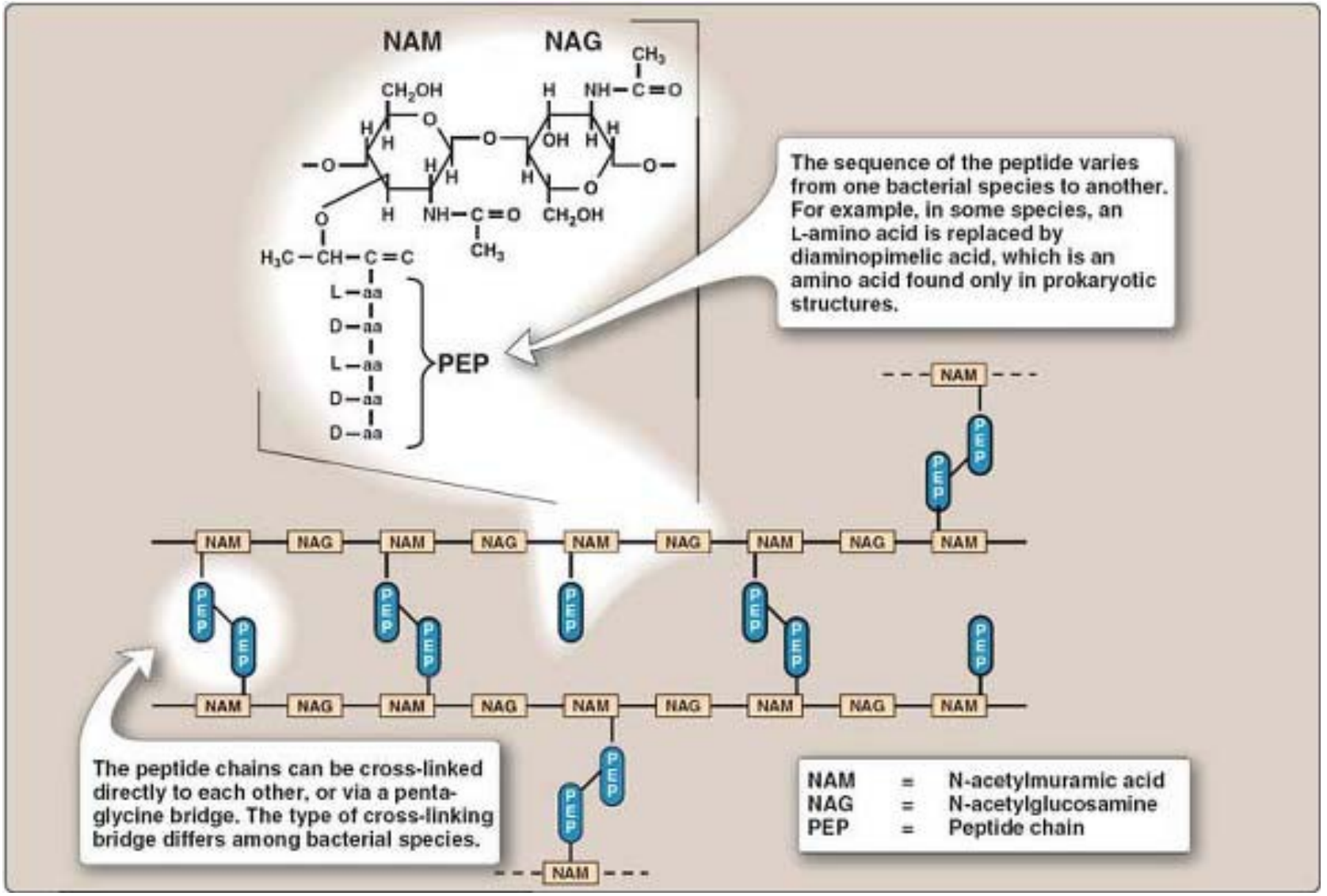
- Selective permeability & transport,
- Electron transport & oxidative phosphorylation (aerobic) (energy generation),
- Secretion of hydrolytic exoenzymes,
- possesses the enzymes and carrier proteins for the biosynthesis of DNA, cell wall polymers & membrane lipids,
- Bearing protein receptors.

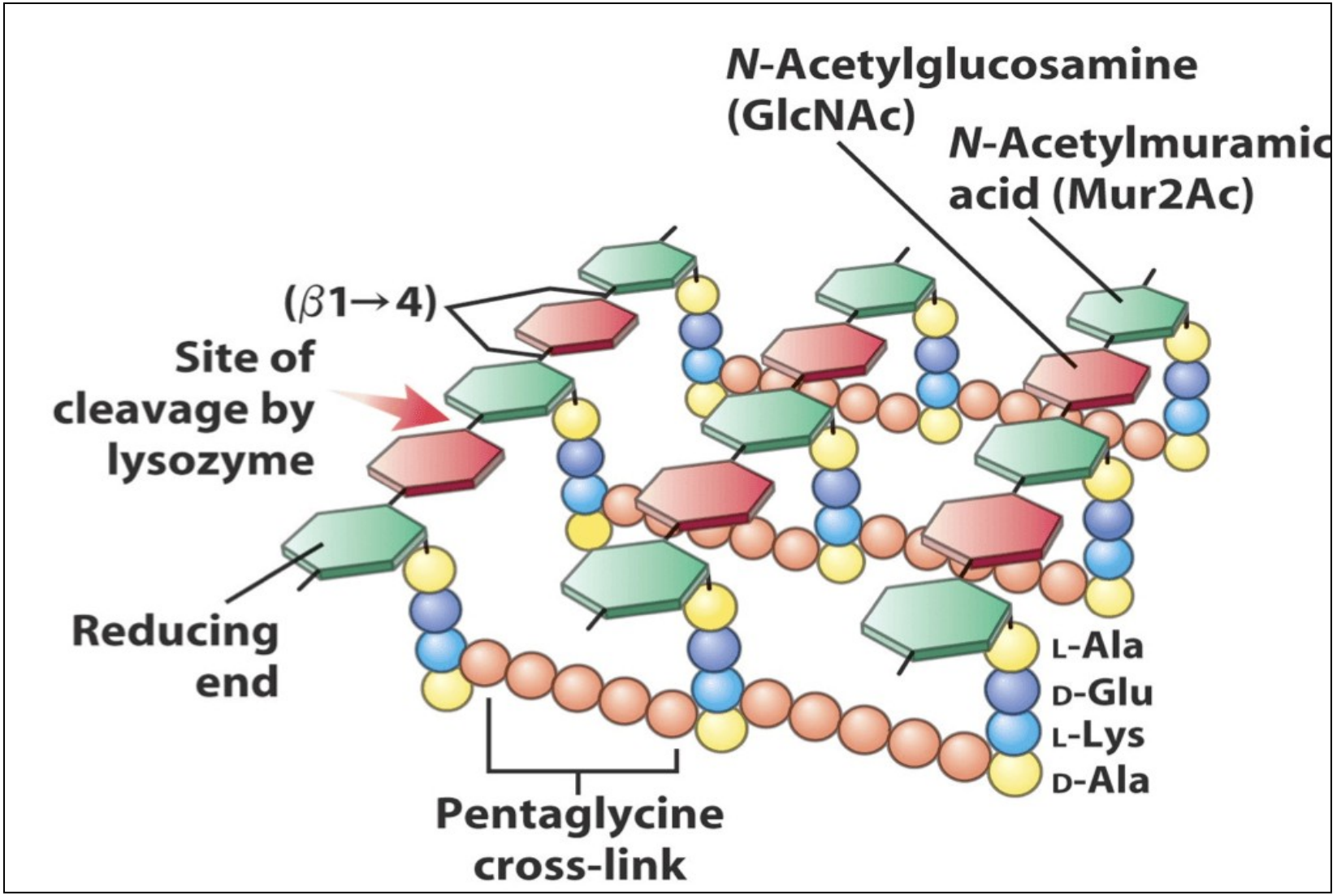
Cell wall

The outermost multilayered component, composed of peptidoglycan (polysaccharides + protein)

- Imparts rigidity and structural Integrity,
- Prevents osmotic lysis
- Its porin proteins, act as channels to allow entry of essential substances (i.e. sugar, amino acids, vitamins, metals & drugs),
- Its polysaccharides and proteins are antigens for laboratory identification,
- It forms basis for gram staining
- Degrades by lysozymes,
- site of action of penicillin and cephalosporin.

Cell wall


NAM
NAG
PEP
The sequence of the peptide varies from one bacterial species to another. For example, in some species, an L-amino acid is replaced by diaminopimelic acid, which is an amino acid found only in prokaryotic structures.
The peptide chains can be cross-linked directly to each other, or via a penta-glycine bridge. The type of cross-linking bridge differs among bacterial species.
NAM = N-acetylmuramic acid
NAG = N-acetylglucosamine
PEP = Peptide chain


N-Acetylglucosamine
(GlcNAc)
N-Acetylmuramic
acid (Mur2Ac)
(β1→4)
Site of
cleavage by
lysozyme
Reducing
end
L-Ala
D-Glu
L-Lys
D-Ala
Pentaglycine
cross-link

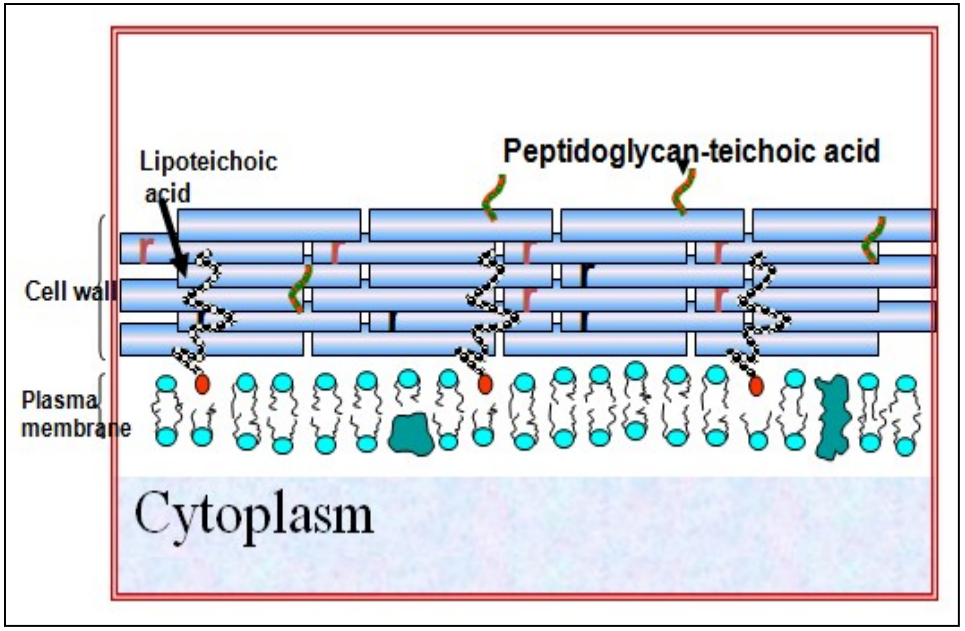
Gram-positive Bacteria

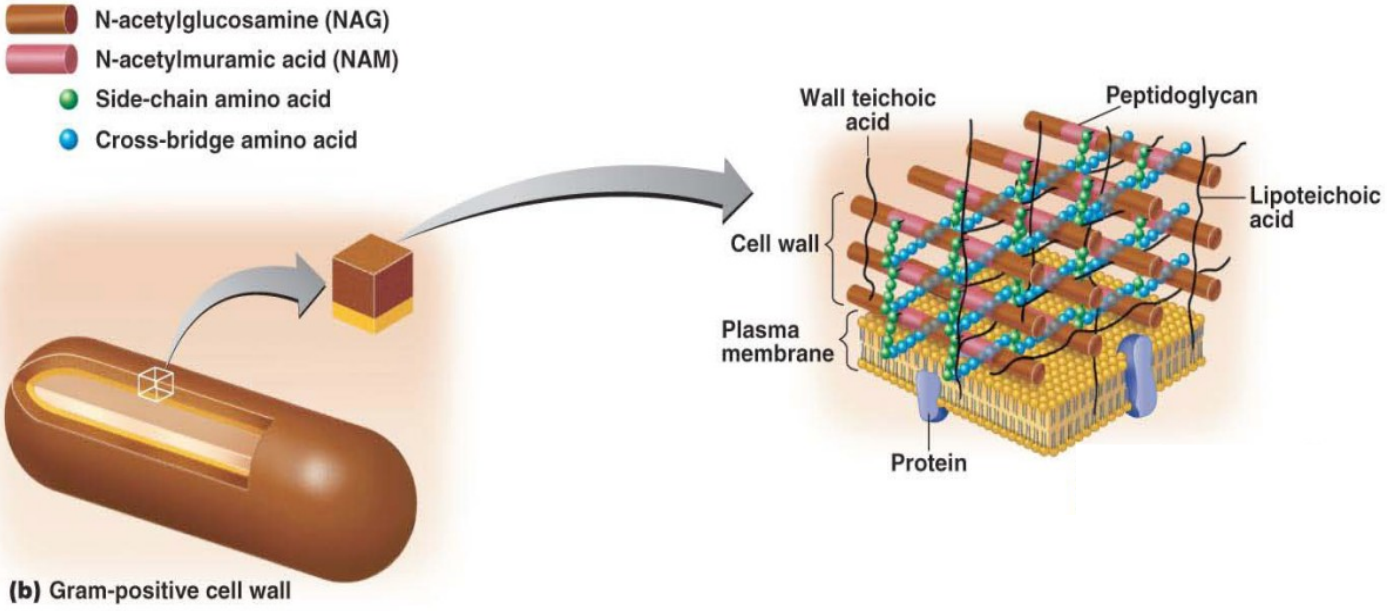
In gram + bacteria, the cell wall consists of

1. several layers of peptidoglycan.
2. **Filaments of teichoic acids** which are unique to the gram-positive cell wall. These filaments run perpendicular to the peptidoglycan sheets.

Gram Positive Cell wall

Thick peptidoglycan layer linked to teichoic acid

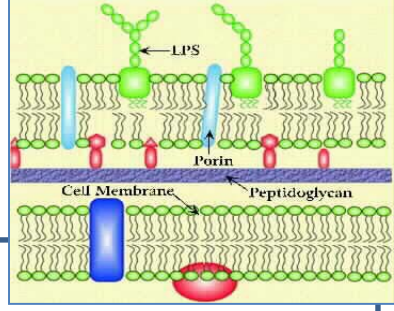


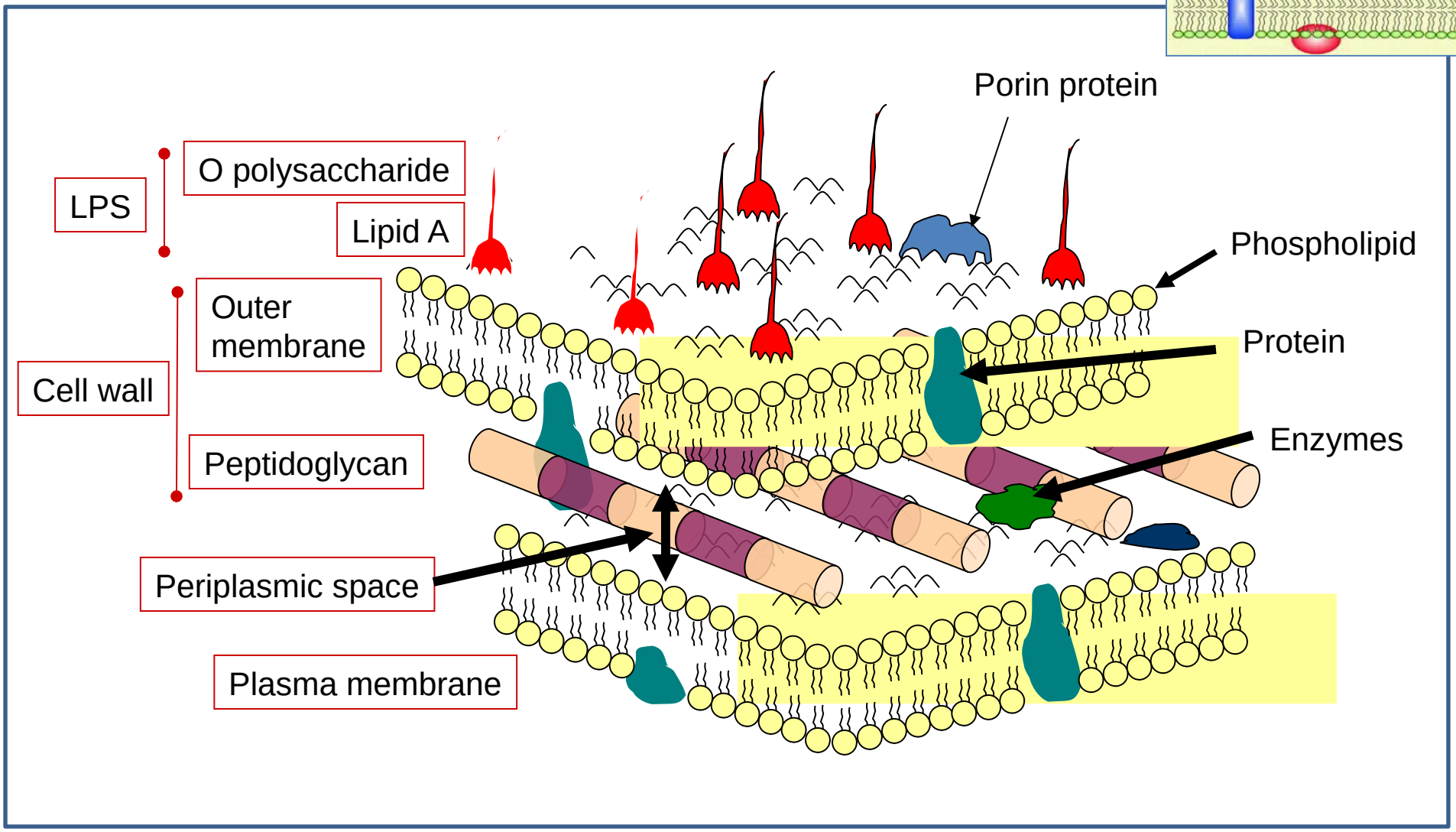


Gram-Negative Bacteria

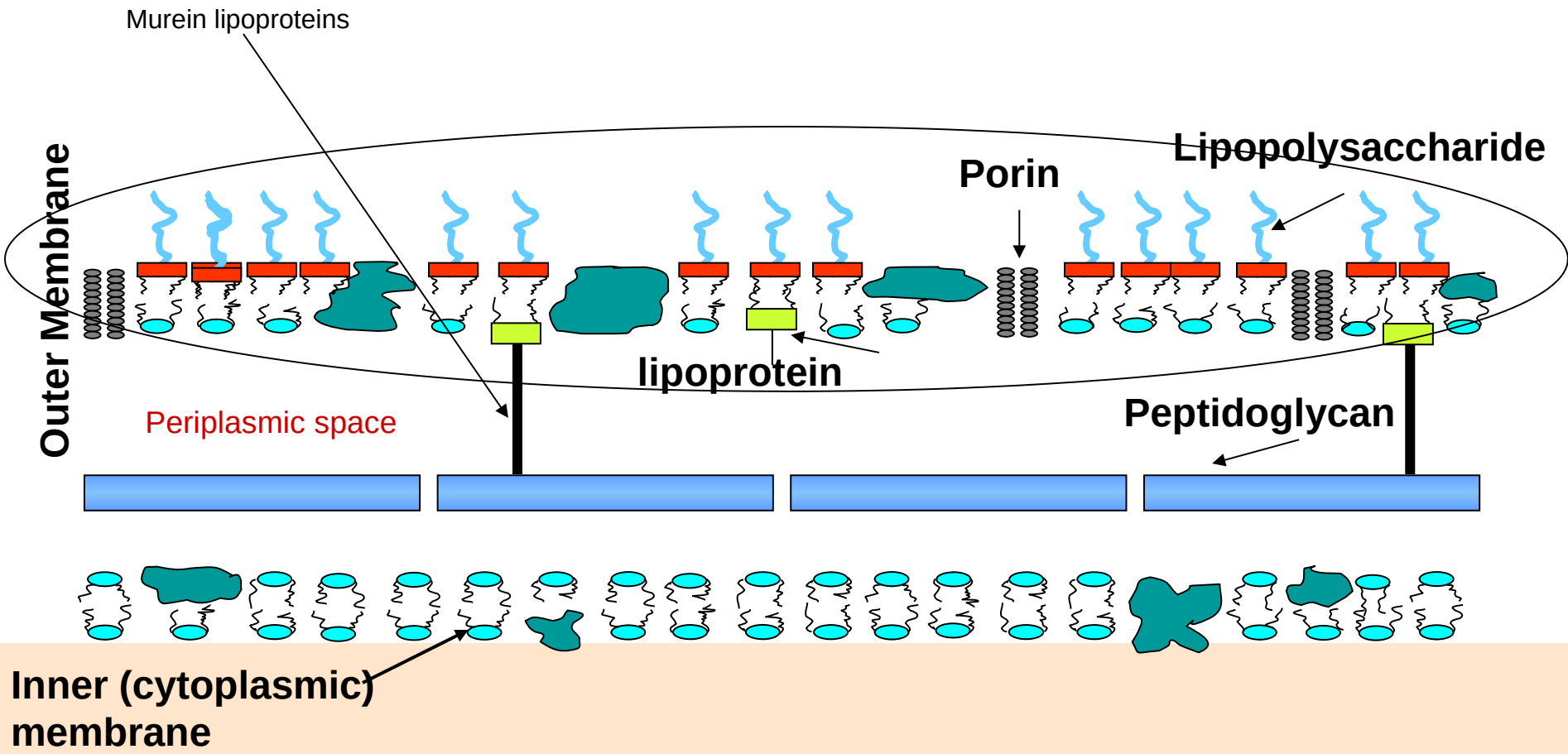
- Gram-negative bacteria possess a double membrane which encases the periplasmic space and peptidoglycan layer.
- The inner (cytoplasmic) membrane can perform active transport, has respiratory chain components, and various proton pumps.
- The periplasm contains the single layer of peptidoglycan, various degradation enzymes or pre-proteins, and signaling molecules (receptors / ligands).
- The outer membrane functions as a surface organelle for the display of carbohydrates and proteins and contains porins, transporters and lipopolysacchrides.
- **Murein lipoprotein** tethers the outer membrane to the peptidoglycan layer.

Gram-negative Cell Wall

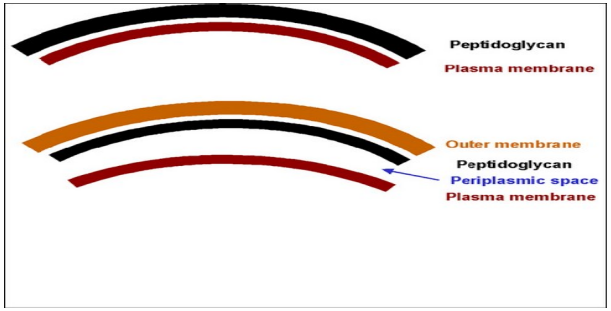




Gram Negative Cell Envelope



Comparative Characteristics of Gram positive and Gram negative bacteria



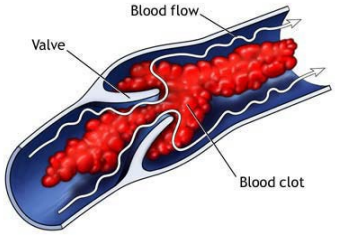
Characteristic	Gram-Positive	Gram-Negative
Peptidoglycan layer	Thick, multilayered	Thin, single layer
Teichoic acids	Present in many	**Absent**
Periplasmic space	**Absent**	Present
Outer membrane	**Absent**	Present
LPS content	Virtually none	High, antigenic (Lipid A toxic)
Toxins	Primarily exotoxins	Primarily endotoxins
Lipid / lipoprotein content	Low	High
Gram reaction	Retain crystal violet	decolorize

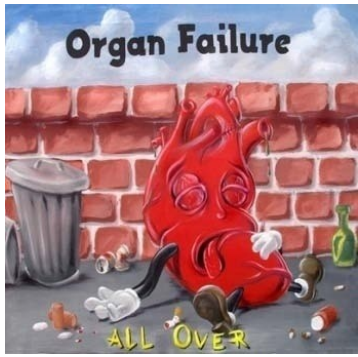
Adapted from Tortora et al. 1997

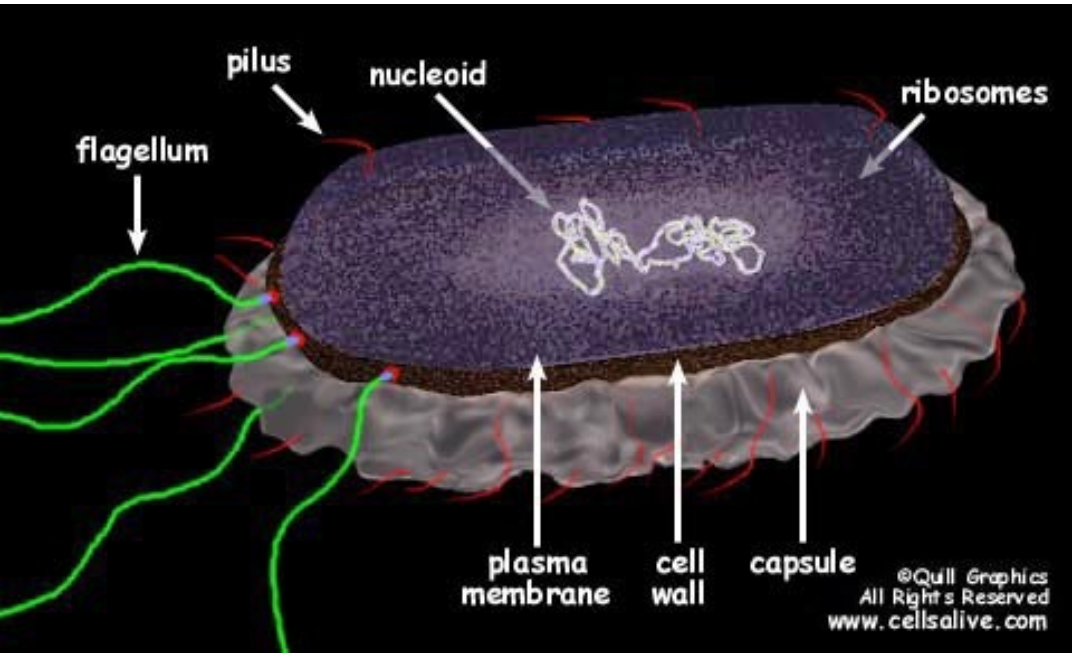
Bacterial Endotoxins

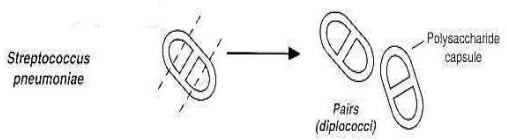
Component of bacterial cell wall (LPS), which liberates when the cell membrane disintegrates after the death of bacteria. They have non-specific & generalized actions

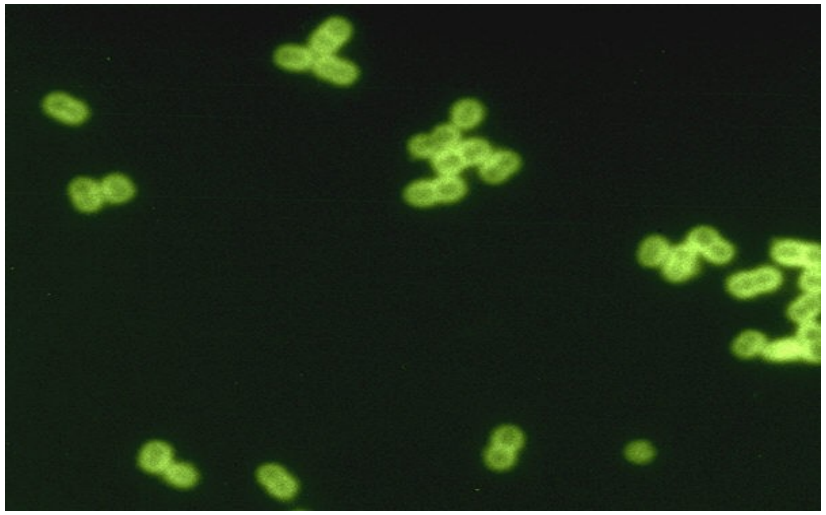
- Main physiologic effects include:
  - fever, shock, hypotension, and thrombosis, collectively referred to as **septic shock**.
- It activates
  - macrophages to release cytokines,
  - complement, and
  - the coagulation cascade.
- Death from multiple organ failure.











Capsule

- A tightly bound, sticky gelatinous, polysaccharide layer,
- (if loosely bound and amorphous glycocalyx)
- help in **adherence** to human tissues
- Determines the virulence (*S pneumoniae*, *K pneumoniae*, *N meningitidis* and *H influenzae*)
- Antiphagocytic, and diffusion barrier against some antibiotics

Ribosomes

- Bacterial ribosomes are the site of protein synthesis.
- Bacterial ribosomes are 70S in size, with 50S and 30S subunits.

Granules

- The cytoplasm contains several different types of granules that serve as storage areas for nutrients and stain characteristically with certain dyes. For example, volutin granules are the reserve of high energy stored in the form of polymerized metaphosphate. It appears as a “metachromatic” granule (a characteristic feature of *Corynebacterium diphtheriae*, the cause of diphtheria).

Nucleoid

- The nucleoid is the area of the cytoplasm in which DNA is located. The DNA of prokaryotes is a single, circular molecule that has a molecular weight (MW) of approximately 2×10^{9} and contains about 2000 genes.

Plasmids

Plasmids are extrachromosomal pieces of circular DNA that encode both exotoxins and many enzymes that cause antibiotic resistance.

- They are capable of replicating independently.
- They can be integrated into the bacterial chromosome.
- Plasmids occur in both gram-positive and gram-negative bacteria

(1) Transmissible plasmids can be transferred from cell to cell by conjugation.

They are large (MW 40–100 million), since they contain about a dozen genes responsible for synthesis of the sex pilus and for the enzymes required for transfer.

(2) **Nontransmissible** plasmids are small (MW 3–20 million), since they do not contain the transfer genes; they are frequently present in many (10–60) copies per cell.

Plasmids functions

Plasmids carry the genes for the following functions and structures of medical importance:

1. Antibiotic resistance, which is mediated by a variety of enzymes.
2. Resistance to heavy metals, such as mercury, the active component of some antiseptics (e.g., merthiolate and mercurochrome), and silver, which is mediated by a reductase enzyme.
3. Resistance to ultraviolet light, which is mediated by DNA repair enzymes.
4. Pili (fimbriae), which mediate the adherence of bacteria to epithelial cells.
5. Exotoxins including several enterotoxins.

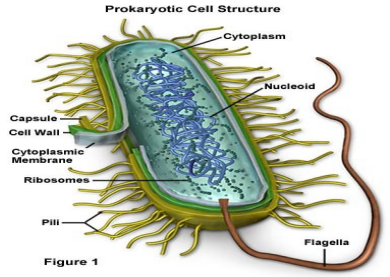
Transposons

- Transposons are pieces of DNA that move readily from one site to another either within or between the DNAs of bacteria, plasmids, and bacteriophages. Because of their unusual ability to move, they are nicknamed “jumping genes.”
- Transposons can code for drug resistant enzymes, toxins, or a variety of metabolic enzymes and can either cause mutations in the gene into which they insert or alter the expression of nearby genes.

Bacterial Appendages

Pili (fimbriae)

- hollow, hairlike structures on the surface of gram negative bactria, & made of protein (pilins), allow bacteria to attach to other cells.
- A specialized pilus, the sex pilus, helps attachment of male to female during conjugation.



Flagella (for motility).

- Flagella are long, tubular structures, composed of FLAGELLIN, embedded in cell membrane
- Bacteria may have one, a few, or many flagella in different positions on the cell.

Glycocalyx (Slime Layer) (loosely bound capsule)

- The glycocalyx is a polysaccharide coating that is secreted by many bacteria. It covers surfaces like a film and allows the bacteria to **adhere firmly** to various structures (e.g., skin, heart valves, prosthetic joints, and catheters).
- The glycocalyx is an important component of biofilms. The medical importance of the glycocalyx is illustrated by the finding that it is the glycocalyx-producing strains of *Pseudomonas aeruginosa*, which cause respiratory tract infections in cystic fibrosis patients

Spore

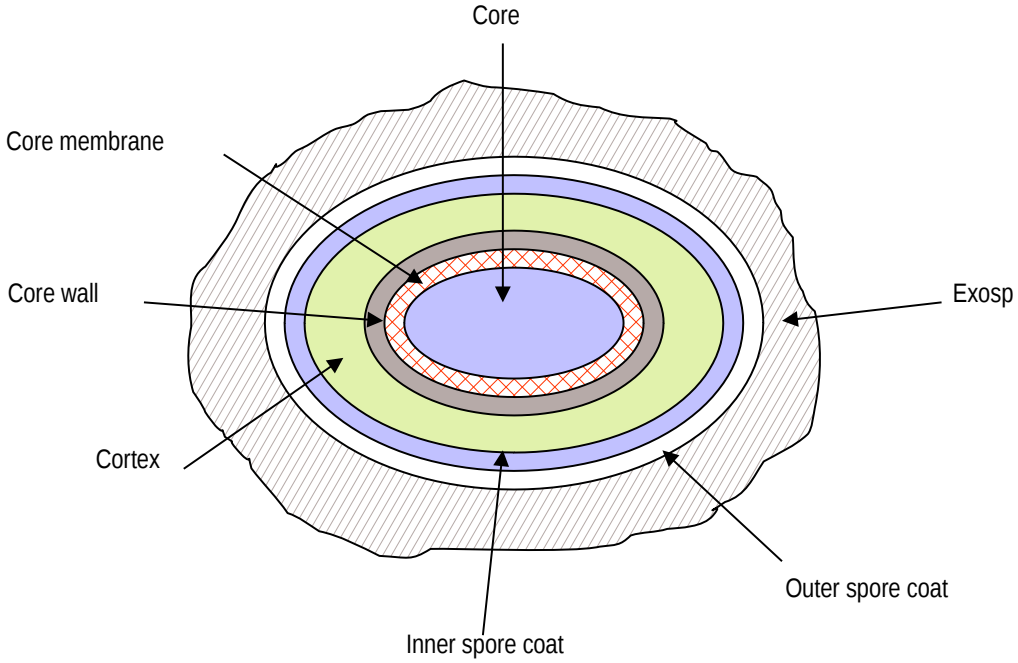
- **It is thick, resistant, multilayered coating secreted by certain G+ bacteria, to be able to survive in hostile environments**

- Dormant
- Almost Inert metabolically
- No division

Spore imparts resistance to

- Heat
- Descication
- UV light
- Certain chemicals

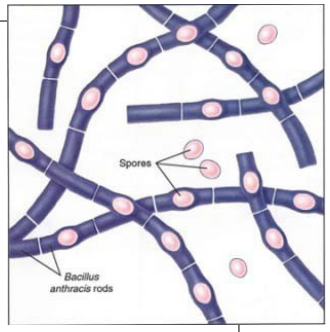
Autoclaving



- *Bacillus anthracis*
- *B. cereus*
- *Claustridium tetani*
- *C. perfringens*
- *C. botulinum*

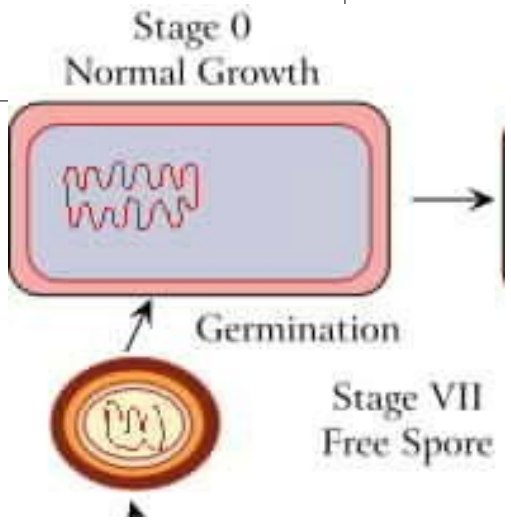
Medical significance of sporulation

- Spores remain
  - viable for many years
  - not killed by boiling, but can be killed by
    - **Sterilization** (autoclave) at >120°C under elevated pressure OR
    - ***Tydallization* / fractional sterilization** (by primary boiling to activate germination & after a short period of vegetative growth, a second boiling.



Spore germination

- Spore coat is weakened by heat / extremes of pH
- Or If the environment is nutritious, germination starts
- And the cell returns to the vegetative state




ASDtags
©2004
Thanks