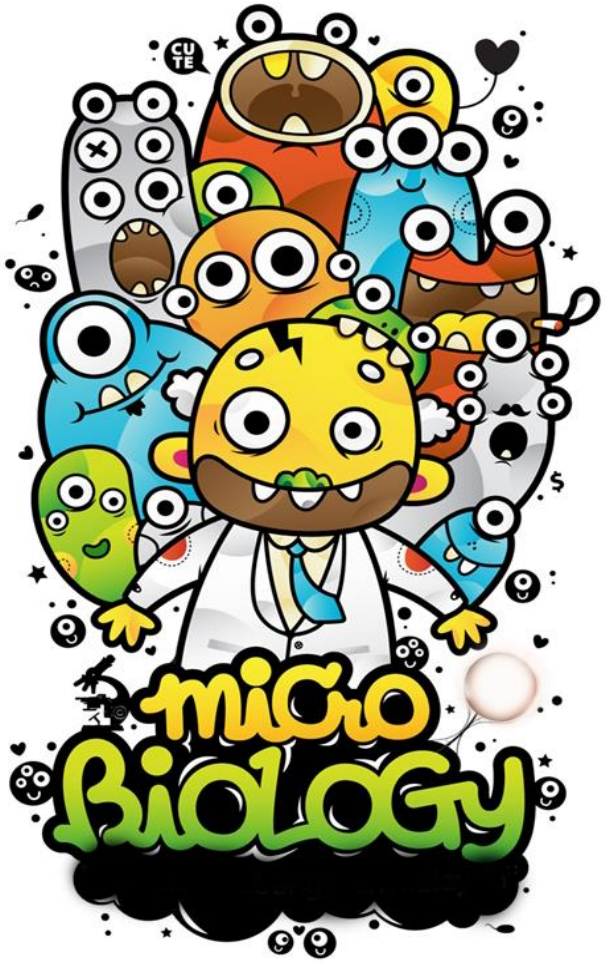

Subject: Structure of Bacterial Cells

Lecture No.: 4

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Structure of Bacterial Cells:

1. Cell Wall:

- Outermost layer of all bacteria; covering the plasma membrane.
- Its major **functions** are:

  a) Maintains the high turgidity of the bacteria without facing lyses or bursting as a result of osmosis.

  b) Maintains the shape of the cell
- It's a rigid structure -unlike the plasma membrane, which is a fluid like material thus doesn't resist high pressure and may burst.
- Bacterial cell wall is highly porous and as such it doesn't form a permeability barrier, it has no significant role in regulating entry of molecules into the cell – unlike the plasma membrane.
- Components of the bacterial cell wall:

  1. Peptidoglycan
  2. Outer membrane (G-ve)
  3. Periplasmic space (Periplasm only in G+ve)

Peptidoglycan layer:

- The most important component of the cell wall.
- It forms a supporting net around bacteria like multiple chain-link fence
- A structure made up of two molecules:

a) Peptide

b) Glycan (sugar),

- Exact structure:
  - Long chains of the polysaccharides
  - Most bacteria are made up of two covalently bonded sugars alternating with one another: the first sugar is known as N-acetylglucosamine (glucose amine) and the second is N-acetylmurmaric acid
  - These two sugars are cross-linked vertically and horizontally to be able to give the rigid characteristics of the cell wall. These cross-linked are as a result of polypeptides.

  a) **Vertical Cross-links:** by tetrapeptide bonds

b) **Horizontal Crosslinks:** not direct bonds but rather they are bonds formed in between the vertical ones. Meaning the vertical bonds are formed between the molecules while the horizontal cross-links are attached to the vertical bonds which gives a fence like appearance.

- From the bacterial cell wall we are able to differentiate between two types of bacteria:

  a) **Gram positive**:

  - The cell wall of such bacteria is composed of a thick layer of peptidoglycan rich in proteins. In addition, there is another substance which is known as Teichoic acid (only present in the gram positive bacteria).

    - Teichoic acid: (phosphate-glycerol-sugar alcohol) extends beyond the rest of cell wall and even the capsule
    - The exact function of teichoic acid is still unclear but it is thought to act as a passageway to ions movement and to facilitate the attachment of bacteriophages.
    - Teichoic acid is the structure that give the cell wall of GRAM POSITIVE bacteria the negative charge.

  - This thick wall in the Gram-Positive bacteria is the reason why this type of bacteria retains the crystal violet.

  b) **Gram negative:**

  - The cell wall is composed of a thin layer of peptidoglycan plus an **outer membrane,** which is a phospholipid bilayer membrane rich in protein.

Outer membrane: (only in gram negative)

- A phospholipid bilayer that forms the outermost layer of the cell wall of **G-ve bacteria**
  It is attached to peptidoglycan by lipoproteins
- Acts as a coarse sieve (help the plasma membrane by block large molecules) & has little control on movement of substances in & out of cells
- Considered as one of the reasons why G-ve bacteria are less sensitive to penicillin (prevents their entry)

- It is attached to peptidoglycan by lipoproteins

- **<u>Unique structures:</u>**
  - **Lipopolysaccharides** also known as endotoxins; important part of the G-ve outer membrane.
  - Used to identify G-ve bacteria.
  - These are toxic substances for the human body.
  - These substance are made up of two parts:

  a) Saccharide (sugar) part;
     - Sugar part is different from one bacterium to the other. Known as the O-antigen because they are specific they are the antigens.

  b) The lipid part;
     - Embedded or integrated into the membrane itself.
     - The lipid part is what makes the toxic effect thus known as ENDOtoxins.
       - They are called ENDOtoxins because these toxins unlike other toxins are not RELEASED they are an integral part of the outer membrane of the bacteria, as long as the bacteria is alive these toxins remain attached (inactive) to the outer membrane. Once the cell dies (destruction of the bacteria) they are released.
       - Clinically important: A patient with a gram negative bacteria if given anti-biotics to kill the bacteria (treatment) this in fact will cause the symptoms to increase and may as well cause death. Due to the fact that these antibiotics will kill the bacteria causing the destruction of the plasma membrane, therefore the endotoxins are to be released which will cause toxicity in the patient's body.

       - **<u>Effect</u>**:

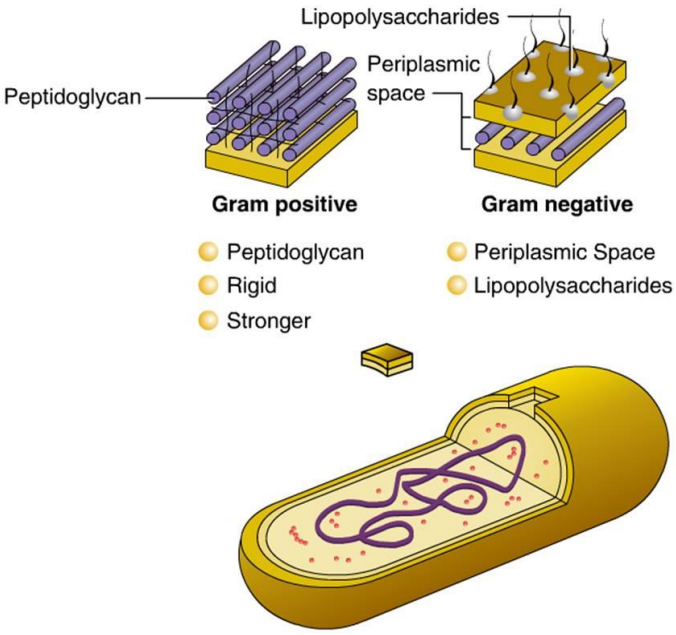
       a) It interferes with the body temperature; increasing it. (Fever)
       b) Results in a generalized vasodilation (systematic vasodilatation) thus the blood pressure will undergo a severe drop known as the **<u>shock</u>** and because it is accompanied with an increase in temperature it is known as **<u>Septic shock</u>**. These patients are treated in the ICU under monitoring and a continuous control of blood pressure and temperature)

Periplamsic space:

- Gram Negative Bacteria contains a **Periplamsic space**:
  - Periplasmic space:
  - Periplasmic space is any space between two biological membranes (space between two phospholipid bilayer).
  - Since the gram negative is made up of peptidoglycan with an outer layer then there is a space between plasma membrane and outer membrane– unlike the gram positive which only has one thick layer of peptidoglycan- and this space is the Periplasmic space.
  - This space is a metabolically active site as it contains proteins, enzymes, transporters, polysaccharides and macromolecules. These components are known as the periplasm.

***Notes:**

a) periplasm is the name released to the contents of the periplasmic space.
b) Gram positive bacteria has peptidoglycan in there cell wall and proteins thus it has a Periplasm but not a Periplasmic membrane (same components but without the space)
c) Peptidoglycan + outer membrane + Periplasmic space all make up the cell wall of the gram-negative bacteria.
d) The outer membrane of the gram negative bacteria does not work as a primary permeability barrier but a course sieve only allowing small and medium molecules to pass but large ones not to. It is not selective in its selection (unlike the plasma membrane) and this is due to the presence of **Porins** that are large units



2. PLASMA MEMBRANE:

- Is a selective barrier allowing some substance to pass while others not and vice versa. Thus maintaining the essential components inside the cell and preventing toxic materials from entering.
- It's a primary permeability barrier and any destruction in the plasma membrane will cause the lethal death of the cell. Therefore, antibiotics effecting the plasma membrane will cause a sidal effect (death) on the cell and not a static (prevents growth.)

- **Structure:**

  - Membrane phospholipids form bilayer: phosphate (hydrophilic), fatty acid non polar chains (hydrophobic).
  - It is dynamic constantly changing membrane
    – Fluid mosaic model: phospholipid in fluid state, proteins form mosaic pattern.
  - Cell membrane is dynamic: lipids & proteins change position, materials flow through pores & through lipids selectively. Some antimicrobials kill bacteria by causing leaks in cell membrane (i.e. polymyxin and daptomycin)

  - Phospholipid bilayer with many proteins embedded in it (similar to eukaryotes) yet bacteria has much more proteins and phospholipids (difference). More than 40% is proteins in bacteria.
  - Proteins present in the plasma membrane may be functional protein such as enzymes, transporters (may be active or passive) and channels and these are selective unlike the porins present in the outer membrane.

- **Notes:**
  - Human cells (Eukaryotes) don't have a cell Wall, but is replaced by the presence of cholesterol in the plasma membrane. While bacteria has a Cell Wall without the presence of cholesterol in the plasma membrane…. the cholesterol gives some what rigidity for the human cell, decreasing the fluidity of the membrane preventing it from bursting in slightly

hypotonic solutions which is already controlled in the bacteria by the cell wall.

← **One exception**: Mycoplasma including Ureaplasma are types of bacteria that have no cell wall thus have sterols (similar to cholesterol) to maintain the rigidity.

- Plasma membrane contain structural and functional proteins. The functional proteins include transporters, enzymes and channels.
- Transporters may either be passive or active. Moreover, in each transporter there will be a transporter cell and a co-transporter.

➢ **Functions of the plasma membrane:**

1. **Selective membrane;**

- This is not the only function of the plasma membrane especially in bacteria because bacteria contain **NO membrane bound organelles**. Therefore the plasma membrane must compensate for the actions that are not being preformed due to the absences of other membranes.
- **For example**: the membrane of the mitochondria in Eukaryotic cells is important to maintain an electrochemical motive force that leads to the production of energy (ATP) through oxidative phosphorylation. Therefore because the bacteria has no mitochondria and the process of electron transport chain can only occur across a membrane, the process will as a result take its course across the plasma membrane and thus the bacteria will generate energy.

2. **Plays an important role in the cell division.**

- Prokaryotic cells undergo binary fission and not mitosis. The only difference between those two processes is the presence of spindle fibers. In mitosis chromosomes are divided in half to the two daughter cell by spindle fibers. Yet, these fibers are not present in prokaryotic cells. Therefore, to separate the chromosomes during cellular division in prokaryotes, proteins present in the plasma membrane (at each end of it) will cause the separation of the chromosomes.

3. **Synthesis of the cell wall components**
4. **Assist in DNA replication**
5. **Secrete proteins**

6. Contains bases of appendages (flagella)

- Catabolic reactions of the bacteria occur in the Periplasmic space while the anabolic reactions occur in the cytoplasm and catabolic reactions also occur in the cytoplasm and more frequently than periplasmic space (major site of metabolism). Moreover, the plasma membrane undergoes anabolic reactions yet these reactions are mainly for the synthesis of cell wall components.

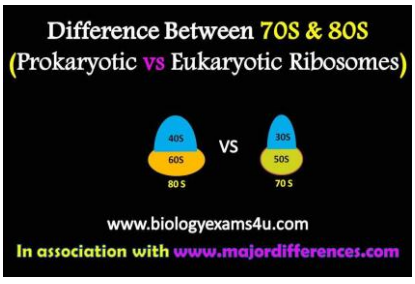
- **Thickness of the plasma membrane:** 2 molecules thick (two phospholipids molecule thick) therefore it's very difficult to differentiate between the plasma membrane and the cell wall. As a result, both the plasma membrane and the cell wall are called the **cellular envelope**. (One name yet different structures and functions)

3. Ribosomes:

- Present in all cells, because they produce the metabolic machinery (enzymes)
- Are ribosomal RNA with associated protein structures.
- They have similar spherical structures in all cells;
  - Large subunit and a small subunit; similar structure in shape
  - Difference between our ribosomes and prokaryotic is the sedimentation rate:

a. In humans: 80s
b. In Prokaryotes: 70s

- Major function of ribosomes is protein synthesis, which is the third defining mechanism of the cell.
- Abundant in cytoplasm of bacteria & often grouped in long chains (polyribosomes)



The most selective drugs/antibiotics used towards bacteria are drugs that effect the cell wall of the bacteria. The second largest antibiotics/drugs that are used are protein synthase inhibitors.
These drugs inhibit ribosomes thus no protein synthesis, but will not effect the human cells as they are selective towards ribosomes (70s) present in the bacteria and not towards (80s) in humans.

Note that these antibiotics will inhibit but not kill (static effect).
since these antibiotics have a static effect on the bacteria that mean if we take these antibiotics out of the bacteria it will resume it's growth.

They are used a lot although they don't kill bacteria because the human body has an immune system that can kill these bacteria. So these drugs inhibit the action of protein synthesis thus prevents the replication of the bacteria. Therefore we'll have static number of bacterial cells allowing the immune system to attack them. Without the static agent the immune system will require a lot of time to attack the bacteria.
Yet keep in mind that a patient with an immune compromise due to any disease (HIV, cancer, organ transplantation ...etc) cannot take these drugs.

4. Cytosol:

- Semi-fluid structure

- Composed of 4/5 water, 1/5 of substances dissolved in water (enzymes, proteins, carbohydrates, lipids, & ions)

- Most anabolic & catabolic reactions occur in the cytosol

- In the bacteria the fluid structure is known as the cytosol and is never called a cytoplasm because it does not contain organelles except for the presence of ribosomes, which are not even seen under the light microscope.

←

- The cytosol of a prokaryotic cell contains all the components that are present inside organelles in the eukaryotic cell such as proteins, lipids, electrolytes…etc. Therefore the concentration of solutes in prokaryotes present in the cytosol is much higher than the concentration (higher osmotic pressure) in eukaryotes. Again this is because all components apart from the nucleoid and the ribosomes are dissolved in the cytosol unlike in Eukaryotes where these components are present in membrane bound organelles.

++Major function of cytosol:

Main site of metabolism, most of the enzymes are dissolved in the cytosol.

5. Nuclear region:

- Nucleoid: is an area that is darker than the cytosol due to the presence if DNA.
- This region contains the DNA, associated proteins (both functions and structural), enzymes (DNA polymerase) and some RNA that has been transcribed.
  - Structural proteins such as histones, which are important for folding.

- **Main function of the DNA:**
  - Carrying the genetic codes, which are encoded directly, or indirectly for all functional and structural properties.
    - How come for all properties if they only code for proteins?

    Example, polysaccharide is INDIRECTLY coded by the genetic information carried by the DNA. Indirectly means that the gene codes for the enzyme needed to form the polysaccharide and not directly codes for the formation of the molecule.

***Notes:**

- Any gene that is important for the survival of the DNA is present in the chromosomes in the nucleoid region, yet other DNA is present elsewhere.
- These DNA are known as **plasmid** and are not important for the survival of the bacteria but gives the bacteria extra properties.

- Plasmid is a circular and much smaller copy (extra chromosomal DNA) carrying small amount of genes (4 for example), which gives the bacteria extra properties such as **anti-biotic resistant gene.**
- Anti-biotic gene is dangerous because plasmid carrying this gene is very small and therefore can move to another bacteria easily

6.Inclusions:

- limited number of bacteria have these inclusions present in every single structure of the cell
- inclusion bodies are either :

1- granules which are solid precipitate of certain chemical such as glycogen granules needed as a reservoir. Also, they are not bounded by membrane but have compacted substances that don't dissolve in cytoplasm.

Examples:

- Polymer of glucose as a reservoir for glucose.
- Polyphosphate as well a reservoir of phosphate and it is important because without phosphate there is no energy production. And for the activation and inhibition of enzymes as these processes occur by phosphorylation.

2- Vacuoles/vesicles, which are membrane bound inclusion bodies (expectations since prokaryotes don't have membrane bound organelles) these inclusion bodies aim to form vacuoles to store something that is not miscible in water.

***NOTE :** vacuoles are more complex in structure than granules because it's a membrane bound organelles.

Examples:

- Gas filled vacuole: by regulating gas inside it, certain bacteria (aquatic photosynthetic bacteria) control the depth at which they flow to obtain optimum light
- Another type of vesicles contains deposit of lipids which serves as storehouse of energy & as source of carbon for building new molecules.

☺ Sorry for Mistakes ☺