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**Lecture-2**

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**Structure of Bacterial Cells**

**Morphology of bacterial cells:**

* **Shape :** it is determined by the bacterial rigid cell wall, the bacteria are classified according to their shapes into four basic groups:

**Cocci**: are spherical shape.

**Bacilli** : are rods shape.

**Spirochetes** : are spiral–shaped.

**Pleomorphic**: appear in many shapes.

* **Size:** the size of bacteria ranged from 0.2-5 micrometer (μm).
* **Arrangement of bacteria:** Certain bacteria are arranged in single cell or in pairs, some in chains, and others in groups.

**Bacterial Structure:**

**1- Cell wall:** is the rigid outermost layer of all bacteria (except mycoplasma species, have only cell membrane without cell wall) located outside the cell membrane. The principal structural component of it is peptidoglycan which provides the structural support and maintain the characteristic shape of the bacterial cell.

The differences in the structure, chemical composition and thickness of the cell wall divide bacteria into two main groups according to the reaction of Gram stain with components of cell wall; Gram positive and Gram negative bacteria.

* Peptidoglycan is much thicker, multiple layers in Gram positive bacteria than in Gram negative bacteria (less and thin layers); also has fibers of teichoic acid protrude outside the peptidoglycan that are absent in Gram negative bacteria.

This thick wall makes gram positive bacteria more susceptible to antibiotic that inhibit cell wall synthesis (such as penicillins).

* Cell wall of Gram negative bacteria have a complex outer membrane which is composed of lipopolysaccharide (LPS) and lipoproteins. The LPS is act as endotoxine (LPS not found in G+ve). The space between inner and outer membrane in gram negative is called periplasmic space (it is not present in cell wall of G+ve).
* Function of cell wall:

1. Protection of internal structures.

2. It gives shape of the cell.

3. It contains toxic components to host cell.

4. Contain pores aid in passage of small molecules into the cells.

5. Acts as a somatic antigen (O-antigen) that is used in Laboratory diagnosis.

**2- Cytoplasmic membrane (inner membrane):**

Located to the inside of the peptidoglycan layer, it is composed of phospholipid bilayer (similar to eukaryotic cell membrane, but this contains much sterol), the only bacteria contains sterol in its cell membrane is Mycoplasma.

Invagination of cytoplasmic membrane into cytoplasm called Mesosome, which functions during cell division.

**Important functions :**

1. Active transport of molecules into the cell because it has selective permeability.

2. Energy generation by oxidative phosphorylation.

3. Secretion of some enzymes and toxins.

4. synthesis of precursors of the cell wall.

**3- Cytoplasm**:

The cytoplasm or protoplasm is the portion of the cell that lies within the cytoplasmic membrane. It is gel-like in consistency and includes single chromosome, ribosomes, and lacks organelles such as mitochondria, Golgi apparatus or endoplasmic reticulum.

The genetic materials are located in area of the cytoplasm which called nucleoid, which is not surrounded by nuclear membrane.

**Ribosome:**

The ribosomes are the site of protein synthesis in both prokaryotes and eukaryotes; but they differ in size and chemical composition.

Bacteria have small ribosomes (70S) and composed of two small subunits (50S and 30S), whereas eukaryotic ribosome is larger (80S) (2 subunit 60S and 40S).

**4- External structures:**

**Capsule:**

Certain bacteria (not all) have a capsule. It is a gelatinous layer covering the entire bacterium. The capsule may be composed of either polysaccharide or polypeptide. Most bacteria are non-capsulated.

**Importance of Capsule**:

1. Protection against deleterious agents eg. Lytic enzymes.

2. Determine the virulence of many pathogenic bacteria by inhibiting phagocytosis, and it play role in adherence of bacteria to human tissues.

3. Variation of sugar components of the capsule aids in specific identification of bacteria.

4. Capsular polysaccharide is used as an antigen in preparation of certain vaccines.

**Flagella:**

Certain bacteria can move by long filamentous appendages (whip-like structure) are called flagella which composed of protein flagellin. The flagellated bacteria may have one or more flagellum. Most flagellated bacteria are rods, therefore motile, whereas most cocci are non-motile

**Function of flagella:**

1- Flagellum is organ of motility (locomotion), toward nutrients and other attractants.

2- The flagella may play a role in pathogenesis.

3- Flagellum acts as antigen (H-antigen) which used in identification of some bacterial species.

**Pili (fimbriae):**

Certain bacteria have hair-like filaments that extend from cell surface (cell membrane) which composed of protein.

* They are shorter, straighter, and the numbers more than flagella.
* They are found mainly in gram negative bacteria.
* Pili have important role:

1. They mediate the attachment of bacteria to specific receptor on human cells.

2. Pili have a role in transfer of genetic material among bacteria through conjugation.

**Bacterial growth**

Bacteria multiply by simple processing unlike eukaryotic cells. They reproduce by binary fission, a process by which one parent cell divides to form two progeny cells.

The time required to give two daughter cells is called generation time (doubling time); which is different according to bacterial species, nutrition, tempratute, pH and other nutritional factors. For example, generation time of *Escherichia coli* is 20 minutes, *Mycobacterium tuberculosis* is more than 20 hours, and *Mycobacterium leprae* is 20 days.

**Phases of bacterial growth cycle:**

**A- Lag phase (adaptation phase):**

During this phase metabolic activity occurs but cells do not divide. It is characterized by:

1. Increase in metabolic rate.

2. Increase in size of cell, but not increase in number of cells (zero growth).

**B- Log phase (logarithmic phase):**

Rapid cell division occur in this phase, that characterize by

1. Bacteria have high rate of metabolism activity.

2. High rate of growth, and increase number of cells (positive growth).

The β-lactam drugs such as penicillin act during this phase because the drugs are effective when cells are making peptidoglycan for cell wall.

**C- Stationary phase:**

The number of new cells produced balance the number of cells that die leading to steady state.

Because multiplication and death of cells almost equal in this phase, so called (zero growth). It may be due to depletion of nutrients, or accumulation of toxic products.

**D- Decline phase:**

During the final stage of bacteria, decrease in number of viable bacteria (negative growth) due to death of cells .

The factors responsible for this phase are:

1. Nutritional exhaustion.

2. End products are increased (toxic accumulation).

3. Autolytic enzymes are common in this phase.

4. Decrease in O2 concentration, and increase in CO2 concentration.

5. Unfavorable ion equilibrium develops (eg. unfavor pH).

**Aerobic and anaerobic growth:**

The organisms may inhabit at different ecosystems depending on their requirement of oxygen and other growth factors to obtain energy. However, they are classified into one of three categories :

**Obligate aerobes:**

* They require oxygen to grow because their ATP- generating system in respiratory pathway is depending on oxygen as hydrogen acceptor (final electron acceptor) in final steps of energy production catalyzed by flavoprotein and cytochrome.
* Because the use of oxygen generates two toxic molecules : hydrogen peroxide (H2O2) and free radical superoxide (O2-). The toxicity of oxygen result from its reduction by enzymes in the cell such as flavoprotein, to hydrogen peroxide and even more toxic free radical superoxide. Accumulation of hydrogen peroxide can cause damage of DNA.
* Aerobes are protected from these products by produce catalase and superoxide dismutase. They require two enzymes to utilize oxygen.

First is superoxide dismutase (SOD), which catalyzes the combination of two molecules of O2- to form H2O2.

O2- + O2- 2H+ H2O2 + O2

Second is catalase which catalyzes the reaction

2 H2O2 2H2O + O2

**Obligate anaerobes:**

* They cannot grow in presence of oxygen because they lack either superoxide dismutase or catalase or both. However, they can use only fermentation pathway to obtain energy. They use variety of small organic molecules such as pyruvate as final electron acceptors.
* Because lack catalase they inability to utilize oxygen and result in accumulation of H2O2 in toxic concentration. They also lack superoxide dismutase that permits accumulation of toxic free radical superoxide.

**Facultative organisms:**

* They can grow in presence or absence of oxygen.
* They utilize oxygen to generate energy by respiration if it is present, but they can use the fermentation pathway to synthesize ATP in absence of oxygen.