College Of Veterinary Medicine .

3rd class First Semester

MICROBIOLOGY- BACTERIOLOGY *The Third- Lecture*

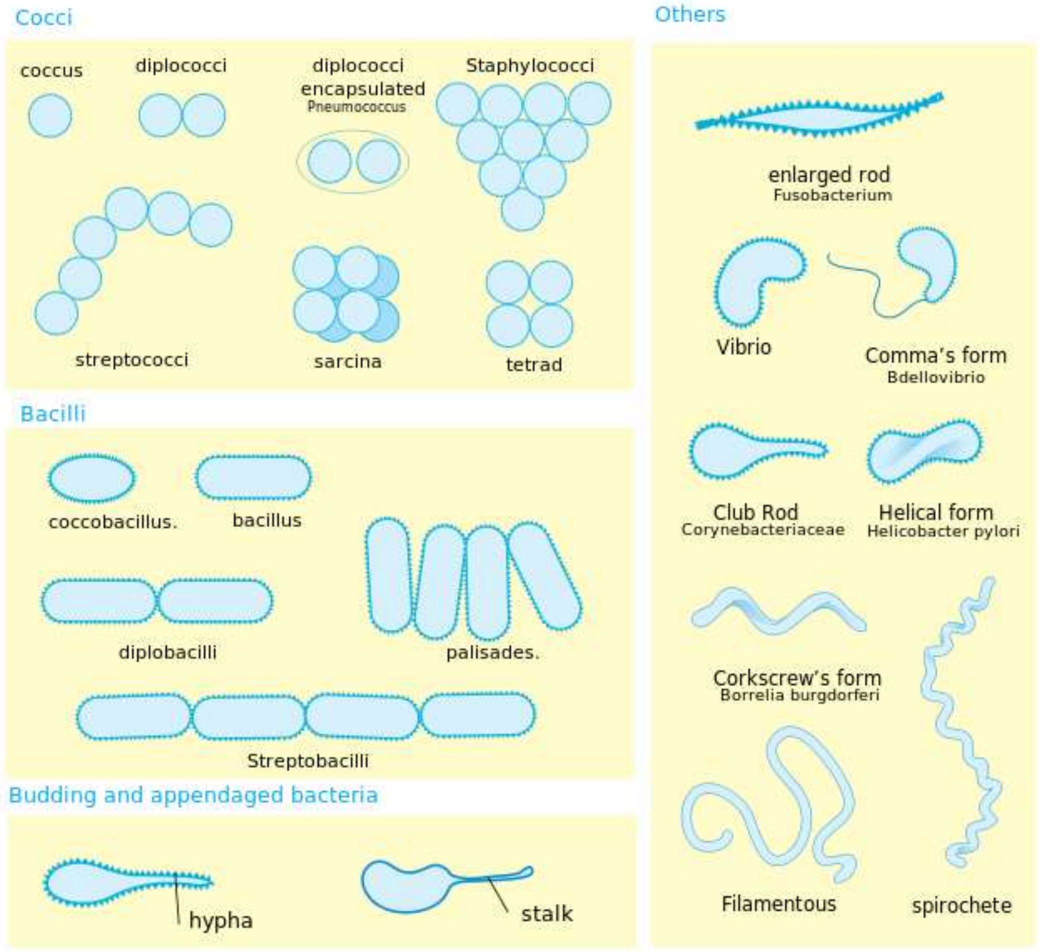
Bacterial cell structure:-

Cell morphology :-

Perhaps the most elemental structural property of bacteria is cell morphology (shape). Typical examples include:

- **coccus** (spherical).
- **bacillus** (rod-like).
- **spirillum** (spiral).
- **filamentous.**

Cell shape is generally characteristic of a given bacterial species, but can vary depending on growth conditions. Some bacteria have complex life cycles involving the production of stalks and appendages (e.g. *Caulobacter*) and some produce elaborate structures bearing reproductive spores (e.g. *Myxococcus*, *Streptomyces*). Bacteria generally form distinctive cell morphologies when examined by light microscopy and distinct colony morphologies when grown on Petri plates. These are often the first characteristics observed by a microbiologist to determine the identity of an unknown bacterial culture.



1

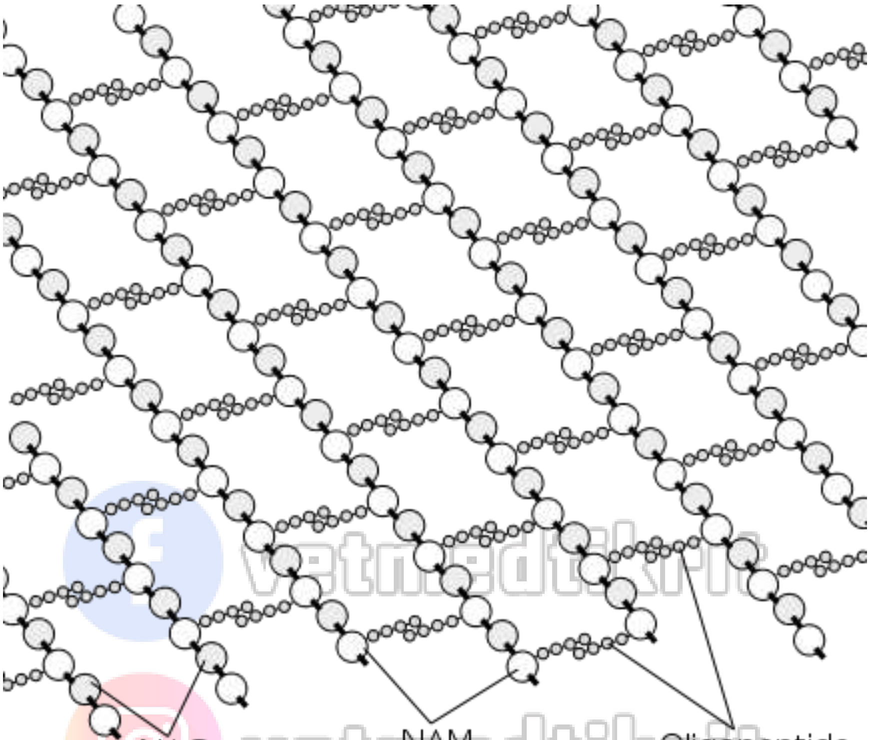
Cell Wall :-

Perhaps the most obvious structural characteristic of bacteria is (with some exceptions) their small size. For example, *Escherichia coli* cells, an "average" sized bacterium, are about 2 micrometres (µm) long and 0.5 µm in diameter, with a cell volume of 0.6 - 0.7 μm^3. This corresponds to a wet mass of about 1 picogram (pg), assuming that the cell consists mostly of water. The dry mass of a single cell can be estimated as 20% of the wet mass, amounting to 0.2 pg. About half of the dry mass of a bacterial cell consists of carbon, and also about half of it can be attributed to proteins.

Small size is extremely important because it allows for a large surface area-to-volume ratio which allows for rapid uptake and intracellular distribution of nutrients and excretion of wastes. At low surface area-to-volume ratios the diffusion of nutrients and waste products across the bacterial cell membrane limits the rate at which microbial metabolism can occur, making the cell less evolutionarily fit. The reason for the existence of large cells is unknown, although it is speculated that the increased cell volume is used primarily for storage of excess nutrients.

The cell envelope is composed of the plasma membrane and cell wall. As in other organisms, the bacterial cell wall provides structural integrity to the cell. In

prokaryotes, the primary function of the cell wall is to protect the cell from internal turgor pressure caused by the much higher concentrations of proteins and other molecules inside the cell compared to its external environment. The bacterial cell wall differs from that of all other organisms by the presence of peptidoglycan (poly-*N*-acetylglucosamine and *N*-acetylmuramic acid), which is located immediately outside of the cytoplasmic membrane. Peptidoglycan is responsible for the rigidity of the bacterial cell wall and for the determination of cell shape. It is relatively porous and is not considered to be a permeability barrier for small substrates. While all bacterial cell walls (with a few exceptions e.g. extracellular parasites such as *Mycoplasma*) contain peptidoglycan, not all cell walls have the same overall structures. Since the cell wall is required for bacterial survival, but is absent in eukaryotes, several antibiotics (penicillins and cephalosporins) stop bacterial infections by interfering with cell wall synthesis, while having no effects on human cells, because human cells don't have cell walls, they only have cell membranes. There are two main types of bacterial cell walls, Gram positive and Gram negative, which are differentiated by their Gram staining characteristics. For both Gram-positive and Gram-negative bacteria, particles of approximately 2 nm can pass through the peptidoglycan. If the bacterial cell wall is entirely removed, it is called a protoplast while if it's partially removed, it is called a spheroplast. *β*-Lactam antibiotics such as penicillin inhibit the formation of peptidoglycan cross-links in the bacterial cell wall. The enzyme lysozyme, found in human tears, also digests the cell wall of bacteria and is the body's main defense against eye infections.



The Gram positive cell wall :-

Gram positive cell walls are thick and peptidoglycans (mucopeptides, glycopeptides, mureins), the structural elements of almost all bacterial cell walls, constitute almost 95% of the cell wall in some Gram positive bacteria and as little as 5-10% of the cell wall in Gram negative bacteria. Peptidoglycans are made up of a polysaccharide backbone consisting of alternating N-acetylmuramic acid(NAM) and N-acetylglucosamine(NAG) residues in equal amounts. The cell wall of some Gram positive bacteria can be completely dissolved by lysozyme, as this enzyme attacks the bonds between GA and MA. In other Gram positive bacteria, e.g. Staphylococcus aureus, the walls are resistant to the action of lysozyme. They have O-acetyl groups on carbon-6 of some MA residues. The matrix substances in the walls of Gram positive bacteria may be polysaccharides or teichoic acids. The latter are very widespread, but have been found only in Gram positive bacteria. There are two main types of teichoic acid: ribitol teichoic acids and glycerol teichoic acids. The latter one is more widespread. These acids are polymers of ribitol phosphate and glycerol phosphate, respectively, and only located on the surface of many Gram positive bacteria. However, the exact function of teichoic acid is debated and not fully understood.

The Gram negative cell wall :-

Gram negative cell walls are thin and unlike the Gram positive cell walls, they contain a thin peptidoglycan layer adjacent to the cytoplasmic membrane. This is

responsible for the cell wall's inability to retain the crystal violet stain upon decolorisation (differentiation) with ethanol-acetic acid during Gram staining.

In addition to the peptidoglycan layer, the Gram negative cell wall also contains an outer membrane composed by phospholipids and lipopolysaccharides, which face into the external environment. As the lipopolysaccharides are highly charged, the Gram negative cell wall has an overall negative charge. The chemical structure of the outer membrane lipopolysaccharides is often unique to specific bacterial strains (i.e. sub-species) and is responsible for many of the antigenic properties of these strains. Gram negative cell walls consist of a few layers of peptidoglycan surrounded by a second lipid membrane containing lipopolysaccharides and lipoproteins. Lipopolysaccharides, also called endotoxins, are composed of polysaccharides and lipid A (responsible for much of the toxicity of Gram-negative bacteria).

Plasma membrane :-

The plasma membrane or bacterial cytoplasmic membrane is composed of a phospholipid bilayer and thus has all of the general functions of a cell membrane such as acting as a permeability barrier for most molecules and serving as the location for the transport of molecules into the cell. In addition to these functions, prokaryotic membranes also function in energy conservation as the location about which a proton motive force is generated. Unlike eukaryotes, bacterial membranes (with some exceptions e.g. *Mycoplasma* and methanotrophs) generally do not contain sterols. However, many microbes do contain structurally related compounds called hopanoids which likely fulfill the same function. Unlike eukaryotes, bacteria can have a wide variety of fatty acids within their membranes.

Extracellular (external) structures :-

Fimbrae and pili :-

Pilus :-

Fimbrae (sometimes called "attachment pili") are protein tubes that extend out from the outer membrane in many members of the *Proteobacteria*. They are generally short in length and present in high numbers about the entire bacterial cell surface. Fimbrae usually function to facilitate the attachment of a bacterium to a surface (e.g. to form a biofilm) or to other cells (e.g. animal cells during pathogenesis)).
A few organisms (e.g. *Myxococcus*) use fimbrae for motility to facilitate the assembly of multicellular structures such as fruiting bodies. Pili are similar in structure to fimbrae but are much longer and present on the bacterial cell in low numbers. Pili are involved in the process of bacterial conjugation where they are called conjugation pili or "sex pili". Type IV pili (non-sex pili) also aid bacteria in gripping surfaces.

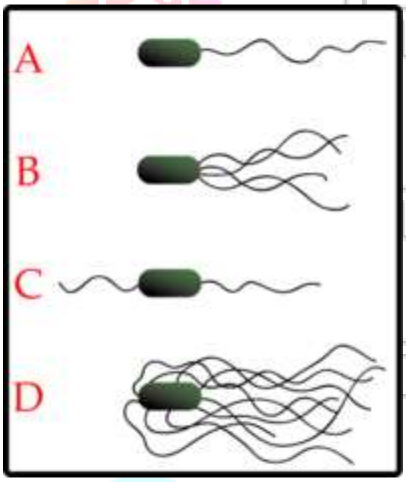
Flagella :-

Flagellum :-

Perhaps the most recognizable extracellular bacterial cell structures are flagella. Flagella are whip-like structures protruding from the bacterial cell wall and are responsible for bacterial motility (i.e. movement). The arrangement of flagella about the bacterial cell is unique to the species observed. Common forms include:

- Monotrichous - Single flagellum
- Lophotrichous - A tuft of flagella found at one of the cell pole
- Amphitrichous - Single flagellum found at each of two opposite poles
- Peritrichous - Multiple flagella found at several locations about the cell.

The bacterial flagellum consists of three basic components: a whip-like filament, a motor complex, and a hook that connects them. The filament is approximately 20 nm in diameter and consists of several protofilaments, each made up of thousands of flagellin subunits. The bundle is held together by a cap and may or may not be encapsulated. The motor complex consists of a series of rings anchoring the flagellum in the inner and outer membranes, followed by a proton-driven motor that drives rotational movement in the filament.



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

Intracellular (intenal) structures :-

In comparison to eukaryotes, the intracellular features of the bacterial cell are extremely simple. Bacteria do not contain organelles in the same sense as eukaryotes. Instead, the chromosome and perhaps ribosomes are the only easily observable intracellular structures found in all bacteria. They do exist, however, specialized groups of bacteria that contain more complex intracellular structures, some of which are discussed below.

Plasmid :-

Unlike eukaryotes, the bacterial chromosome is not enclosed inside of a membrane-bound nucleus but instead resides inside the bacterial cytoplasm. This means that the transfer of cellular information through the processes of translation, transcription and DNA replication all occur within the same compartment and can interact with other cytoplasmic structures, most notably ribosomes. The bacterial chromosome is not

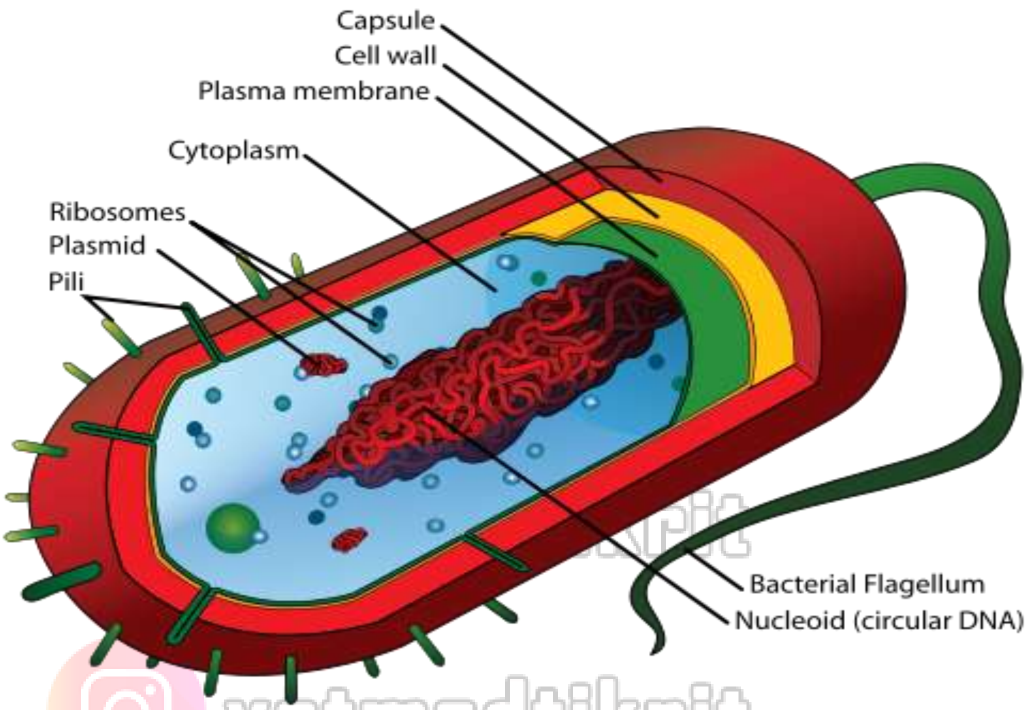
packaged using histones to form chromatin as in eukaryotes but instead exists as a highly compact supercoiled structure, the precise nature of which remains unclear. Most bacterial chromosomes are circular although some examples of linear chromosomes exist (e.g. *Borrelia burgdorferi*). Along with chromosomal DNA, most bacteria also contain small independent pieces of DNA called plasmids that often encode for traits that are advantageous but not essential to their bacterial host. Plasmids can be easily gained or lost by a bacterium and can be transferred between bacteria as a form of horizontal gene transfer.

Ribosome :-

In most bacteria the most numerous intracellular structure is the ribosome, the site of protein synthesis in all living organisms. All prokaryotes have 70S (where S=Svedberg units) ribosomes while eukaryotes contain larger 80S ribosomes in their cytosol. The 70S ribosome is made up of a 50S and 30S subunits. The 50S subunit contains the 23S and 5S rRNA while the 30S subunit contains the 16S rRNA. These rRNA molecules differ in size in eukaryotes and are complexed with a large number of ribosomal proteins, the number and type of which can vary slightly between organisms. While the ribosome is the most commonly observed intracellular multiprotein complex in bacteria other large complexes do occur and can sometimes be seen using microscopy.

Intracellular membranes :-

While not typical of all bacteria some microbes contain intracellular membranes in addition to (or as extensions of) their cytoplasmic membranes. An early idea was that bacteria might contain membrane folds termed mesosomes, but these were later shown to be artifacts produced by the chemicals used to prepare the cells for electron microscopy. Examples of bacteria containing intracellular membranes are phototrophs, nitrifying bacteria and methane-oxidising bacteria. Intracellular membranes are also found in bacteria belonging to the poorly studied Planctomycetes group, although these membranes more closely resemble organellar membranes in eukaryotes and are currently of unknown function. Chromatophores are intracellular membranes found in phototrophic bacteria. Used primarily for photosynthesis, they contain bacteriochlorophyll pigments and carotenoids .



Endospores :-

Endospore :-

Perhaps, the most well known bacterial adaptation to stress is the formation of endospores. Endospores are bacterial survival structures that are highly resistant to many different types of chemical and environmental stresses and therefore enable the survival of bacteria in environments that would be lethal for these cells in their normal vegetative form. It has been proposed that endospore formation has allowed for the survival of some bacteria for hundreds of millions of years (e.g. in salt crystals) although these publications have been questioned. Endospore formation is limited to several genera of Gram-positive bacteria such as *Bacillus* and *Clostridium*. It differs from reproductive spores in that only one spore is formed per cell resulting in no net gain in cell number upon endospore germination. The location of an endospore within a cell is species-specific and can be used to determine the identity of a bacterium. Dipicolinic acid is a chemical compound which composes 5% to 15% of the dry weight of bacterial spores. It is implicated as responsible for the heat resistance of the endospore.