Bacterial cell structure:

Bacteria, contain a well-developed cell structure which is responsible for many of their unique biological structures. Many structural features are unique to bacteria and are not found among archaea or eukaryotes.

Cell wall

The structure of peptidoglycan.

The cell envelope is composed of the plasma membrane and cell wall. 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 which is located immediately outside of the cytoplasmic membrane. Peptidoglycan is made up of a polysaccharide backbone consisting of alternating N-Acetylmuramic acid (NAM) and N-acetylglucosamine (NAG) residues in equal amounts. 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, not all cell walls have the same overall structures. Since the cell wall is required for bacterial survival, but is absent in eukaryotes, There are two main types of bacterial cell walls, those of Gram-positive bacteria and those of Gram-negative bacteria, which are differentiated by their Gram staining characteristics. For both these types of 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.

The Gram-positive cell wall

Gram-positive cell walls are thick and the peptidoglycan (also known as murein) layer constitutes 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. The cell wall of some Gram-positive bacteria can be completely dissolved by lysozyme, as this enzyme attacks the bonds between GA and MA. 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. The lipid element is to be found in the membrane where its adhesive properties assist in its anchoring to the membrane.

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. The chemical structure of the outer membrane's lipopolysaccharides is often unique to specific bacterial sub-species and is responsible for many of the antigenic properties of these strains. Lipopolysaccharides, also called endotoxins, are composed of polysaccharides and lipid A which are responsible for much of the toxicity of Gram-negative bacteria. It consists of characteristic lipopolysaccarides embedded in the membrane.

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.

As a phospholipid bilayer, the lipid portion of the outer membrane is impermeable to charged molecules. However, channels called porins are present in the outer membrane that allow for passive transport of many ions, sugars and amino acids across the outer membrane. These molecules are therefore present in the periplasm, the region between the cytoplasmic and outer membranes. The periplasm contains the peptidoglycan layer and many proteins responsible for substrate binding or hydrolysis and reception of extracellular signals. The periplasm is thought to exist in a gel-like state rather than a liquid due to the high concentration of proteins and peptidoglycan found within it.

Extracellular (external) structures

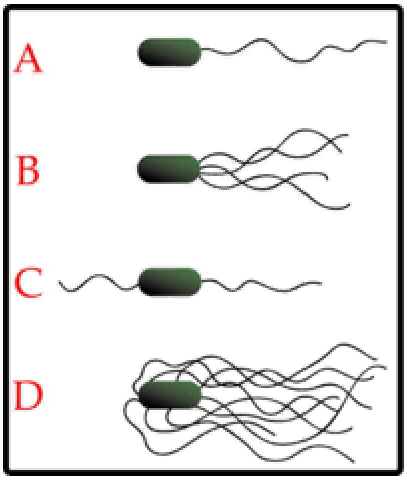
Fimbriae (sometimes called "attachment pili") are protein tubes that extend out from the outer membrane. They are generally short in length and present in high numbers about the entire bacterial cell surface. Fimbriae usually function to facilitate the attachment of a bacterium to a surface (e.g. to form a biofilm) or to other cells (e.g. animal cells during pathogenesis). A few organisms (e.g. *Myxococcus*) use fimbriae for motility . Pili are similar in structure to fimbriae 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".

S-layers

An S-layer (surface layer) is a cell surface protein layer found in many different bacteria and in some archaea, where it serves as the cell wall. All S-layers are made up of a two-dimensional array of proteins and have a crystalline appearance. The exact function of S-layers is unknown, but it has been suggested that they act as a partial permeability barrier for large substrates , an S-layer may help to facilitate survival within the host by conferring protection against host defence mechanisms.

Glycocalyx

Many bacteria secrete extracellular polymers outside of their cell walls called glycocalyx. These polymers are usually composed of polysaccharides and sometimes protein. Capsules are relatively impermeable structures that cannot be stained with dyes such as India ink. They are structures that help protect bacteria from phagocytosis and desiccation. Slime layer is involved in attachment of bacteria to other cells or inanimate surfaces to form biofilms. Slime layers can also be used as a food reserve for the cell.



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

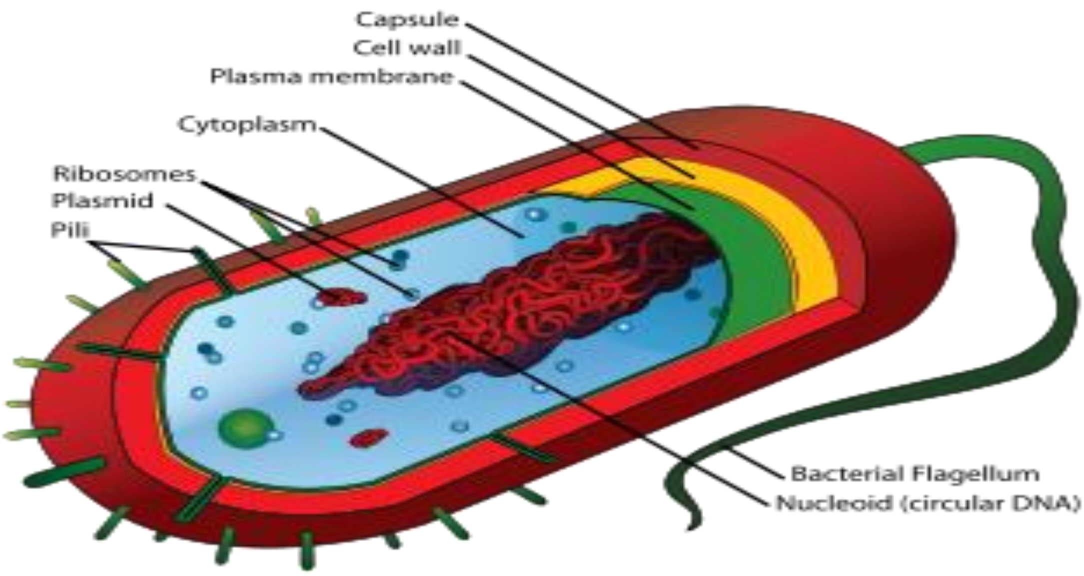
Flagella

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 , a proton-driven motor that drives rotational movement in the filament.

Intracellular (internal) structures



Cell structure of a Gram positive prokaryote

The bacterial DNA and plasmids

Unlike eukaryotes, the bacterial DNA is not enclosed inside of a membrane-bound nucleus but instead resides inside the bacterial cytoplasm. Most bacterial DNA are circular although some examples of linear DNA exist . 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.So plasmids can be described as an extra chromosomal DNA in a bacterial cell.

Ribosomes and other multiprotein complexes

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.

Endospores

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.

Steps of the spore formation

1. the bacterium senses that its home or habitat is turning bad
2. it makes a copy of its chromosome
3. the rubbery cell membrane that surrounds the bacterial cell fluid begins pinching inward around this chromosome copy.
4. the membrane of the mother cell surrounds and swallows up the daughter cell.
5. between these two membranes a thick wall forms made out of stuff called peptidoglycan.
6. a tough outer coating made up of a bunch of proteins forms around all this, closing off the entire daughter cell.