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Lec. 2 & 3

Medical microbiology

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Bacterial structure and functions

A- Surface Appendages

Two types of surface appendage can be recognized: Flagella, which are organs of movement, and Pili (in Latin =hairs), which are also known as fimbriae (in Latin = fringes).

Flagella occur on both Gram-positive and Gram-negative bacteria, and their presence can be useful in identification. For example, they are found on many species of bacilli but rarely on cocci. In contrast, pili occur almost on all Gram-negative bacteria and are found on only a few Gram-positive organisms (e.g., Corynebacterium renale). Some bacteria have both flagella and pili. The Fig. below shows the characteristic wavy appearance of flagella and two types of pili on the surface of Escherichia coli.

1. Flagella

Bacterial flagella are long (3 to 12 µm), filamentous surface appendages about 12 to 30 nm in diameter. A flagellum consists of three parts:

(1) The long filament, which lies external to the cell surface.

(2) The hook structure at the end of the filament.

(3) The basal body, to which the hook is anchored and which imparts motion to the flagellum.

The ability of bacteria to swim by flagella provides them with the mechanical means to undergo chemotaxis (movement in response to attractant and repellent substances in the environment).

Chemically, flagella are constructed of a class of proteins called flagellins. Flagellins are immunogenic, these antigens are called the H antigens, which are characteristic of a species or strain of bacteria. The number of flagella on bacterial surface is a characteristic for classification. Flagella formation can be inhibited by chloramphenicol it blocks regeneration of flagella and the protein (flagellin) synthesis.

2. Pili

The terms pili and fimbriae are usually used to describe the thin, hairlike appendages on the surface of many Gram-negative bacteria and proteins of pili are referred to the pilins. Pili (plural of pilus) are more rigid than flagella. In some bacteria, such as Shigella species and E. coli, pili are distributed over the cell surface as 200 per cell.

As in E. coli, pili can come in two types: **short,** most common pili, and sex pili (one to six of very long pili). The sex pili attach male to female bacteria during conjugation.

Pili in many enteric bacteria offer t he adhesive properties on the bacterial cells, enabling them to adhere to various epithelial surfaces and to the RBCs (causing hemagglutination). These adhesive properties play an important role in bacterial pathogenesis; colonization of epithelial surfaces and are therefore called colonization factors.

B- Surface Layers

1. Capsules and Loose Slime

Some bacteria form capsules, they are thick layer of viscous gel. Capsules may be up to 10 µm thick. Some organisms lack a well-defined capsule but have loose slime layers external to the cell wall or cell envelope. The hemolytic Streptococcus mutans, the primary organism found in dental plaque is able to synthesis a large extracellular mucoid glucan from sucrose.

Not all bacterial species produce capsules; the capsules of encapsulated pathogens are often important determinants of virulence. In both groups, Gram-positive and Gram-negative bacteria; most capsules are composed of high molecular-weight polysaccharides outside the cell wall or envelope except the capsule of *Bacillus anthracis* (the pathogen of anthrax), it is unusual in that it is composed of a g-glutamyl polypeptide. Mutation can cause loss of enzymes involved in the biosynthesis of the capsular polysaccharides can result change from the smooth-to-rough as seen in the pneumococci.

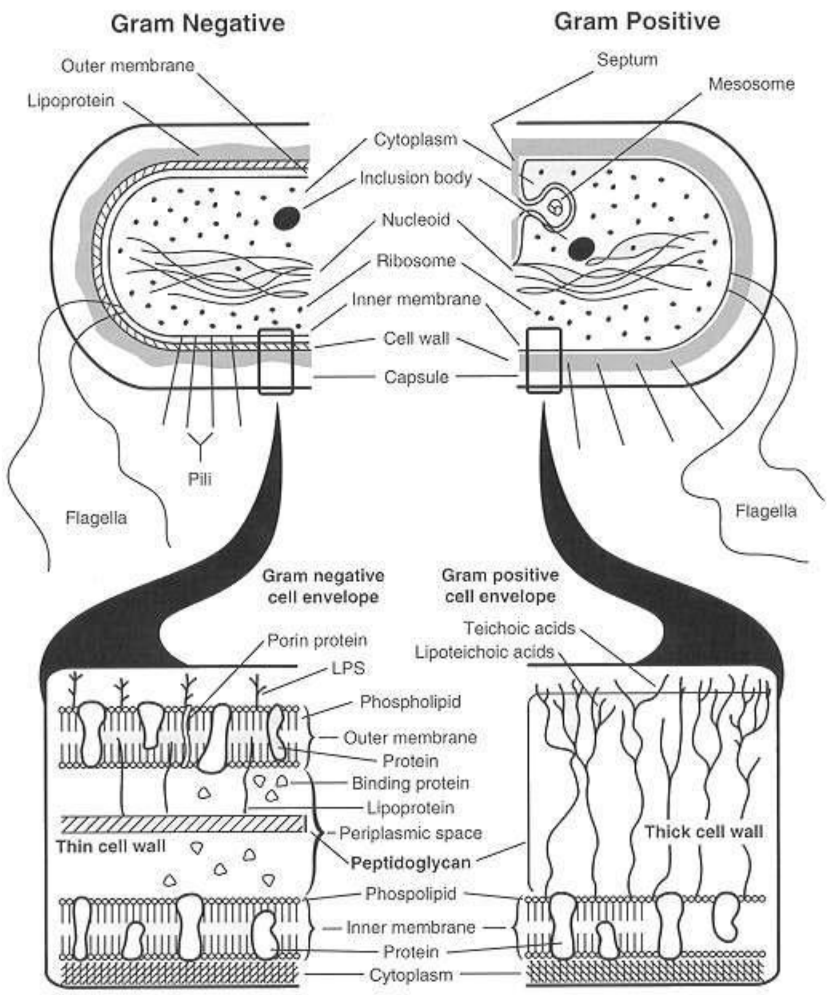
The exact function of capsule is resistance to phagocytosis and protection of the bacterial cell against the host defenses during invasion. Some bacterial capsules work as main virulence factor.

2. Cell Wall

The Gram stain differentiates bacteria into Gram-positive and Gram-negative groups. Gram-positive and Gram-negative organisms differ in the structures of their cell walls, see figure below.

Most Gram-positive bacteria have a thick (about 20 to 80 nm), cell wall composed of peptidoglycan (also known as mucopeptide or murein). In thick cell walls, some other cells have other wall polymers (such as the teichoic acids, polysaccharides, and peptidoglycolipids) are attached to the peptidoglycan. The peptidoglycan layer in Gram-negative bacteria is thin (about 5 to 10 nm thick).

The basic differences in surface structures of Gram-positive and Gram-negative bacteria explain the results of Gram staining.



❖ Peptidoglycan

Unique composition in all prokaryotic cells (except for mycoplasmas) is the peptidoglycan, this layer help in mechanical protection and there are specific enzymes involved in its biosynthesis. These enzymes are target sites for inhibition of peptidoglycan synthesis by specific antibiotics. The primary chemical structures of peptidoglycans consist of a polymer backbone of disaccharides of N-acetylmuramyl-N-acetylglucosamine and are linked through the carboxyl group by amide linkage of muramic acid residues.

There are two groups of bacteria that lack the peptidoglycan, the Mycoplasma species (causes atypical pneumonia and some genitourinary tract infections) and the L-forms. The mycoplasmas and L-forms are all Gram-negative and insensitive to penicillin.

❖ Teichoic Acids

The teichoic acids are found only in some Gram-positive bacteria (such as Staphylococci, Streptococci, Lactobacilli, *and* Bacillus spp); they are not found in gram- negative bacteria. Teichoic acids are polyol phosphate polymers, with either ribitol or glycerol linked by phosphodiester bonds. It can act as a specific antigenic determinant.

❖ Lipopolysaccharides

A characteristic of Gram-negative bacteria is the lipopolysaccharide (LPS), only one Gram-positive organism, Listeria monocytogenes, has been found to contain LPS. The LPS are also called endotoxins, they are cell-bound, heat-stable toxins and differ from heat-labile, protein exotoxins secreted into culture media. Endotoxins possess an array of powerful biologic activities and play an important role in the pathogenesis of many Gram-negative bacterial infections.

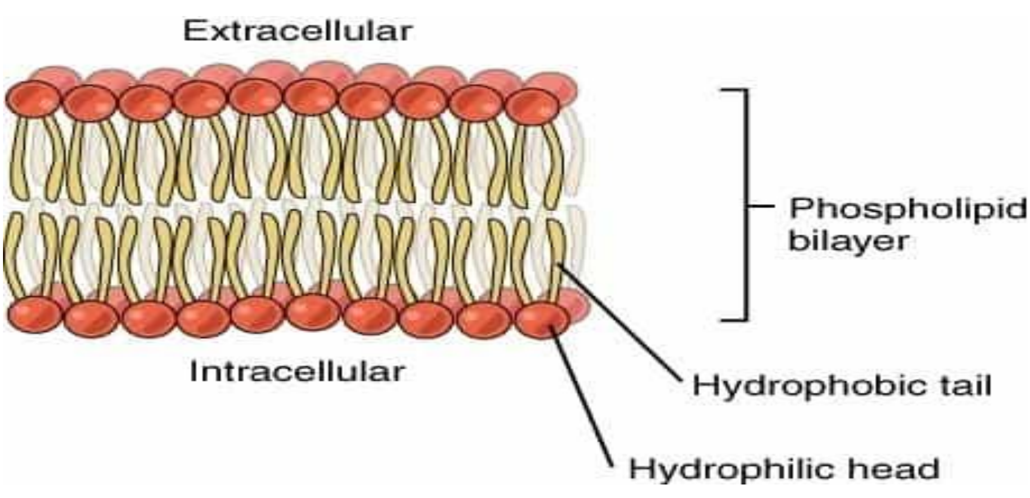
In addition, LPS is pyrogenic and causes endotoxic shock, can activate macrophages and complement system, it is mitogenic for B lymphocytes, induces interferon production, causes tissue necrosis and tumor regression, and has adjuvant properties. The endotoxic properties of LPS is due to the lipid A components. Usually, the LPS molecules have three regions: The lipid A attached to the core composed of polysaccharide chains which are linked to the O-antigens responsible for serologic specificity of the Gram-negative bacteria.

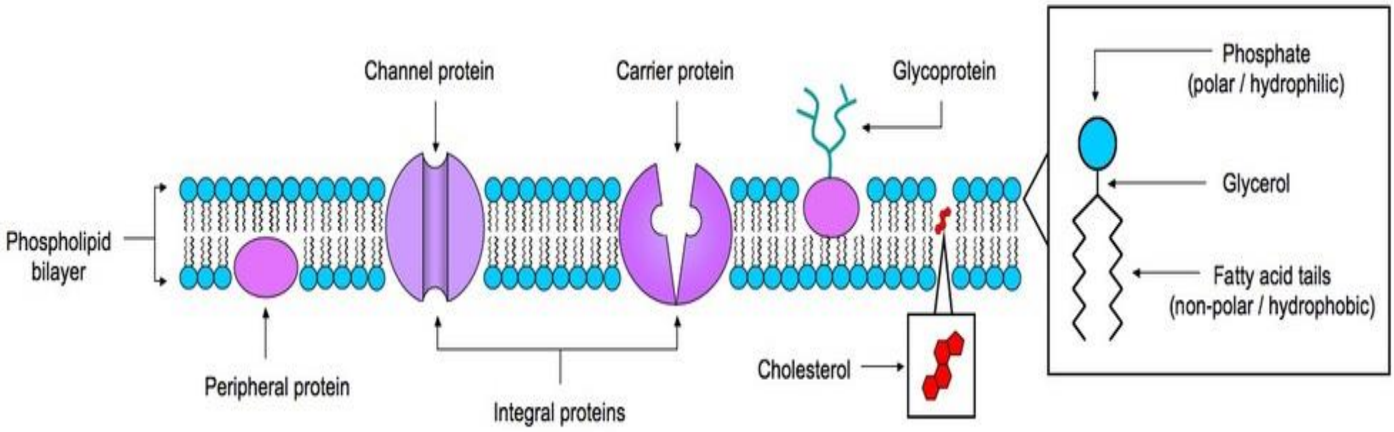
C- Intracellular Components

1. Plasma (Cytoplasmic) Membranes

Bacterial plasma membranes are similar to eukaryotic plasma membranes in function, are referred to cytoplasmic or protoplast membranes, they are composed primarily of proteins and lipids (phospholipids). Protein-to-lipid ratios of bacterial plasma membranes are approximately 3:1, close to those for mitochondrial membrane.

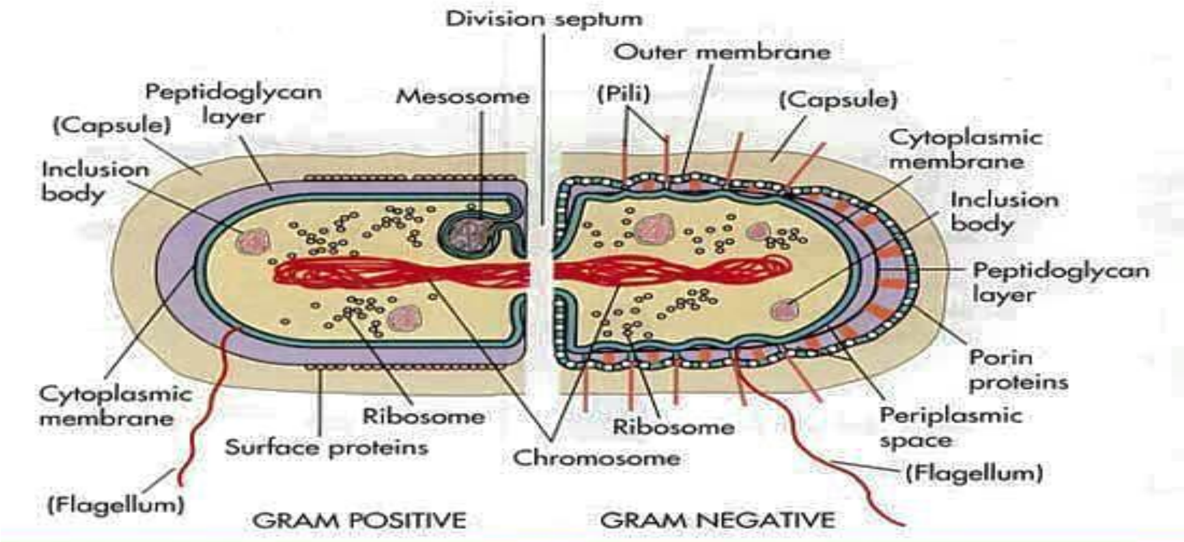
Plasma membranes are the site of active transport, respiratory chain components, energy-transducing systems, the ATPase of the proton pump, and membrane stages in the biosynthesis of phospholipids, peptidoglycan, LPS, and capsular polysaccharides. The bacterial cytoplasmic membrane is a multifunction structure similar to mitochondrial transport and biosynthetic functions of eukaryotic cells. The plasma membrane is also the anchoring site for the bacterial DNA.





2. Mesosomes

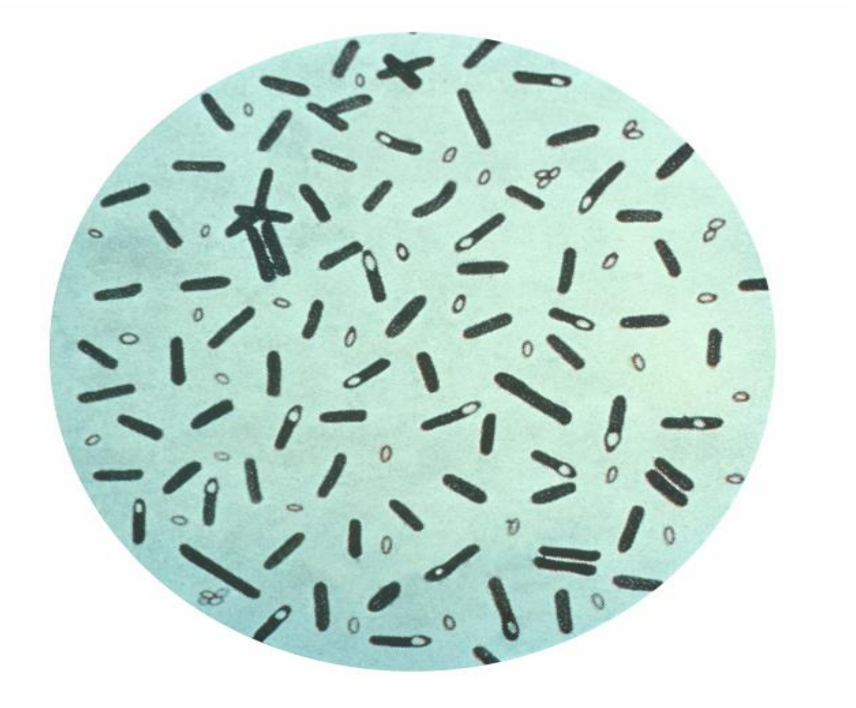
The mesosomes are tubular-vesicular membrane structures found in Gram-positive bacteria which are formed by an invagination of the plasma membrane. These structures equivalent to bacterial mitochondria; and may be related to events in the cell division cycle.



3. Other Intracellular Components

- **Ribosomes** of the 70S type; ribonucleoprotein particles are not arranged on a membranous rough endoplasmic reticulum as they are in eukaryotic cells, they are found in the cytoplasm.
- **Endospores** are highly heat-resistant, dehydrated cells formed intracellularly in some bacteria like Bacillus and Clostridium. Sporulation, is the process of forming endospores because of many biochemical and morphologic changes begins in the stationary phase of the vegetative cell cycle due to decrease nutrients (sources of carbon and nitrogen). Also, formation of unusual peptidoglycan which contains calcium dipicolinate, help in resistance to heat, radiation, pressure, and organic solvents.

The spore protoplast, or core, contains a complete chromosome, ribosomes, and energy generating components. During germination, the spore wall becomes the vegetative cell wall and cortex will be released.



Endospores of Clostridium