**I. SCOPE OF MICROBIOLOGY**

**A. Domains of living organisms**

**1. Archaea:** include prokaryotes with cell walls that are biochemically different from bacteria and that inhabit extreme environments of heat, cold, pH, or salts. Archaea are not a medically important domain of microorganisms.

**2. Eukarya:** contains some microorganisms—for example, **fungi** (yeasts and molds) , **protozoa**, and algae—along with macroscopic organisms such as **mushrooms**, **plants**, and **animals**. Dimorphic fungi are those that can exist in either the unicellular (yeast) or the filamentous (mold) phase, depending on the incubation temperature (e.g. , Histoplasma and Blastomyces) .

**a. Fungi** are classified into phyla based on the type of reproductive structures observed or the lack of observable sexual reproductive structures.

(1) Ascomycota (ascus) (e.g. , Candida and Histoplasma)

(2) Basidiomycota (basidium) (e.g., Cryptococcus)

(3) Zygomycota (zygote) (e.g., Rhizopus)

(4) Deuteromycota (asexual, also called fungi imperfecti) (e.g., Coccidioides).

Recently, some sexual reproductive states have been identified in fungi classiffied as belonging to Deuteromycota.

**b. Protozoa,** unicellular , nonphotosynthetic eukaryotes characterized by mode of motility, include the following:

(1) Mastigophora (flagellates) (e.g. , Giardia)

(2) Sarcodina (amoebae) (e.g. , Entamoeba)

(3) Ciliophora (ciliates) (e.g., Balantidium)

(4) Sporozoa (nonmoti le) (e.g. , Plasmodium)

**3. Bacteria:** contain a wide variety of prokaryotes, including gram-positive and gram negative bacteria.

**B. Nonliving, but medically significant entities** are the following:

**1. Viruses,** which are classiffied by:

a. *Capsid structure*, which is the protein coating around the nucleic acid

b. *Type and strandedness of nucleic acid*, which could be DNA or RNA, either single or double stranded

c. *Presence or absence of a lipid envelope surrounding the protein capsid*

d. *Presence of enzymes*, which may be either incorporated into the lipid envelope or found in the capsid near the nucleic acid

**2. Prions,** infectious proteins, are implicated in some spongiform encephalopathies (e.g. , mad cow disease, Creutzfeldt-Jakob disease, and kuru).

**II. TAXONOMY AND NOMENCLATURE OF BACTERIA**

**A. Taxonomy:** Bacteria are **prokaryotes** that belong to the Bacteria domain and the Eubacteria kingdom and are grouped and named primarily by morphology, biochemical and metabolic differences, and immunologic and genetic relationships. DNA technology has led to the reclassification of some organisms based on DNA sequences and homology. Bacteria are named using the **Linnaean** or **binomial** system as a genus and species (e.g., *Homo sapiens* is the genus and species for humans).

**B. Morphology:** is the classification of bacteria by shape and structure.

1. Cultural morphology: is based on the size, shape, and texture of colonies that are grown in pure culture on an agar plate. Each colony originates from a colony forming unit (CFU), consisting of a single cell or group of adherent cells.

2. Microscopic morphology: describes bacteria on the basis of the size, shape, and arrangement of the cells.

**C. Stains:** Because of their small size and relative transparency, bacteria must be stained to be visible under the light microscope. Staining is also used as a classification system. The major types of staining reactions are the following:

**1. Simple stain:** A single dye (e.g., Gentian violet, safranin) that colors the cells.

**2. Gram stain:** A differential staining procedure that divides bacterial cells into either gram-positive (purple) or gram-negative (pink).

**3. Acid-fast stain:** A procedure that stains cells that have an outer layer of a waxy lipid (acidfast) but not cells that lack that layer (non-acid-fast).

**4. Spore stain:** A procedure that uses heat to help dye enter the spore.

**5. Capsule stain:** Two dyes are used to stain the cell and the background, allowing visualization of the unstained capsular material.

**D. Bacterial cell shape and arrangement:**

**1. Cocci:** are spherical and exist in chains (*Streptococcus pyogenes*), pairs or

diplococci (*Streptococcus pneumoniae*, *Neisseria gonorrhoeae*) , clusters

(staphylococci) , and packets of four or eight (sarcinae).

**2. Bacilli:** are cylindrical and rod-shaped organisms (pseudomonas, Escherichia).

**3. Coccobacilli:** are short rounded rods (Brucella).

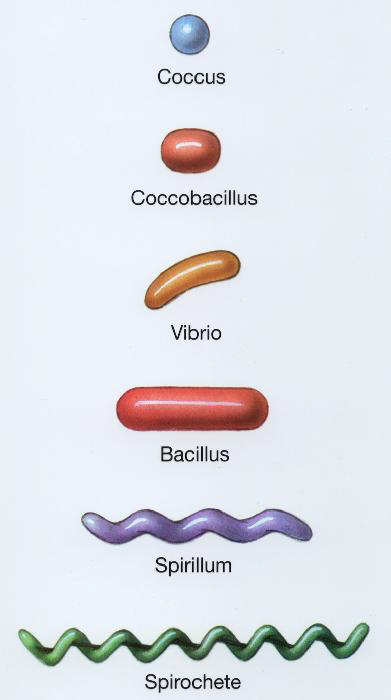
**4. Spirochetes and Spirilla:** are helical, like a cork screw (Treponema pallidum) ; **spirilla** are rigid helices, whereas spirochetes are flexible helices.

**5. Fusobacteria:** have tapered ends and are slightly curved (i.e., fusiform ; *Fusobacterium mortiferum*).

**6. Filamentous organisms:** are branching organisms and are associated with mold like bacteria (*Actinomyces bovis*).

**7. Vibrios:** are comma shaped rods (Vibrio cholerae).

**8. Pleomorphic organisms:** exist in varied forms (Haemophilus, Legionella, Corynebacteria).



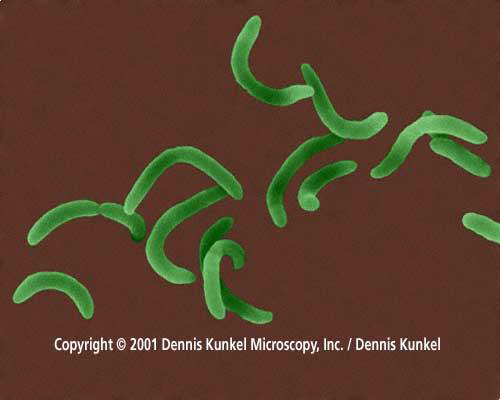
Coccus (pl. Cocci)



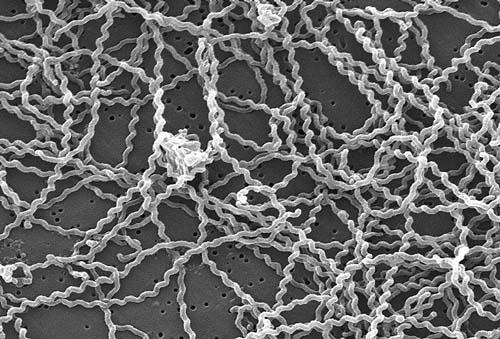
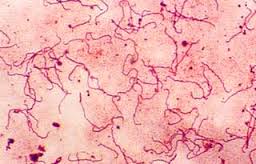
Bacillus (pl. Bacilli)



Coccobacillus

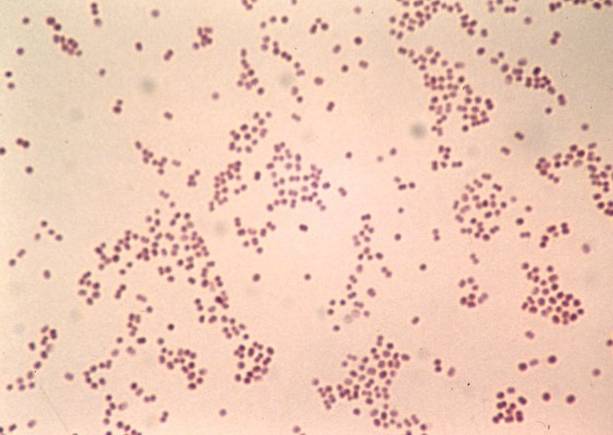


Vibrio



Spirillum

Spirochete



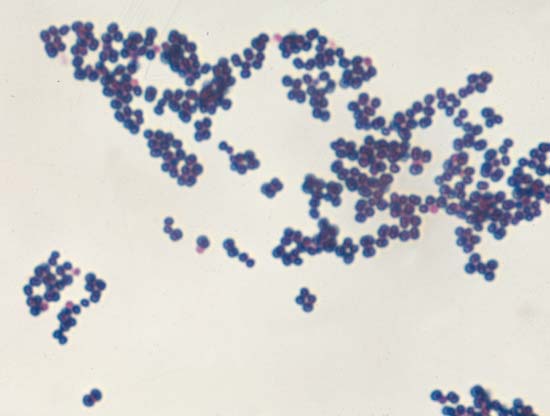
**A: Diplococci: (*Neisseria* spp.)**

**B: Streptococci:**

**(*Streptococcus* spp.)**

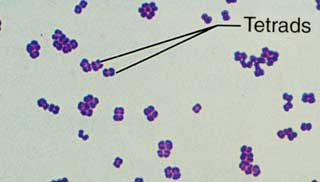


**C: Clusters: *Staphylococus* spp.**



**D: tetrads:**

e.g some spp of ***Micrococcus***.



**E. Other classification parameters:**

**1. Presence or absence of**

**a. Spores** used for survival (*Bacillus anthracis*) .

**b. Capsules** or **slime layers** used for adherence. Capsules are also antiphagocytic (*Streptococcus pneumoniae*, *Neisseria meningitidis*).

**2. Motility and the type of flagella**

a. Monotrichous. A single flagellum

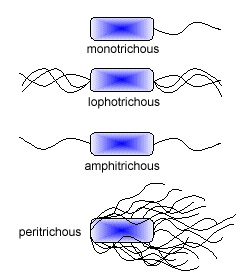
b. Lophotrichous. A tuf t of flagella at one pole

c. Amphitrichous. A flagellum at both poles

d. Peritrichous. Flagella distributed evenly over the entire cell

e. Axial filaments. Periplasmic flagella wrapped around spirochetes

f . Gliding motility. As demonstrated by slime molds.



**FUNCTIONAL ANATOMY OF PROKARYOTIC & EUKARYOTIC CELLS:**

**III. STRUCTURE OF THE PROKARYOTIC CELL:**

**A. Overview:** Prokaryotic (Gr. pro, before, + karyon, nucleus) cells (bacteria) are small (their diameter is usually about 1 Mm) and relatively simple.Most prokaryotes are[**unicellular**](http://en.wikipedia.org/wiki/Unicellular)**.** Prokaryotes belong to two[**taxonomic**](http://en.wikipedia.org/wiki/Taxonomy)domains: the[**bacteria**](http://en.wikipedia.org/wiki/Bacteria)and the**[archaea](http://en.wikipedia.org/wiki/Archaea).** They have the following characteristics:

1. Contain no internal membrane bound organelles (no intra cytoplasmic membranous organelles e.g., plastids, endoplasmic reticulum, vacuoles) but have complex cell wall structures.

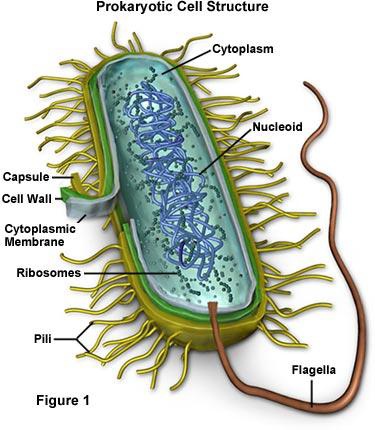
2. Lack a true nucleus or a nuclear envelope separating the genetic material (DNA) from other cellular constituents (**lack a**[**cell nucleus**](http://en.wikipedia.org/wiki/Cell_nucleus)). In addition, prokaryotes have no histones (specific basic proteins) bound to their DNA.

3. Multiply asexually by binary fission rather than by mitosis or meiosis. But it also can conjugate sexually by conjugation.

4. Protein synthesis is mediated by 70s rather than by 80s ribosome.

5. Bacterial genetic information is arranged on a single super coiled circular strand of double-stranded DNA ; the nucleoid is the area of the cell containing the tightly coiled chromosome.

6. Some bacteria contain storage granules, or inclusion bodies, the staining of these granules may also be useful in identifying the bacteria.

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**B. External structures:**

**1. Capsule and slime layer:**

**a.** The **capsule** is an adherent, surface coat made up of long chain repeats of carbohydrates or peptides. The capsule differs in composition among bacteria of different genus and species. Antigenic differences among capsules can be used to identify strains within a single species of bacteria (*Streptococcus pneumoniae*). Capsules are usually polysaccharide in nature ; however, the capsule of Bacillus is polypeptide. The capsule has several functions:

(1) Increases the virulence (degree of organism pathogenicity) of a microorganism.

(2) Prevents phagocytosis of the organism by macrophages and neutrophils.

(3) Aids in adherence of the organism to host cells

**b.** If the polysaccharide is non adherent, it is called a **slime layer**.

**c.** **Transformation** from smooth to rough colonies on media indicates capsule loss. Concurrently, there is a loss of virulence. This capsular material is immunogenic, thereby inducing the production of antibodies, which act as opsonins to enhance phagocytosis (**opsonization**).

**2. Flagella:**

**Flagella** are proteinaceous, helically coiled organs used for movement that extend outward from the cytoplasm through the cell wall into the environment (Figure 9-2). Flagella rotate either clockwise or counterclockwise, allowing a series of runs and tumbles in response to chemicals in the environment. The direction of movement is controlled by a complex mechanism involving chemoreceptors and an intracellular cascade of methylation and phosphorylation reactions, causing bacteria to move toward nutrient chemoattractants and away from repellants.

**a. Structure:**

(1) Flagella are composed of flagellin, a protein called Hantigen, which is antigenically distinct from other flagella in eucaryotes.

(2) Flagella have three parts:

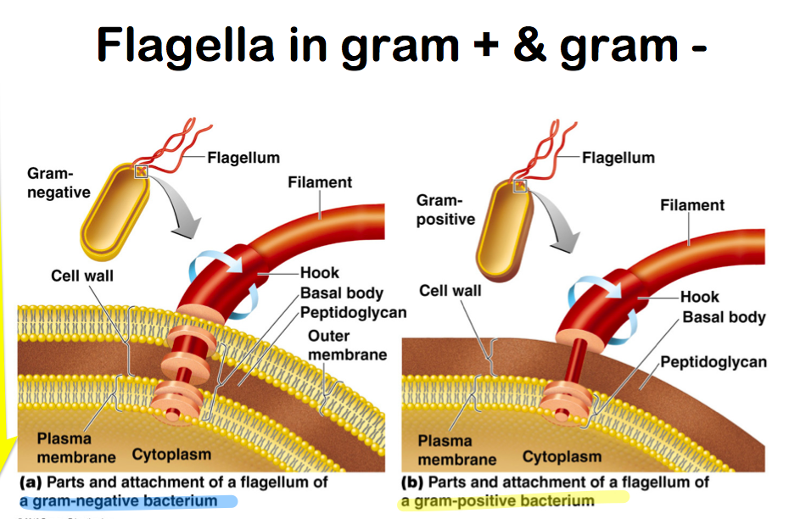
(a) Basal body:

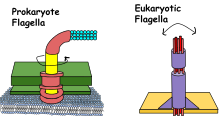
(i) Attaches the flagella to the cytoplasmic membrane and cell wall

(ii) The number of rings that make up the basal body differ in gram-positive (two) and gram-negative (four) organisms. The L and P rings are absent in Gram-positive organisms.

(b) Hook

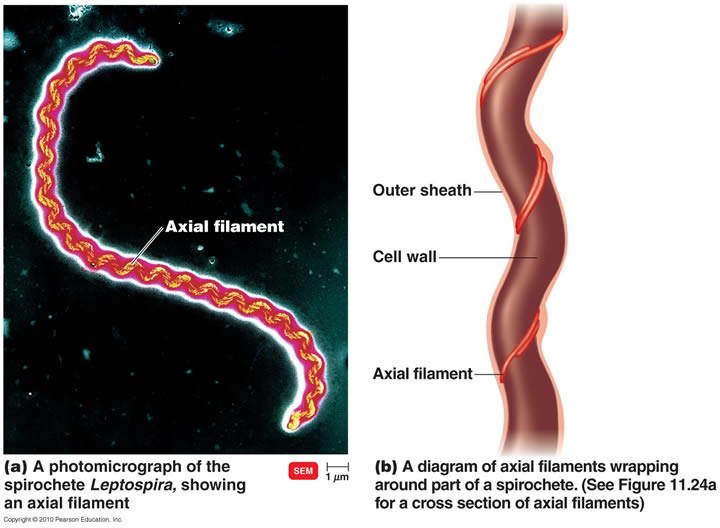
(c) Filament

[](http://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0CAcQjRxqFQoTCOeF_O3BysgCFcH-cgodcDkNig&url=http://www.easynotecards.com/print_list/17960&psig=AFQjCNEgmhYjfbUXWvvbWKtYsVL2ZOQZqg&ust=1445205782332028)

[](https://en.wikipedia.org/wiki/File:Difference_Between_Prokaryote_and_Eukaryote_Flagella.svg)

Prokaryotic flagella run in a rotary movement, while eukaryotic flagella run in a bending movement. The prokaryotic flagella uses a rotary motor,and the eukaryotic flagella uses a complex sliding filament system. Eukaryotic flagella is ATP driven, while prokaryotes are proton driven.

**b. Periplasmic flagella:**, also called **axial filaments**, occur in spirochetes and are embedded into the cell wall's outer membrane. Because they cause a corkscrew type of motion on contraction, these organisms are not hindered by the viscosity of media.

[](http://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0CAcQjRxqFQoTCMmO382dy8gCFcMscgodV7AKRQ&url=http://classes.midlandstech.edu/carterp/courses/bio225/chap04/lecture3.htm&psig=AFQjCNH5sW3GBgVcXRbCSi9p5l66aFd1eQ&ust=1445230261135727)

**3. Pili (fimbriae):**

**Pili (fimbriae)** are proteinaceous, hair-like extensions that are shorter than flagella and composed of regularly arranged protein subunits called pilin or fimbrilin. They are more common in gram-negative organisms but can be found in gram-positive organisms. There are two morphological and functional varieties:

**a. Common (attachment) pili:**

(1) Appear in greater numbers than sex pili.

(2) Have adhesive properties, which are important in the formation of biofilms.

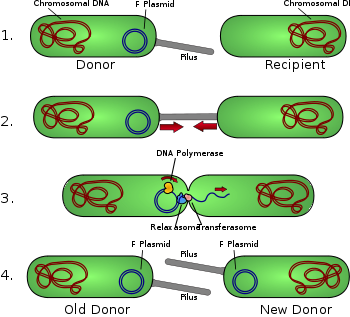
(3) Are lectins, which are responsible for trophism, the ability of the organism to bind to specific receptors on host cells.

**b. Sex (conjugative or F) pili:**

(1) Are longer than common pili.

(2) Form in groups of < 10.

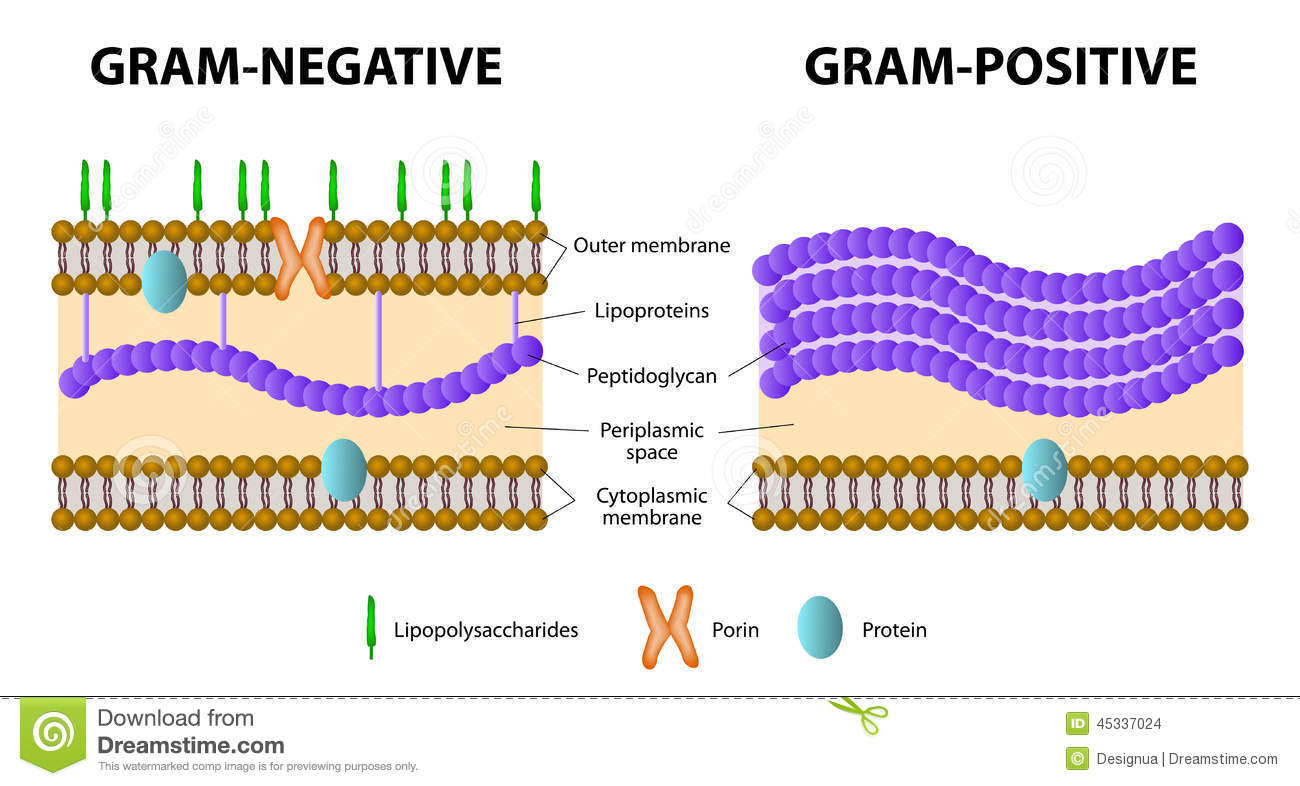
(3) Are involved in the transport of DNA between donor and recipient cells.

[](https://en.wikipedia.org/wiki/File:Conjugation.svg)

Schematic drawing of bacterial conjugation. **1-** Donor cell produces pilus. **2-** Pilus attaches to recipient cell, brings the two cells together. **3-** The mobile plasmid is nicked and a single strand of DNA is then transferred to the recipient cell. **4-** Both cells recircularize their plasmids, synthesize second strands, and reproduce pili; both cells are now viable donors.

C. The cell wall, periplasmic space, and cytoplasmic membrane:

**1.** The **cell wall** is rigid. Although it provides the general shape of the cell, its function is to protect the cell from osmotic shock. If the cell wall is destroyed, the bacterial cells are susceptible to alterations in the tonicity of the environment. The wall is composed of a basic **peptidoglycan layer,** which in turn is composed of repeating disaccharide units (a polymer of ***N*-acetyl glucosamine** and ***N*-acetyl muramic** **acid**), with a four-amino-acid side chain that is covalently linked to amino acids from neighboring disaccharide units, forming a stable cross-linked structure. Most bacteria are designated as either gram-positive or gram-negative, based on fundamental differences in the components of the cell wall. Owing to the uniqueness and the importance of the cell wall to bacterial viability, it is the target of many antibiotic agents.

[](http://www.google.ca/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0CAcQjRxqFQoTCN77rtS-ysgCFcgHLAod2loOyg&url=http://www.dreamstime.com/stock-illustration-gram-positive-gram-negative-bacteria-difference-bacterial-image45337024&psig=AFQjCNHPhMEM73JR5zLLvSZYq2hBH8LM2g&ust=1445205088516347)

**a. Gram-positive organisms** have a thick cell wall, which is 90% peptidoglycan, with extensive cross-linking that is approximately 40 layers thick and forms a layered network around the cytoplasmic membrane. Within the cell wall, a variety of elements serve to stabilize the cell wall, maintain its association with the cytoplasmic membrane, and act as receptors and antigenic determinants. These elements include proteins, polysaccharides and teichoic acid (glycerol or ribitol phosphodiesters).

**(1) Teichoic acids** (glycerol or ribitol phosphodiesters)

**(a) Membrane-associated teichoic acids** (lipoteichoic acid) are covalently linked to glycolipids of the cytoplasmic membrane.

**(b) Wall-associated teichoic acids** are covalently linked to the glycan chain of peptidoglycan.

**b. Gram-negative organisms'** cell walls are multi layered with a thin peptidoglycan layer that has no teichoic acids. External to this is the **outer membrane,** a complex cell wall layer, which is linked to the peptidoglycan layer by the **lipoprotein** layer. The outer membrane acts as a hydrophobic diffusion barrier and consists of:

**(1) Phospholipid,** a bilayer similar to the cytoplasmic membrane with protein channels, called **porins,** for nutrient transport. The phospholipid layer of the outer membrane faces the cytoplasmic membrane.

**(2)** The **lipopolysaccharide (LPS)** component projects from the cell surface and is both toxic and antigenic (**O antigen**). In a gram-negative organism, the LPS **blocks** **diffusion** of low molecular weight substances into the cell, so antibiotics and chemicals that attack the cell wall (e.g., lysozyme, penicillin) cannot easily pass through. LPS, also known as **endotoxin,** is toxic to humans and is composed of three parts:

**(a) Lipid A:** toxic portion that can either slough off intact cells or be released into circulation upon lysis of the cell, causing nonspecific inflammation, including diarrhea, fever, and septic shock.

**(b) Core polysaccharide:** similar within genera

**(c) O-specific side chain:** species specific

**(3) Protein**

**2.** The **periplasmic space,** an area between the cell wall and the cytoplasmic membrane, contains a gel of several types of molecules (e.g., hydrolytic enzymes, periplasmic-binding proteins) that process molecules before they enter the cytoplasm. It also contains proteins that act as chemoreceptors for chemotaxis, others that act as carr iers of nut r ients (similar to car riers in the cytoplasmic membrane), and antibiotic-inactivating enzymes.

**3.** The **cytoplasmic membrane** is a phospholipid bilayer matrix of a fatty acid core (hydrophobic) and glycerol phosphate (hydrophilic). In the presence of proteins embedded in the matrix, these membranes are actively and passively engaged in several **cellular functions.**

**a. Transportation** of nutrients through:

**(1)** Passive diffusion.

**(2)** Facilitated diffusion.

**(3)** Active transport (this method is the only one that actively uses energy because molecules are moving into the cell against a concentration gradient).

**b.** The site of **respiration proteins** used for **electron transport** and energy

formation.

**c.** **Enzymes** involved in the assembly of the cell wall components.

**d. Secretion of exotoxins** and other substances for the breakdown of

macromolecules.

**D. Internal Structures:**

**1. Storage granules** are inclusion bodies used for food or energy storage (e.g., polyphosphate complexes, carbohydrate).

**2. Ribosomes** are cellular units that synthesize protein by the translation of

messenger RNA (mRNA) base sequences into amino acid protein sequences. These ribosomes, unlike those in eukaryotic cells, are 70s units and are not associated with membranes such as mitochondria or rough endoplasmic reticulum.

**3.** The **nuclear region** of bacteria is a condensed area (a nucleoid) containing the bacterial chromosome, which lacks a nuclear membrane and consists of a long, double-stranded, supercoiled, circular DNA molecule.

**4.** Some organisms contain **plasmids,** circular double-stranded pieces of DNA that are found outside of the bacterial chromosome. These structures are autonomous (not controlled by the bacterial chromosome), contain information for heavy metal and antibiotic resistance, are conjunctive, and carry genetic elements called **transposons.**