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Bacterial Cell Structure and Function

Prokaryotes and Eukaryotes:

The chief distinguishing characteristics of Prokaryotes:

1- Their DNA (genetic material) is not enclosed within a membrane and is one circular chromosome.

2- Their DNA is not associated with histones (special chromosomal proteins found in eukaryotes) other proteins are associated with the DNA.

3- They lack membrane-enclosed organelles.

4- Their cell walls almost always contain the complex polysaccharide peptidoglycan.

5- They usually divide by binary fission. During this process, the DNA is copied and the cell splits into two cells. Binary fission involves fewer structures and processes than eukaryotic cell division.

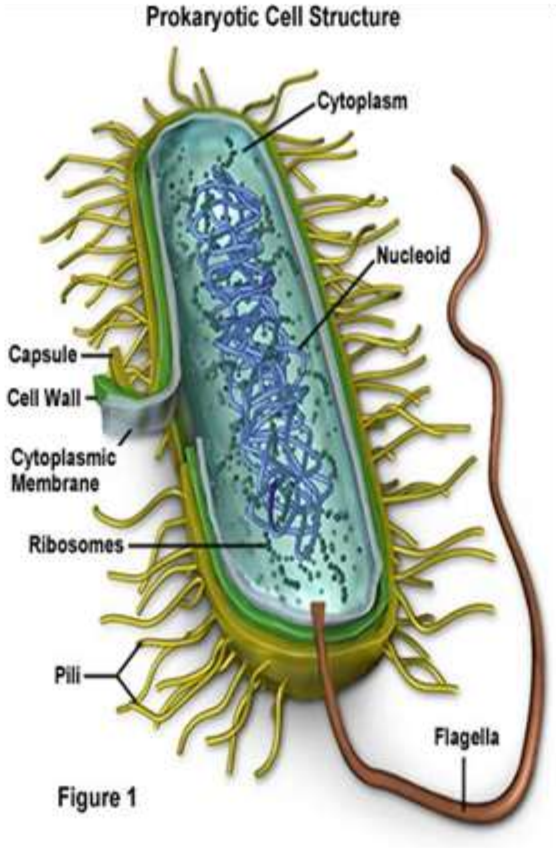


Figure 1

The chief distinguishing characteristics of Eukaryotes:

1- Their DNA is found in the cell's nucleus, which is separated from the cytoplasm by a nuclear membrane, and the DNA is found in multiple chromosomes.

2- Their DNA is consistently associated with chromosomal proteins called histones and with non histones.

3- They have a number of membrane-enclosed organelles, including mitochondria, endoplasmic reticulum, Golgi complex, lysosome, and sometimes chloroplasts.

4- Their cell walls, when present, are chemically simple.

5- They usually divide by mitosis, in which chromosomes replicate and an identical set is distributed into each of two nuclei. This process is guided by the mitotic spindle, a football-shaped assembly of microtubules. Division of the cytoplasm and other organelles follows so that the two cells produced are identical to each other.

Basis for COMPARISON	**PROKARYOTIC CELLS**	**EUKARYOTIC CELLS**
Size	0.5-3um	2-100um
Kind of Cell	Single-cell	Multicellular
Cell Wall	Cell wall present, comprise of peptidoglycan or mucopeptide (polysaccharide).	Usually cell wall absent, if present (plant cells and fungus), comprises of cellulose (polysaccharide).
Presence of Nucleus	Well-defined nucleus is absent, rather 'nucleoid' is present	A well-defined nucleus is present enclosed within nuclear membrane.
Shape of DNA	Circular, double-stranded DNA.	Linear, double-stranded DNA.
Mitochondria	Absent	Present
Ribosome	70S	80S
Golgi Apparatus	Absent	Present
Endoplasmic Reticulum	Absent	Present

Basis for COMPARISON	PROKARYOTIC CELLS	EUKARYOTIC CELLS
Mode of Reproduction	Asexual	Most commonly sexual
Cell Divison	Binary Fission, (conjugation, transformation, transduction)	Mitosis
Lysosomes and Peroxisomes	Absent	Present
Chloroplast	(Absent) scattered in the cytoplasm.	Present in plants, algae.
Transcription and Translation	Occurs together.	Transcription occurs in nucleus and translation in cytosol.
Organelles	Organelles are not membrane bound, if present any.	Organelles are membrane bound and are specific in function.
Replication	Single origin of replication.	Multiple origins of replication.
Number of Chromosomes	Only one	More than one.
Examples	Bacteria.	Plants and Animals.

The bacterial cell

There are a great many sizes and shapes among bacteria. Most bacteria range from 0.2-2.0 µm in diameter and from 2-8 µm in length. They have a few basic shapes:

A- Spherical coccus: Cocci are usually round but can be oval, elongated, or flattened on one side. When cocci divided to reproduce, the cells can remain attached to one another:

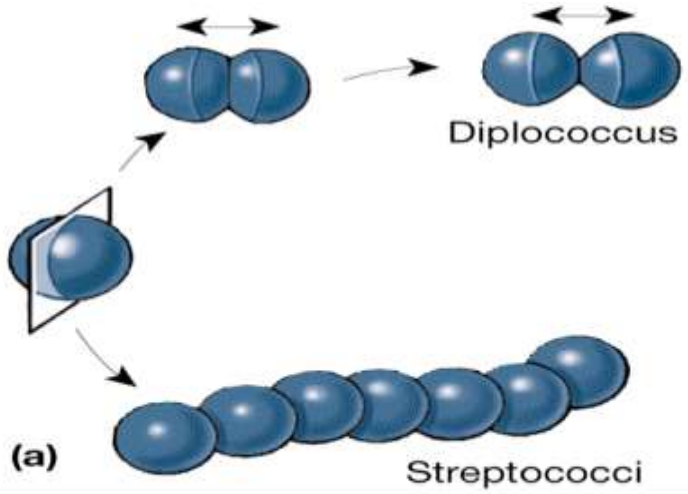
1- cocci that remain in pairs after dividing are called diplococci

2- Those that divided and remain attached in chain linke patterns are called streptococci

3- Those that divided in two planes and remain in groups of four are known as tetrads.

4- Those that divided in three planes and remain attached in cube like groups of eight are called sarcinae

5- Those that divide in multiple planes and form grapelike clusters or broad sheets are called staphylococci



B- Rod shaped bacillus: bacilli divide only across their short axis,

1- Most bacilli appear as single rods.

2- Diplobacilli appear in pairs

3- Streptobacilli occur in chains

4- Coccobacilli are oval and look so much like cocci.

C- Spiral :

1- have one or more twists; they are never straight. Bacteria that look like curved rods are called vibrios.

2- Have ahelical shape, like a corkscrew, and fairly rigid bodies.

3- Another group of spirals are helical and flexible, they are called spirochetes.

The shape of bacterium is determined by heredity. Genetically, most bacteria are monomorphic.

Structures

Glycocalyx: (meaning sugar coat) is the general term used for substances that surround cells. The bacterial glycocalyx is viscous, gelatinous polymer that is external to the cell wall and composed of polysaccharide, polypeptide, or both.

If the substances is organized and is firmly attached to the cell wall, the glycocalyx is described as a **capsule.**

Function of capsules:

1- Important in contributing to bacterial virulence.

2- Capsules often protect pathogenic bacteria from phagocytosis by the cells of the host. Example, *Bacillus anthrax*.

3- help cell on biofilm attach to their target environment (such as rocks-plant).

4- source of nutrition by breaking it down and utilizing it when energy stores are low.

If the substances is unorganized and only loosely attached to the cell wall, the glycocalyx is described as a **slime layer.**

Flagella

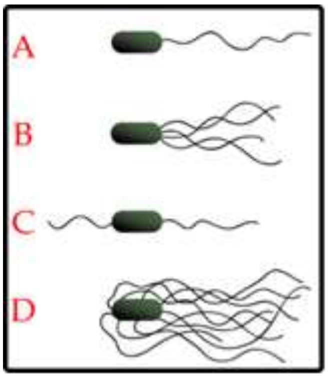
Are long filamentous appendages that propel bacteria. Bacterial cells have four arrangements of flagella:

a- monotrichous (a single polar flagella)

b- lophotrichous (a tuft of flagella at one end of the cell)

c- amphitrichous (flagella at each end of the cell)

d- peritrichous (flagella distributed over the entire cell)



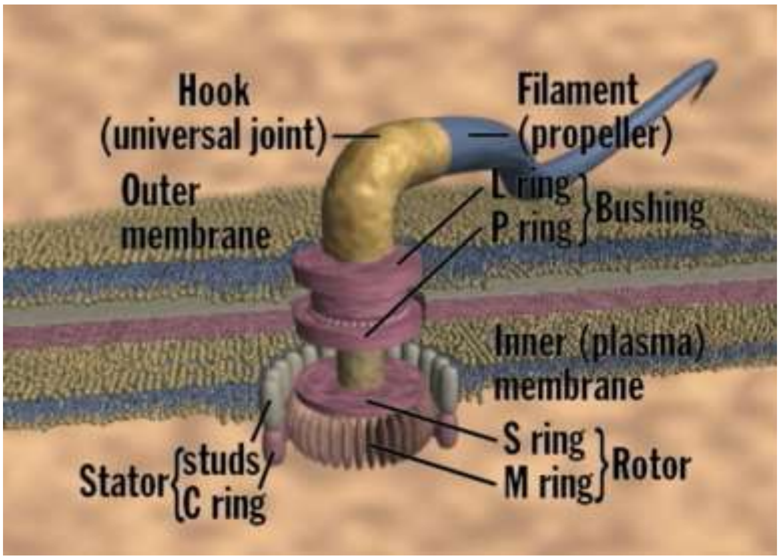
A flagellum has threat basic parts:

1- The long outer most region, the **filament**, is constant in diameter and contains the globular (roughly spherical) protein flagellin arranged in several chains that intertwine and form a helix around a hollow core.

2- The filament is attached to a slightly **wider hook**, consisting of a different protein.

3- **basal body**, which anchors the flagellum to the cell wall and plasma membrane.

The basal body is composed of a small central rod inserted into a series of rings. Gram- negative bacteria contain two pairs of rings.



Bacteria with flagella are motile; that is, they have the ability to move on their own. Flagellum is a semi rigid, helical structure that moves the cell by rotating from the basal body. The movement of a bacterium toward or away from a particular stimulus is called **taxis**. Such stimulus include chemicals (chemotaxis) and light (phototaxis).

Axial Filaments

Axial filaments or **endoflagella,** bundles of fibrils that arise at the ends of the cell beneath an outer sheath and spiral around the cell.

Axial filaments which are anchored at one end of the spirochete, have a structure similar to that of flagella.

Pili and fimbria

Fine, straight, hair-like appendages that are shorter straighter and thinner than flagella , are used for attachment and transfer DNA from one cell to another (called conjugation) rather than for motility. composed of the protein pilin, are attached to the cell wall of many Gram- negative bacteria.

The number of fimbria more than pili. they have different functions in pathogenic bacteria, **fimbria function** can help bacteria to adhere on epithelial cell of the host e.g. fimbria E.coli O157enable this bacteria to adhere to the lining of the small intestine.

Cell wall

The cell wall of bacterial cell is a complex ,semirigid structure responsible for shape of bacteria , cell walls of bacteria protect them from mechanical damage and osmotic lysis.

Function of cell wall

1. They are an essential structure for viability.
2. Responsible for the shape of the cell.
3. Protect the interior structure of the cell from adverse changes in outside environment.
4. Prevent bacterial cell from rupturing when the water pressure inside the cell is greater than that outside the cell.
5. Serve as a point of anchorage for flagella.
6. Contributes to the ability of some species to cause disease.
7. Site of action of some antibiotics.
8. Chemical composition of cell wall is used for differentiate major types of bacteria.
9. They cause symptoms of disease in animals.
10. They play a role in cell growth.
11. They provide for immunological distinction and immunological variation among strains of bacteria.

Peptidoglycan:

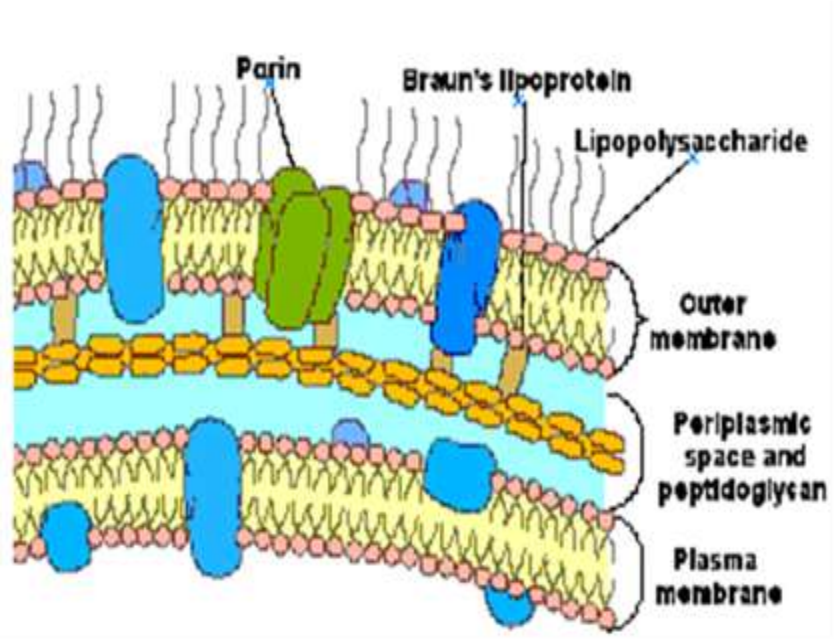
A polymer unique to prokaryotic cells, imparts rigidity to the cell wall. This polymer is composed of chains of alternating subunits of N-acetyleglucosamine and N-acetylmuramic acid (glycan) croos-linked by short tetra peptide side chains and peptide cross-bridges.

Bacteria can be divided into two major groups, Gram-positive and Gram-negative on the basis of colure when stained by the Gram's stain , this colure reaction is determined by the composition of the cell wall.

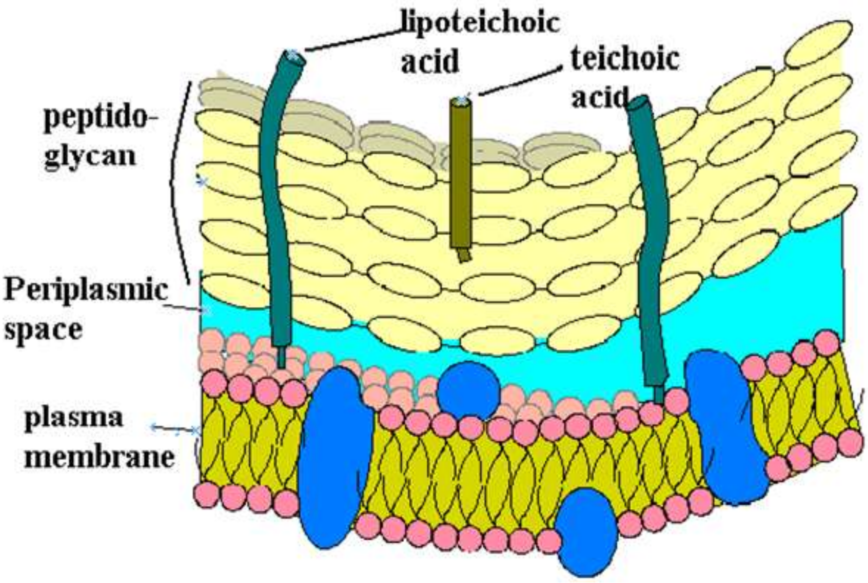
***Gram- positive bacteria** which stain purple have relatively thick uniform cell wall which is composed mainly of peptidoglycan ,teichoic acids {which is consist from an alcohol(such as glycerol or ribitol) and phosphate} and lipoteichoic acid.

***Gram- negative bacteria**, which stain red, have cell walls with a more complex structure, consisting of an outer membrane and a periplasmic space containing **small amount of peptidoglycan.**

The **outer membrane** is a protein-containing asymmetrical lipid bilayer. The structure of the inner surface of the membrane resembles that of the cytoplasmic membrane, whereas that of the outer surface is composed of lipopolysaccharide (LPS) molecules. Low molecular weight substances such as sugars and amino acids enter through specialized protein channels, known as porins, in the outer membrane. The outer membrane LPS, the endotoxin of Gram- negative bacteria, is released only after cell lysis. The major components of LPS molecules are core polysaccharide bound to lipid A and long external 0 polysaccharide side chain. The polysaccharide side chains of the LPS molecules stimulate antibody production and correspond to the somatic (O) antigens used for serotyping of gram-negative cells. Lipid A is the molecular component in which endotoxic activity resides.



Gram negative cell wall



Gram positive cell wall

The mycoplasmas comprise an important group of bacteria without cell walls. Conventional bacteria, exposed to the action of antibiotics such as penicillin, or other substances which interfere with the synthesis of peptidoglycan, cannot produce cell walls and are termed L form

Grams stain = a differential stain procedure, different results, + and (-)

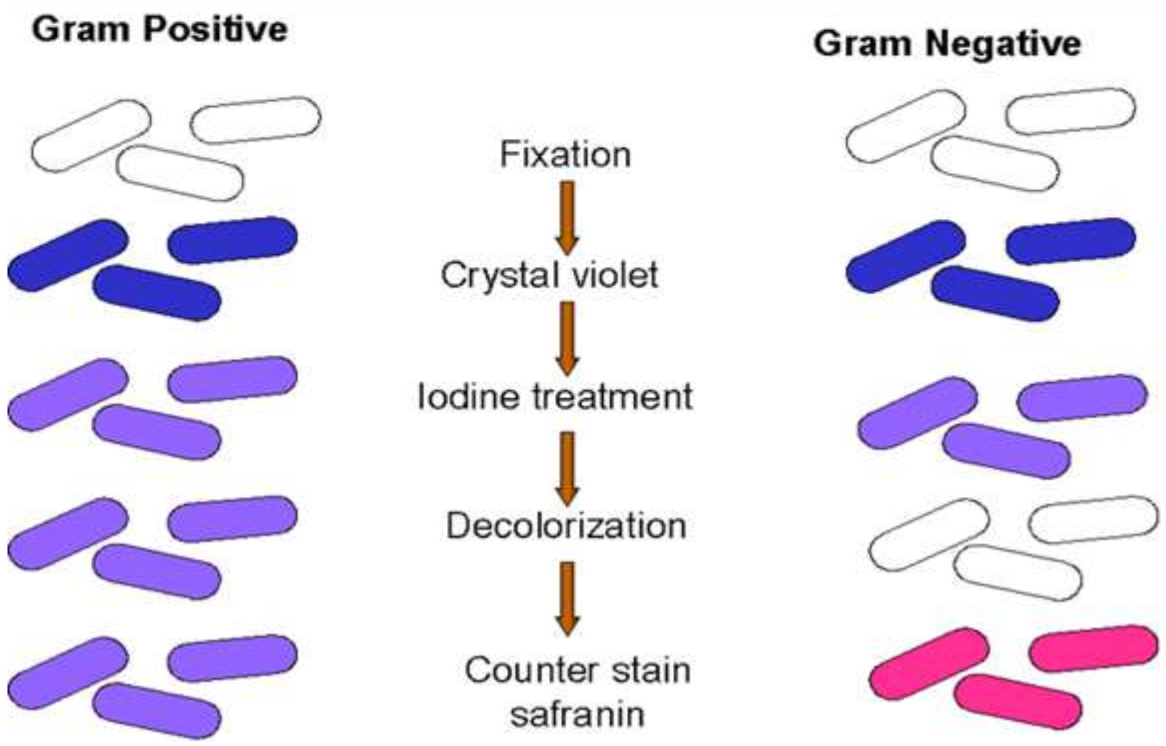


Table: some comparative characteristics between Gram positive and Gram negative bacteria

Property	Gram-positive	Gram-negative
Peptidoglycan (murein)	thick (multilayered)	thin (single
Outer membrane	Absent	Present
Periplasmic space	Absent	Present
Teichoic acids in wall	Present	Absent
Protein/lipoprotein content	Low	High
Lipopolysaccharide	None	High
Sensitivity to penicillin	Sensitive	Resistant
Sensitivity to lysozyme	Sensitive	Resistant

Plasma **(Cytoplasmic) membrane**

The cytoplasmic membrane of bacterial cells is flexible structures composed of **phospholipids and proteins.** They can be observed only by electron microscopy and are structurally similar to the plasma membranes of eukaryotic cells. However, bacterial cytoplasmic membrane,(with the exception of those present in mycoplasmas), do not contain sterol.

The inner and outer faces of cytoplasmic membranes are hydrophilic while the interior is hydrophobic, forming a barrier to most hydrophilic molecules. Only a limited range of small molecules such a water, oxygen, carbon dioxide and some lipid-soluble compounds can enter bacterial cells by **passive diffusion.**

Two type of protein molecule can be arranged in variety ways : **peripheral proteins ,integral proteins .**

Major functions of the cytoplasmic membrane:

1-protect the cytoplasm and inner structure of the cell.

2-serve as a selective barrier through which material inter and exit the cell (**selective permeability**).

3-important to breakdown nutrients and the production of energy as ATP.(contain enzymes)

4-site of electron transport for bacterial respiration,

5-the active transport of nutrients into the cell and the elimination of waste metabolites

, require the expenditure of energy.

6- Mediation of chromosomal segregation during replication

Cytoplasm

The cytoplasm, which is enclosed by the cytoplasmic membrane, is essentially an aqueous fluid containing the nuclear material, ribosomes, nutrients and the enzymes and other molecules involved in synthesis, cell maintenance and metabolism. Storage granules may be present under certain environmental conditions, usually those unfavorable for bacterial growth, these granules, which may be composed of starch, glycogen, polyphosphate or other compounds, (inclusion bodies).

Ribosomes

A sit of protein synthesis, these structures are composed of two subunit, which consist of protein and a type of RNA called ribosomal RNA (ribonucleoproteins) and are up to 25 nm in size. Prokaryotes ribosom are called **70s Ribosomes** They consist of two subunits, a larger 50S subunit and a smaller 30S subunits. **The Svedberg (S) unit which indicate the relative rate of during ultra- high speed centrifugation. sedimentation rate, which is dependent on both the size ,weight and shape of particle.**

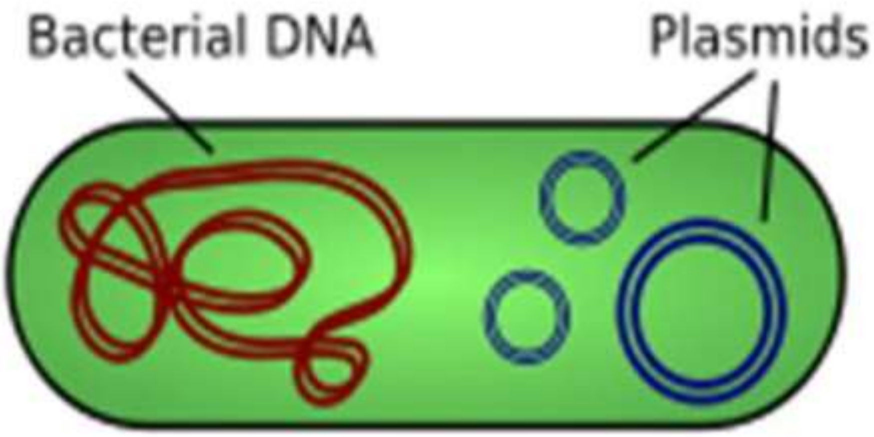
Ribosomal ribonucleic acid (r RNA) is complexed with many different proteins and accounts for about 80% of the RNA of the cell. Smaller amounts of transfer RNA (t RNA) and messenger RNA (m RNA) account for the remaining cellular RNA. Ribosomes may be present either in the cytoplasm or associated with the inner surface of the cytoplasmic membrane. During active bacterial growth and rapid protein synthesis individual ribosomes are joined by m RNA into long chains known as polysomes.

Nucleoid

The bacterial genome is composed of a single circular chromosome containing double-stranded DNA (bacterial chromosome) which carry all the information required for the cell structure and function. bacterial chromosome are not surrounded by nuclear envelope and dot contain histones. Because of its length, the bacterial chromosome is extensively folded to form a dense body which can be seen by electron microscopy.

Plasmids – Extrachromosomal DNA

Small circular pieces of double –stranded DNA which are separate from the genome, are capable of autonomous replication. Copies of plasmids can be transferred from cell to cell during binary fission or through conjugation. Plasmid DNA may code for characteristics such as antibiotic resistance and exotoxin production.



Inclusion body:

Are several kinds of reserve deposits known(inclusion bodies), or granules, in the bacterial cytoplasm. These bodies are never enclosed by a membrane and serve as storage vessels. Glycogen, which is a polymer of glucose, is stored as a reserve of carbohydrate and energy. Volutin, or metachromatic granules, contains polymerized phosphate (poly phosphate)can be used in synthesis of ATP.

Endospores

Dormant highly resistance bodies, termed endospores, are formed by some bacteria to ensure survival during adverse environmental conditions. The only genera of pathogenic bacteria which contain endospore- forming, are *Bacillus* and *Clostridium*.

Endospores, which are produced inside the bacterial cell, show species variation in shape, size and position within the mother cell (**central, terminal, subterminal**).

Because of the resistance and impermeability of the spore coat, **special staining** procedures which employ heat are required to demonstrate endospores.

the resistant of endospores is attributed to their layered structure, their dehydrated state, negligible metabolic activity and high content of dipicolinic acid (DPA) occurs in the spore wall with high amounts of calcium. Because spore are thermostable they can be destroyed by moist heat at 121c for 15 minutes.

If other environmental conditions including the presence of adequate nutrients are favorable germination will occur. the spore cortex and coat are degraded ,water is absorbed, DPA is released and outgrowth develops.