



# Bacterial Structure , Function & Genetics

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# Objectives

- Define the cellular organization of bacteria and recall the differences between Eukaryotes and Prokaryotes.
- Recall major structures of bacteria and its function.
- Describe the structure of cell wall of bacteria including the differences between Gram positive and Gram negative bacteria and main functions.

# Objectives, cont.,

- Describe the external and internal structures of bacteria and their functions.
- Describe bacterial spores and its application in the practice of medicine.
- Recall basic information about bacterial genetics and replication of bacteria .

# Objectives, cont.

- Describe plasmids , its origin , types and its importance in clinical practice.
- Recall genetics variations, including ; mutation and mechanisms of gene transfer and its implication on bacterial resistance to antimicrobial agents.

# Definition

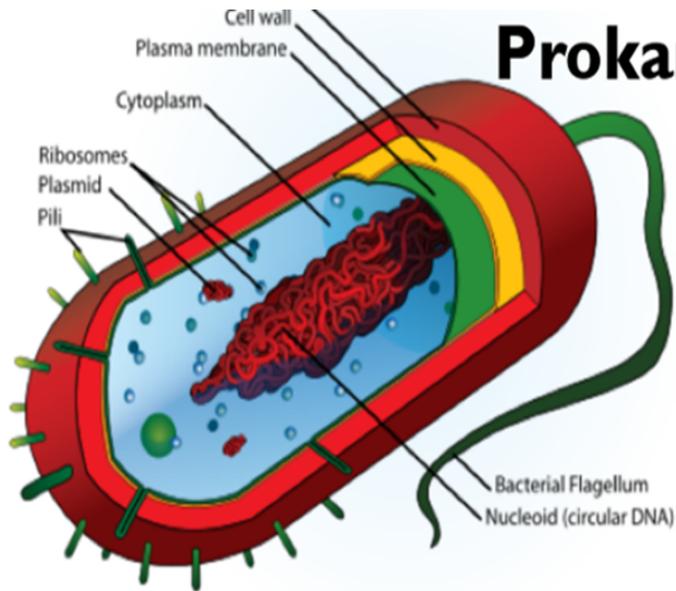
**Bacteria** : a heterogenous group of unicellular organisms , about 1-8  $\mu\text{m}$  in diameter

Bacteria is a **Prokaryote** (has a primitive nucleus):

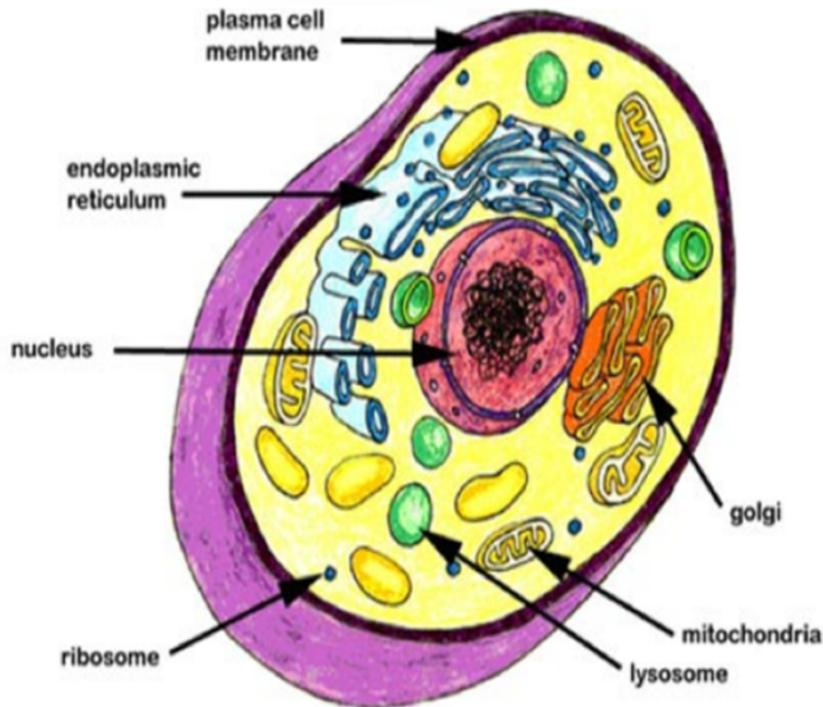
- ~ one chromosome
- ~ no nuclear membrane
- ~ no mitochondria
- ~ no sterols

**Bacteria contain Plasmids:** an extra piece of **DNA**.

# Prokaryotic Cell (Bacteria)



# Eukaryotic Cell (Plant)



# Eukaryotic Cell (Animal)

# Shapes & Types of Bacteria

- Spherical / Oval.....Cocci
- Rods.....Bacilli
- Very short Bacilli.....Coccobacilli
- Tapered end .....Fusiform
- Club-shaped / Curved.....Vibrio
- Helical / Spiral... .....Spirochaetes

# Arrangements of Bacteria

## Arrangements among cocci :

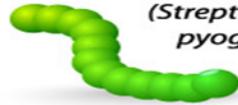
- Pairs.....Diplococci
- Chains.....Streptococci
- Clusters.....Staphylococci
- In four.....Tetrad
- Palisades.....*Corynebacterium*

# BACTERIA SHAPES

## SPHERES (COCCI)

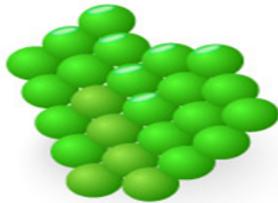


**Diplococci**  
(*Streptococcus pneumoniae*)



**Streptococci**  
(*Streptococcus pyogenes*)

**Tetrad**



**Staphylococci**  
(*Staphylococcus aureus*)



**Sarcina**  
(*Sarcina ventriculi*)

## RODS (BACILLI)



**Chain of bacilli**  
(*Bacillus anthracis*)



**Flagellate rods**  
(*Salmonella typhi*)



**Spore-former**  
(*Clostridium botulinum*)

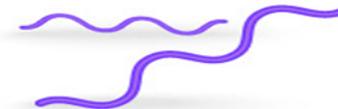
## SPIRALS



**Vibrios**  
(*Vibrio cholerae*)



**Spirilla**  
(*Helicobacter pylori*)



**Spirochaetes**  
(*Treponema pallidum*)



Coccus



Coccobacillus



Vibrio



Bacillus

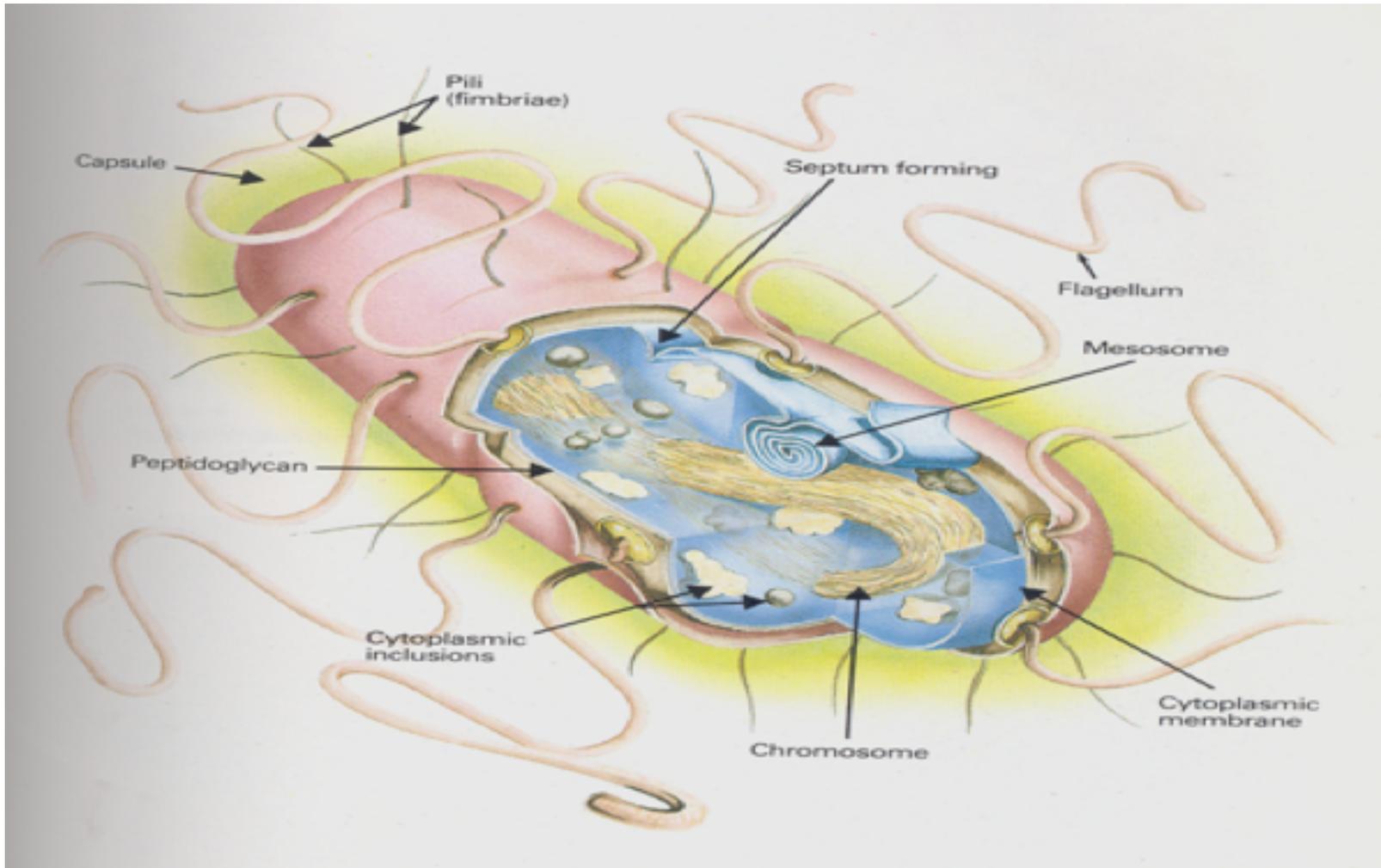


Spirillum



Spirochete

# Structure of Bacteria



# Cell Wall of Bacteria

- Bacteria are cells with rigid cell wall surround cytoplasmic membrane and internal structures.

## Functions of cell wall:

- Rigidity
- Shapes bacteria
- Protection
- Porous / permeable to low molecular weight molecules
- Cell division
- Antigenic determinants

# Cell Wall of Bacteria

- Two groups of bacteria depending on reaction to **GRAM stain** :

Gram positive: stain **blue/purple** .

Gram negative: stain **red** .

**Note** : *Mycoplasma* naturally have no cell wall.

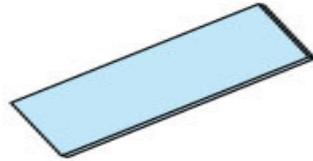
## Chemical structure of bacterial cell wall:

### **Peptidoglycan** :

Rigid part , mucopeptide composed of alternating strands of *N- acetyl muramic acid* and *N- acetyl glucosamine* linked with peptide sub units.

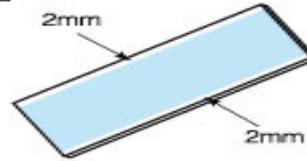
# GRAM STAINING

1



Wipe bottom of biofilm slide clean

2



Clean top edges of slide about 2mm

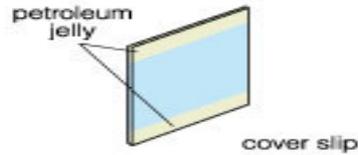
Flow Through Procedure

3



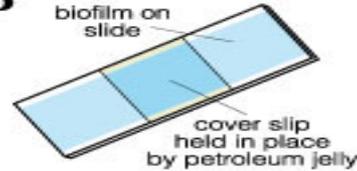
Build up a ridge of petroleum jelly on the top and bottom of a cover slip

4



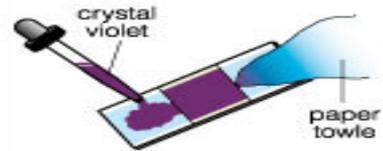
Cover slip with petroleum jelly

5



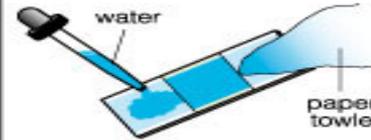
Biofilm on slide with cover slip

6



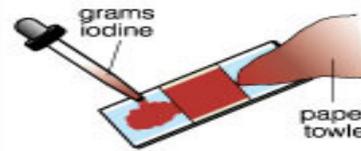
Add crystal violet-wait 30 sec.

7



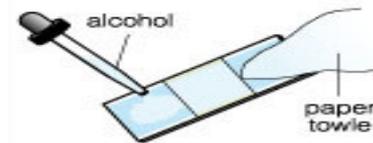
Wash with water

8



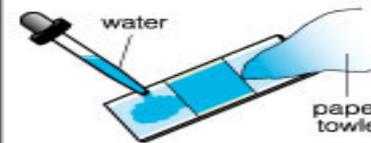
Add Grams iodine -wait 1.5 min.

9



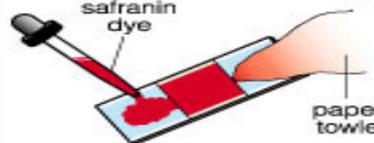
Decolorize with alcohol

10



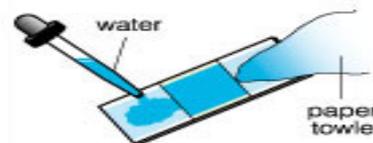
Wash with water

11



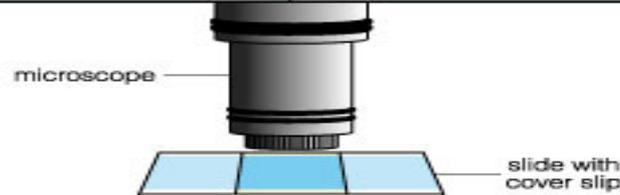
Stain with Safranin dye-wait 30 sec.

12



Wash with water

13



Examine under oil immersion through the cover slip

GRAM +



Fixation

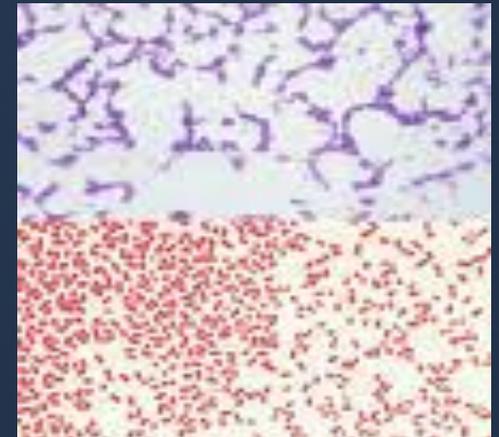
Crystal Violet

Iodine Treatment

Decolorization

Counter stain (safranin)

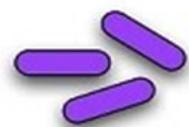
GRAM -



GRAM-POSITIVE



GRAM-NEGATIVE



Fixation



Crystal Violet



Iodine Treatment



Decolorisation



Counter stain with  
Safranin

# Cell Wall of Gram Positive Bacteria

- Peptidoglycan is **thick**
- Closely associated with cytoplasmic membrane.
- Contain :

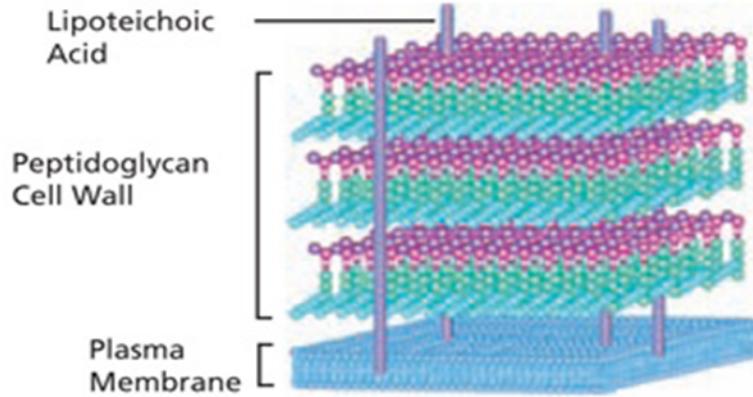
**Teichoic acid** : anchors cell wall to cell membrane , epithelial cell adhesion.

**Antigens** : ~ polysaccharides (Lancefield)  
~ protein (Griffith)

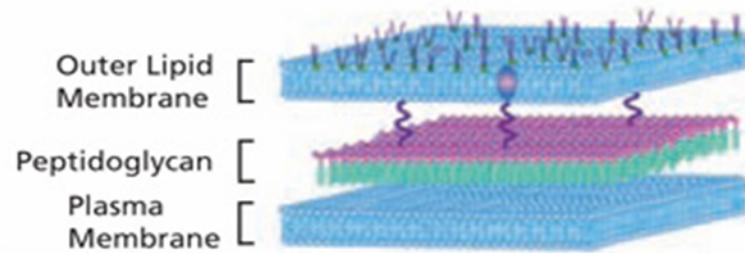
# Cell Wall of Gram Negative Bacteria

- **Thin** Peptidoglycan
- Has an outer membrane that contains :
  - specific proteins (porins) important in the transport of hydrophilic molecules
  - lipopolysaccharide (**Endotoxin**)

## Gram-Positive Bacterial Cell Wall

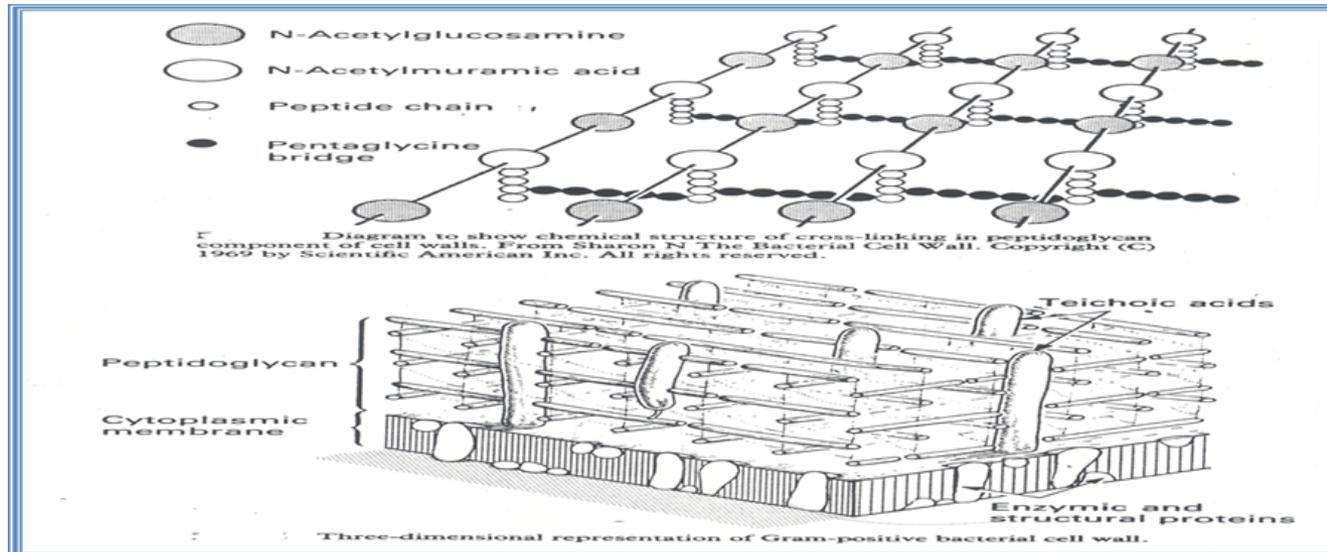
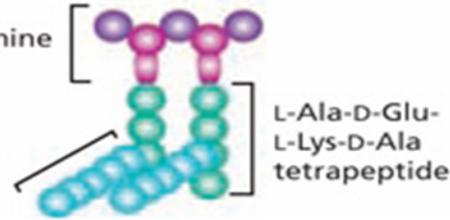


## Gram-Negative Bacterial Cell Wall



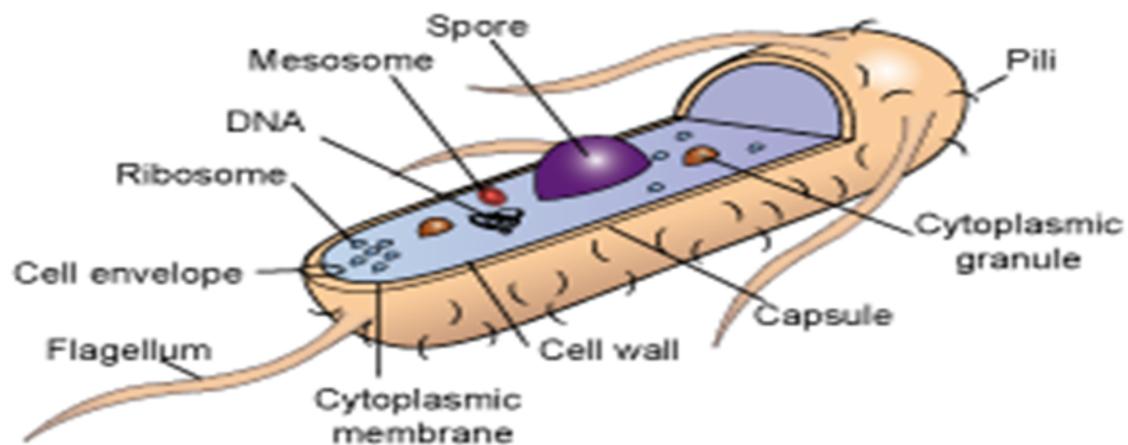
Alternating copolymer of  $\beta(1 \rightarrow 4)$ -N-acetyl-D-glucosamine and N-acetylmuramic acid

Pentaglycine cross-link

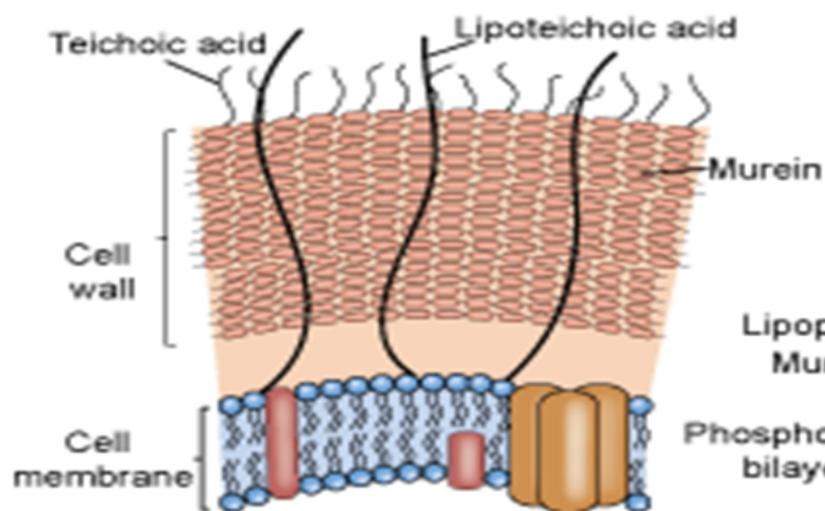


a

## Bacterial Cell Structure

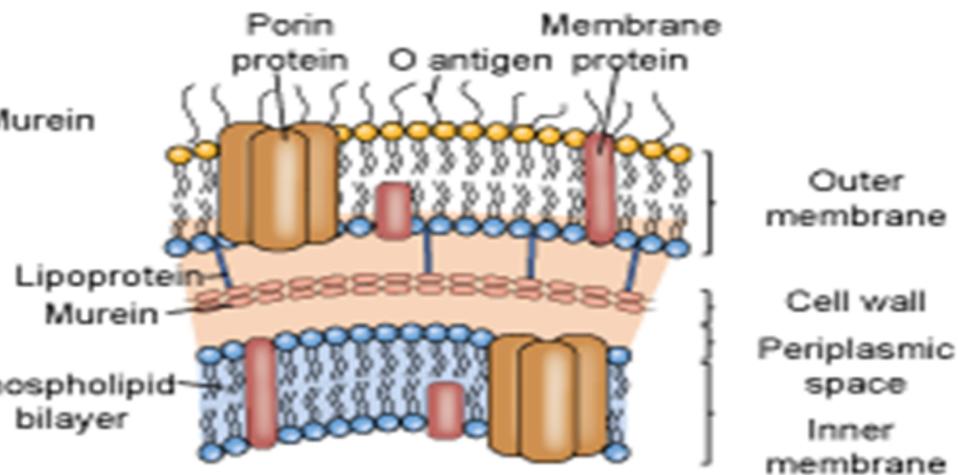


b



Gram+

c



Gram-

# External Structures of Bacteria

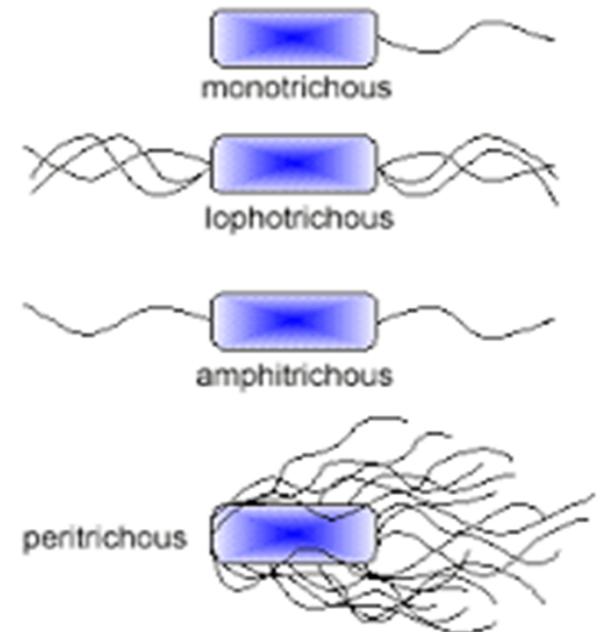
External protrude from the cell into the environment:

- **Flagella**
- **Pili**
- **Capsule**

# Flagella



- Helical filaments
- Composed of protein **FLAGELLIN**.
- Found in Gram positive & Gram negative bacteria.
- **Function** : motility& chemotaxis
- **Distribution:**
  - ~ Peritrichous
  - ~ Monotrichous
  - ~ Lophotrichous
  - ~ Amphitrichous



# Pili

Fine short filaments extruding from cytoplasmic membrane.

Found on the surface of many Gram negative & Gram positive bacteria.

Composed of protein **Pilin**.

Two types:

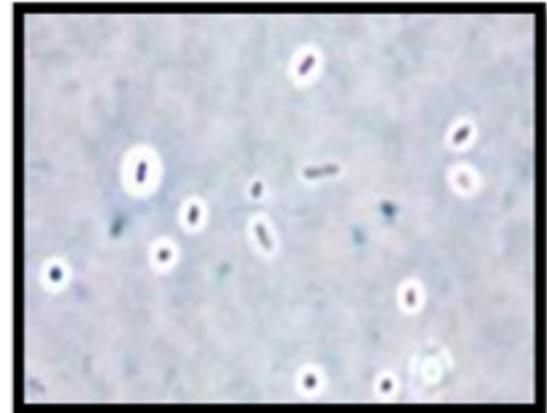
- 1~ **Common pili** (*fimbriae*): covers the surface—  
responsible for: adhesion & colonization
- 2~ **Sex pili** : in some bacteria only, responsible for  
conjugation.

# Capsules and Slime layer

- These are the structures surrounding the outside of cell envelop. Can be seen by India ink or special stains
- Usually consist of **polysaccharide**, however ;in some bacteria consist of polypeptide(**protein**).
- They are not essential for cell viability, some strains within species produce capsule while others do not .

## **Functions, include :**

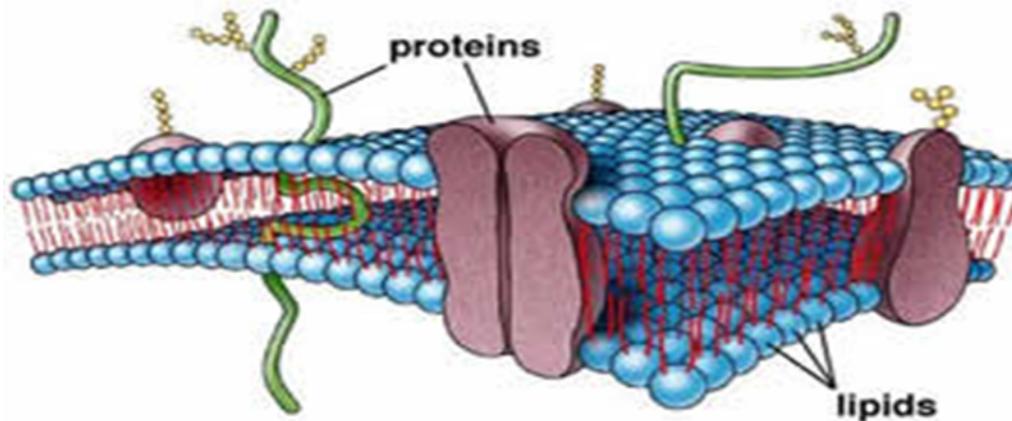
- Attachment
- Protection from phagocytic engulfment
- Resistant to dryness
- Reservoir for certain nutrient



# Cytoplasmic Membrane (plasma membrane)

- Double layered structure composed of phospholipid & protein
- Act as semi- permeable membrane (passive diffusion)
- Site of numerous enzymes involved in active transport of nutrients and various metabolic processes

**Small Portion of a Plasma Membrane**



# Internal structures of bacteria

**Mesosomes** :convolutes invaginations of cytoplasmic membrane .

## **Function:**

1. Involved in DNA segregation during cell division and respiratory activity
2. Contain receptors involved in chemotaxis
3. Permeability barrier (active transport of solutes).

# Core of Bacteria

Core composed of : Cytoplasmic inclusions  
Nucleoid ( nuclear body)  
Ribosomes

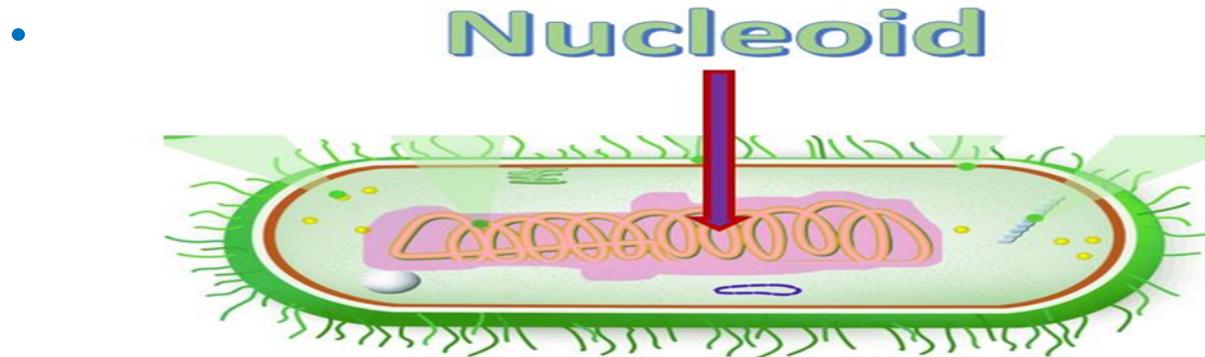
## Cytoplasmic inclusions:

Are nutritional storage granules , examples:

- ~ Volutin
- ~ Lipid
- ~ Starch / or Glycogen

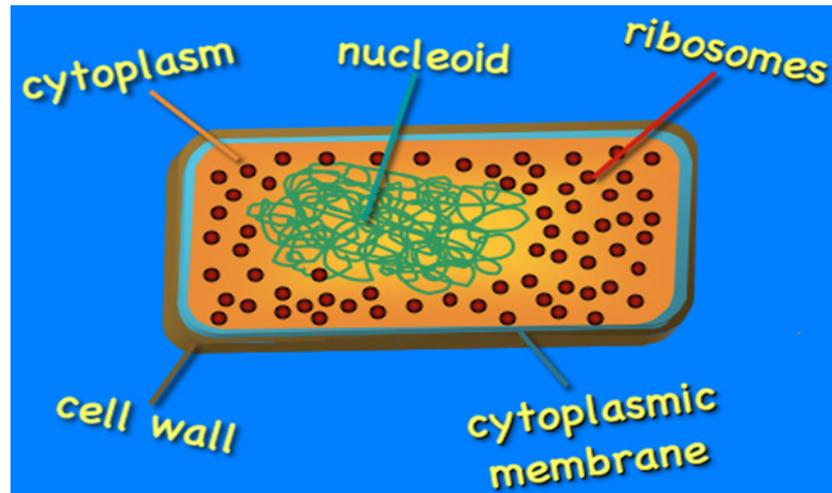
# Nucleoid ( Nuclear Body)

- Circular single stranded chromosome (bacteria genome or DNA)
- No nuclear membrane
- DNA undergoes semi-conservative replication , bidirectional from a fixed point



# Ribosomes of Bacteria

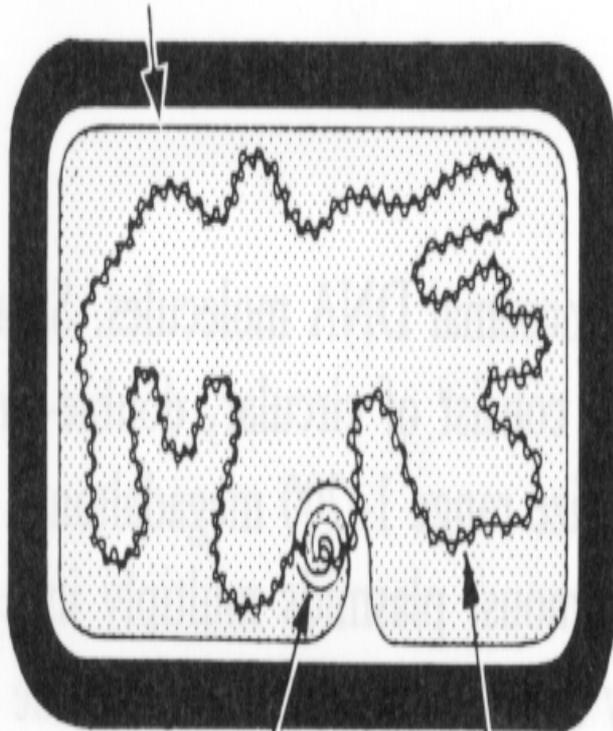
- Distributed throughout the cytoplasm
- Site of protein synthesis
- Composed of RNA and protein



# Bacterial Chromosomes

- Haploid, circular molecule of double stranded~ DNA attached to cell membrane.
- Genetic code in Purine and Pyrimidine bases of nucleotides that makes DNA strand.
- 3 bases comprise one code, each triplet codon codes for one amino acid.
- Replication is semiconservative ,takes place by **binary fission** .

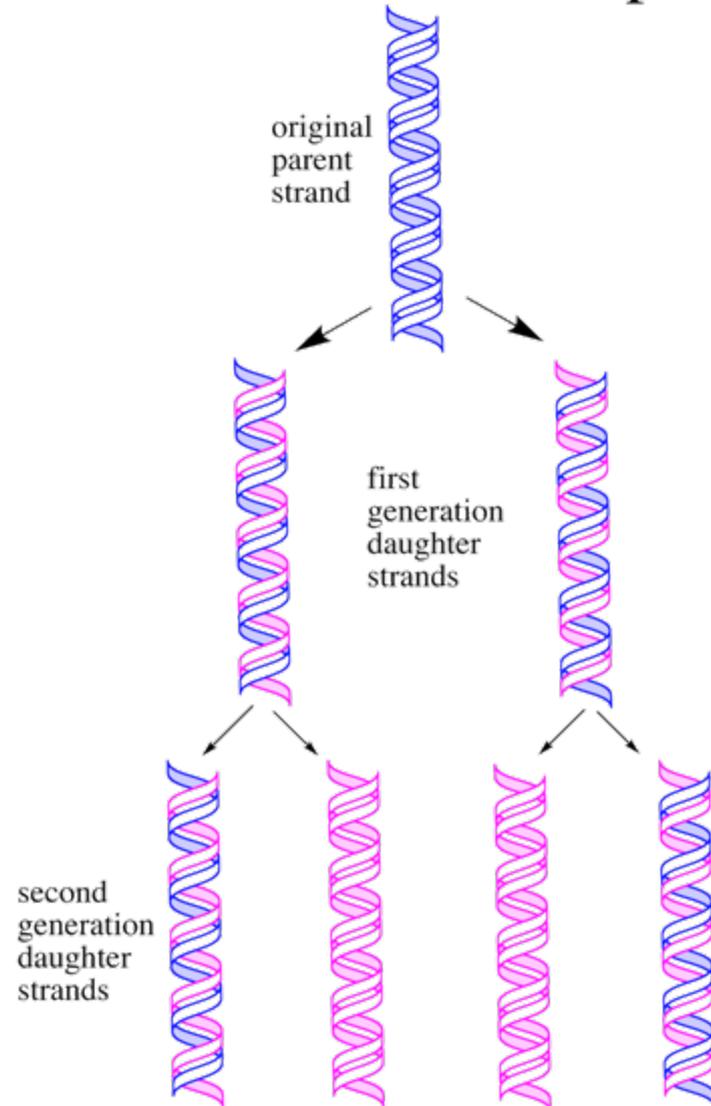
Cytoplasmic membrane



Mesosome

Chromosome of circular double-stranded DNA

## Semiconservative Replication



original parent strand

first generation daughter strands

second generation daughter strands

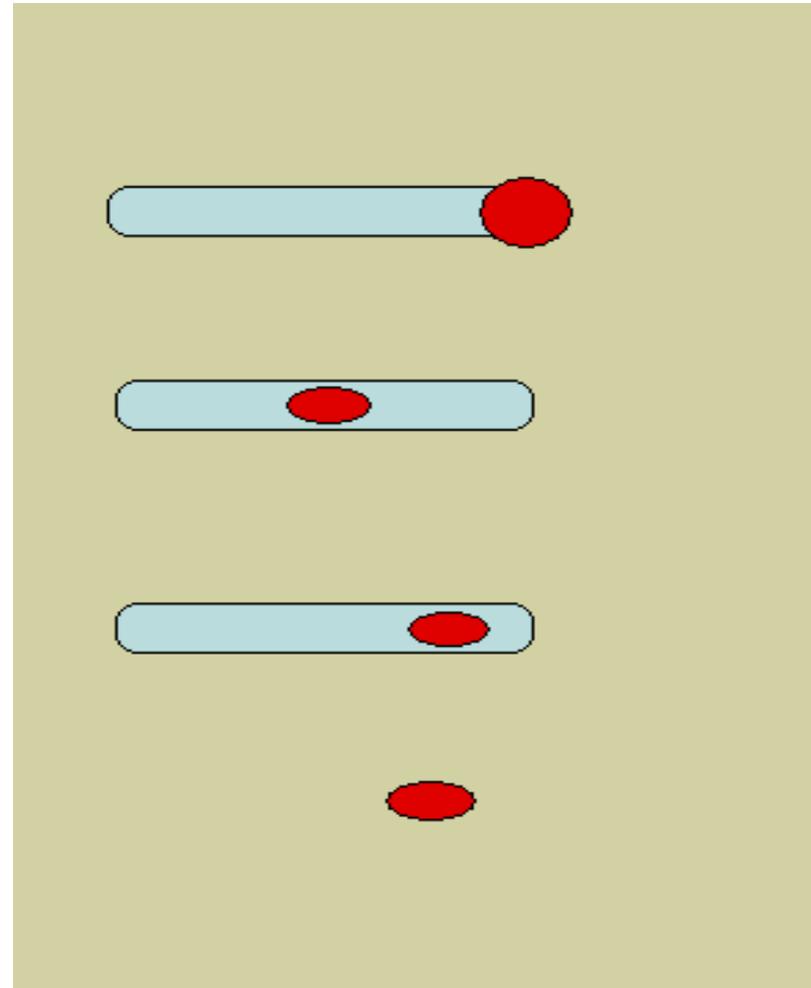
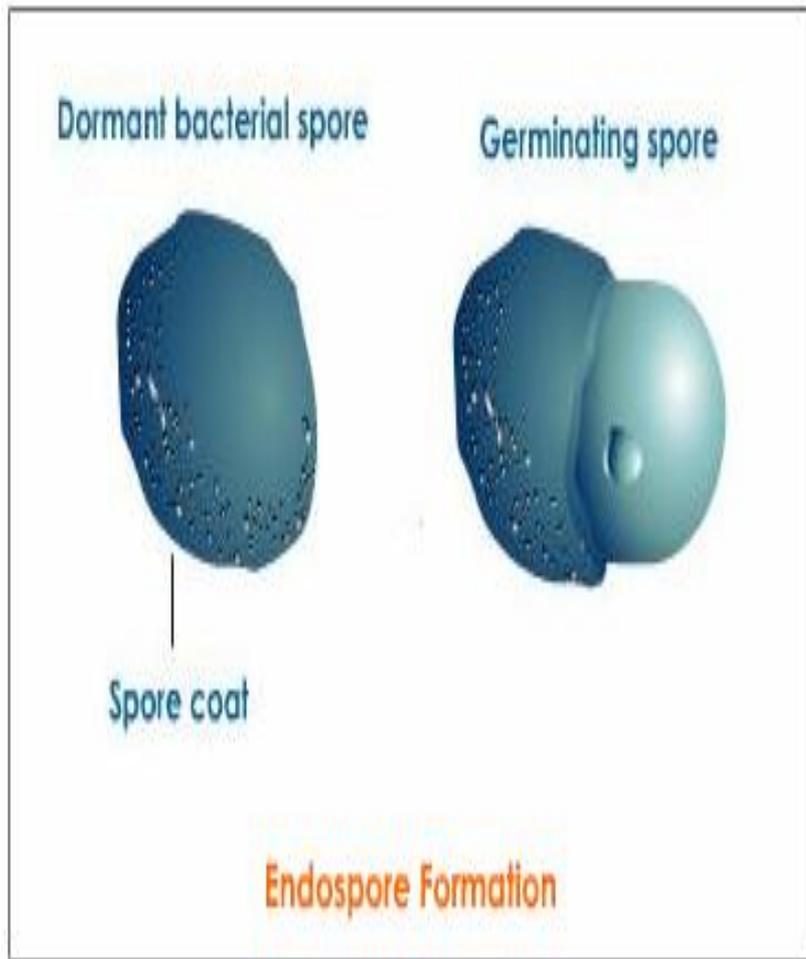
# Spores of Bacteria

- Small , dense, metabolically inactive , non-reproductive structures produced by *Bacillus* & *Clostridium*
- Enables the bacteria to survive adverse environmental conditions.
- Contain high concentration of Calcium dipicolonate.
- Resistant to heat, dissection & disinfectants
- Often remain associated with the cell wall

# Spores of Bacteria-cont.

- Spores are described as :
  - 1~ **Terminal** spores
  - 2~ **Sub-terminal** spores
  - 3~ **Central** spores
- Spores germinate when growth conditions become favorable to produce vegetative cells.
- Application in medical practice :spore preparations used for checking the efficacy of **Autoclaves**, eg. *Bacillus subtilis & Bacillus sterothermophilus.*

# Spores of Bacteria





# **BACTERIAL GENETICS**

# Bacterial Genetics: definitions

- **Genetics** is the study of inheritance and variation.
- Genetic information encoded in DNA.

## Function of genetic material:

1~ Replication of the genome

2~ Expression of DNA to mRNA then to protein.

# Definitions-cont.

- **Genotype:** the complete set of genetic determinants of an organism.
- **Phenotype:** expression of specific genetic material .
- **Wild type:** reference (parent) strain
  - **Mutant:** progeny with mutation.

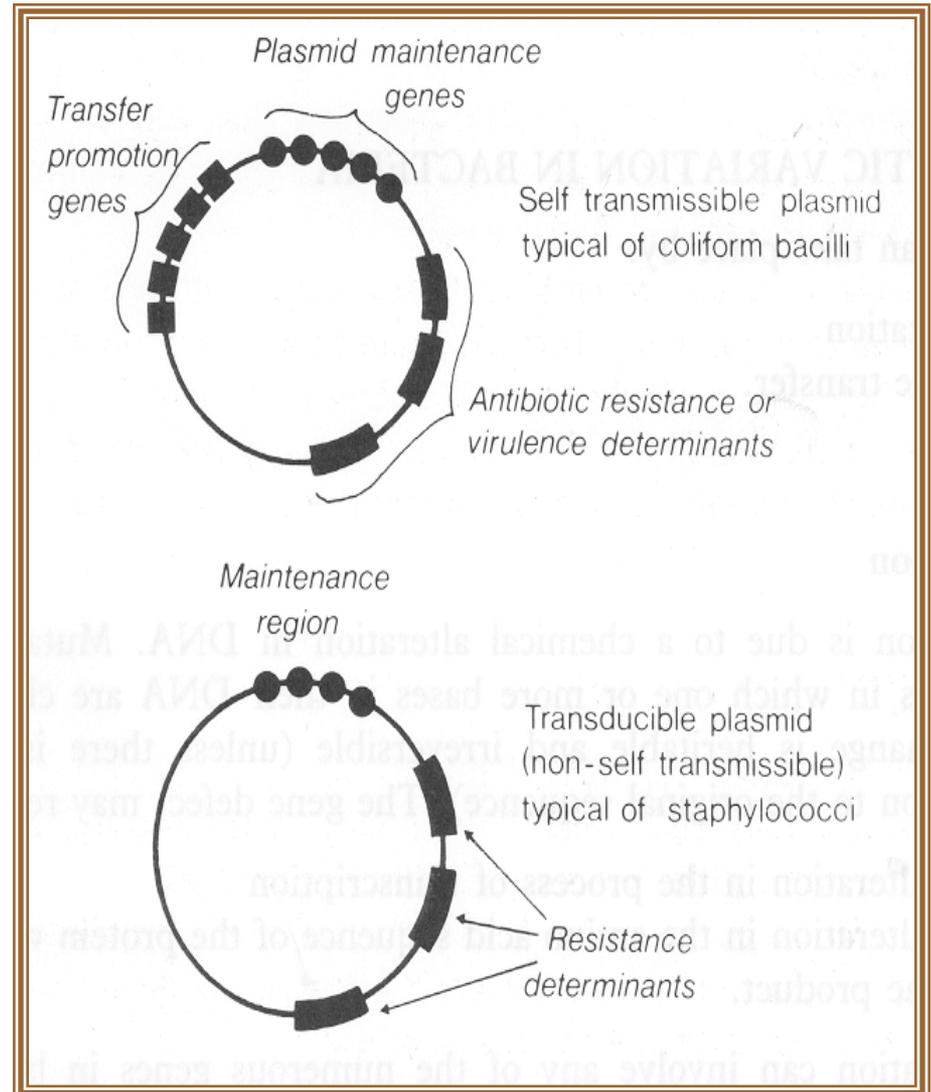
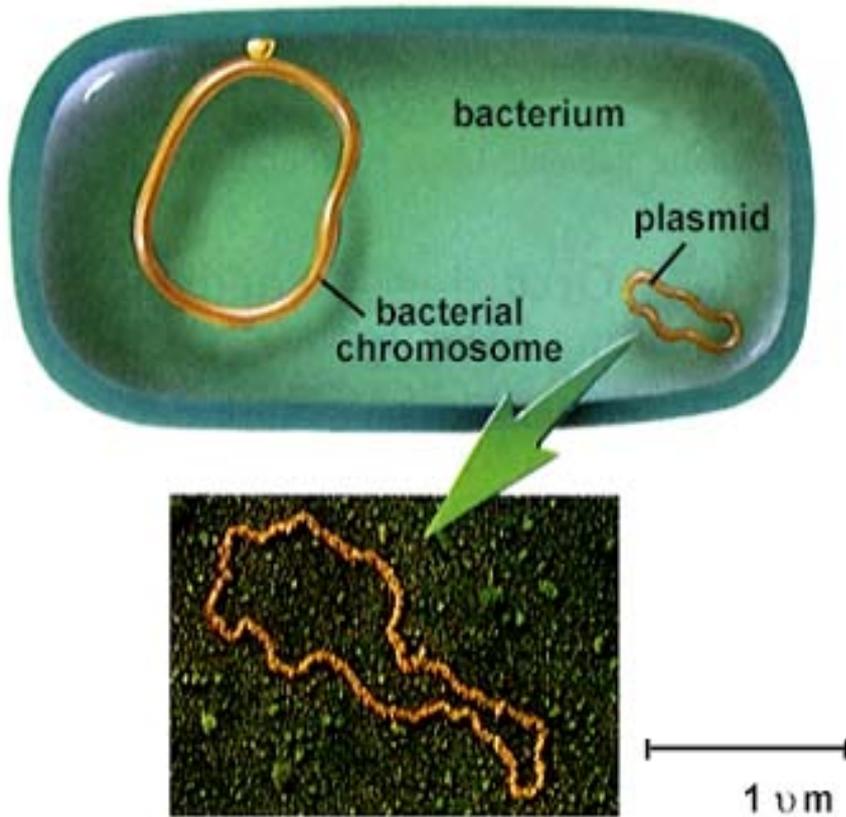
## Two types of DNA in bacteria

- Chromosomal
- Extra-chromosomal (**Plasmid**).

# Plasmids

- Extra chromosomal DNA composed of double stranded-DNA.
- Found in most species of bacteria.
- Origin?
- Govern their own replication
- **Application** :in genetic exchange, amplify genes
- Transfer to other bacteria by **conjugation**

# Plasmids



# Types of Plasmids

- 1- **R-plasmids**: genes code for antibiotic resistance particularly Gram negative bacteria.
- 2- **Col-plasmids**: in Enterobacteria, codes for extracellular toxins.
- 3- **F-plasmids**: (fertility) factor, transfer of chromosome during mating .

# Genetic variation in bacteria

**Takes place by:**

**1~ Mutations**

**2~Gene transfer**

# Mutation

- Inheritable changes in the structure of genes (DNA).
- Chemical changes in one or more bases of DNA.

## Mutation /gene defect leads to alteration in:

- Transcription,
- Amino acid sequences,
- Function eg. **Bacteria become resistant to antibiotic.**

# Classification of Mutation

Depends on biological sequencing:

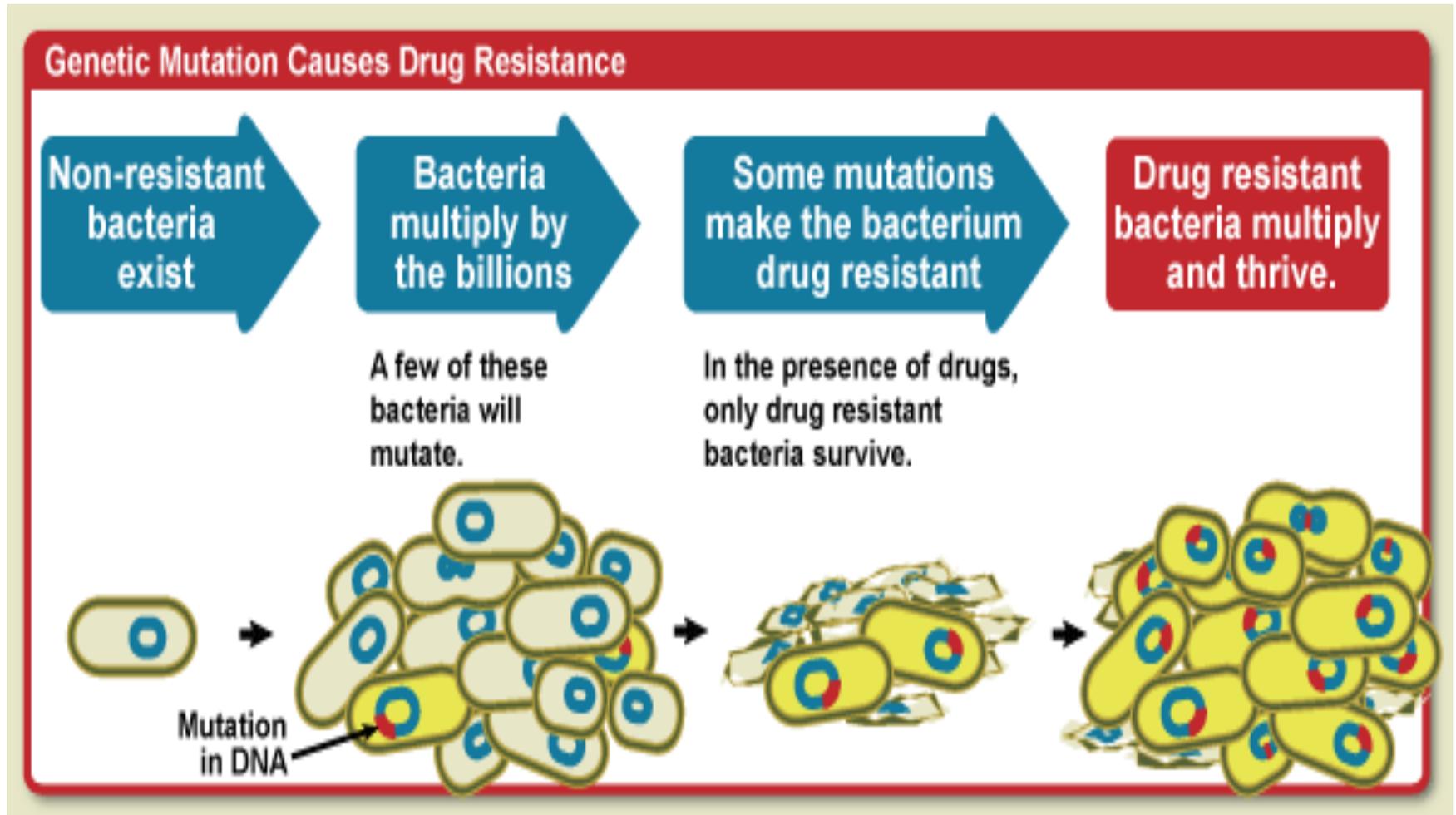
1- **Resistance mutation**: affects structure of cell protein. Main application in medical practice.

Bacteria become resistant to antibiotics.

2- **Auxotrophic mutation**: affects biosynthetic enzyme resulting in a nutritional requirement of mutant cell.

3- **Lethal mutation**: leads to death of bacteria.

# Mutation Causes Antimicrobial Resistance

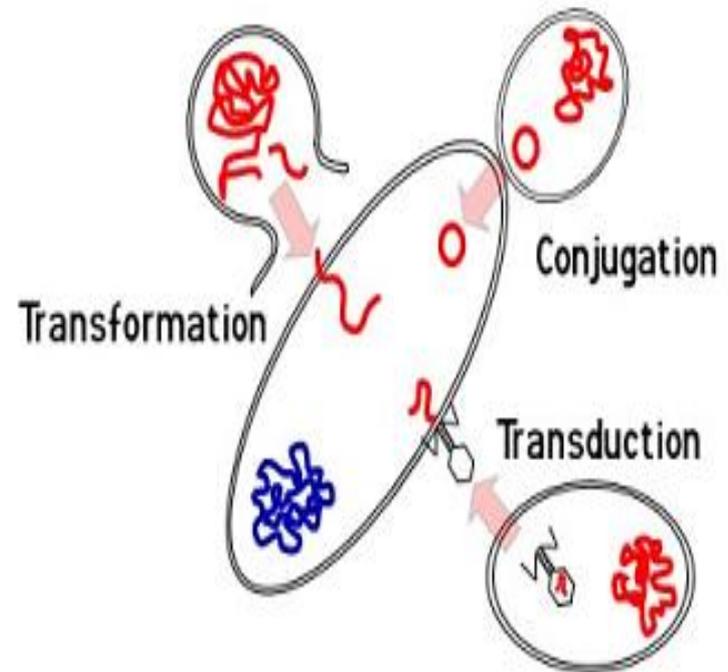


# Gene Transfer Among Bacteria

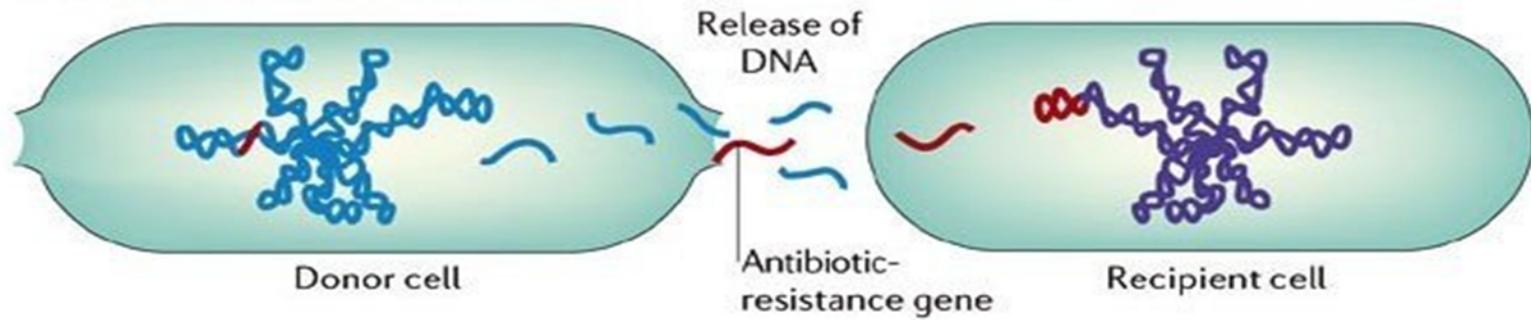
## Three mechanisms:

- 1~ Transformation
- 2~ Transduction
- 3~ Conjugation.

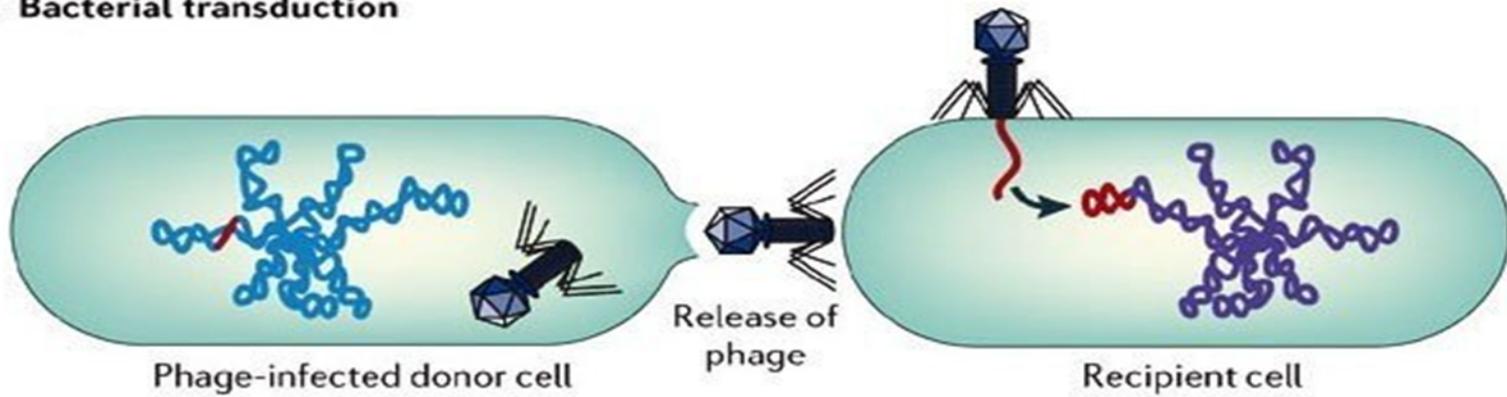
## Mechanisms of Gene Exchange



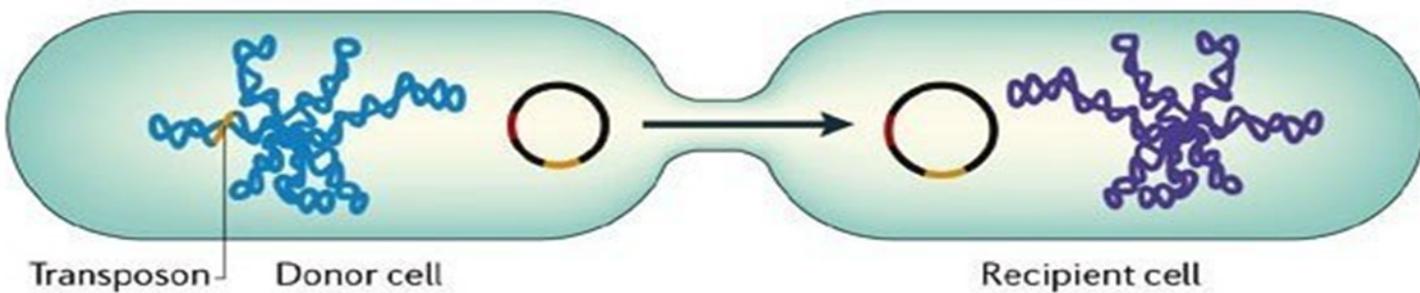
**a Bacterial transformation**



**b Bacterial transduction**



**c Bacterial conjugation**



# Transformation

- A fragment of exogenous naked bacterial DNA are taken up and absorbed into recipient cells.
- Common in *Haemophilus influenzae* & *Streptococcus pneumoniae*.
- Bacteria become resistant to Ampicillin.

# Transduction

- **Phage** mediated transfer of genetic information from donor to recipient cells.

## Examples:

- **Beta – Lactamase production in *Staphylococcus aureus*** : Bacteria becomes resistant to penicillin.
- **Toxin production by *Corynebacterium diphtheriae*.**

# Conjugation

- Major way bacteria acquire additional genes.
- **Plasmid mediated**( F factor)
- Cell contact required and genes reside on plasmid resident within donor cells transfer to recipient cell (**mating**).
- **Conjugation is the common way of transfer of genes resistance to antibiotics among bacteria in hospitals.**

# Genetic Recombination

After gene transfer, there are three possible fates:

1~Exogenous DNA degraded by nuclease.

2~Stabilized by circulization and become plasmid.

3~ Form a partially hybrid chromosome with segment derived from each source.

# Reference Book

*Sherris Medical Microbiology, an Introduction to Infectious Diseases.*

Latest edition, Kenneth Ryan and George Ray.  
Publisher : McGraw Hill .