General Microbiology

Lecture 3

(Bacterial Structure, Classification, and Growth)

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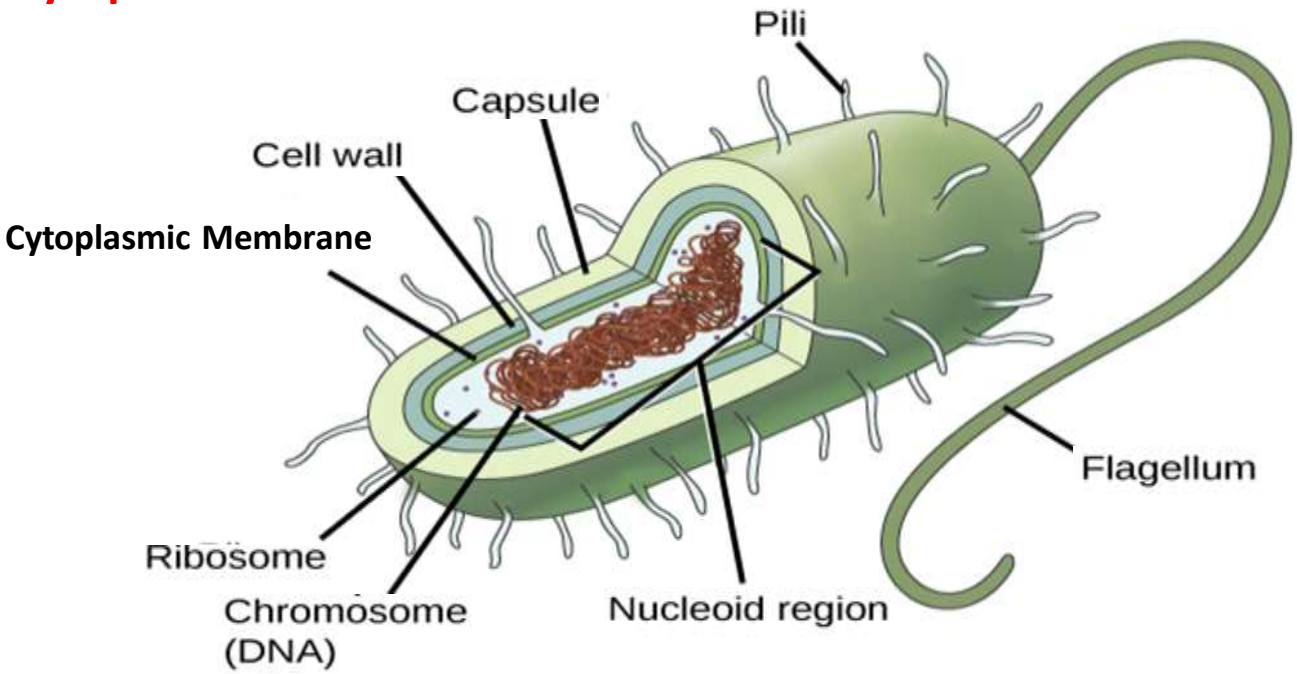
The Ultrastructure of bacterial cell

Structures external to the cytoplasmic membrane:

- Cell wall
- Capsule
- Flagella
- Pili (Fimbriae)

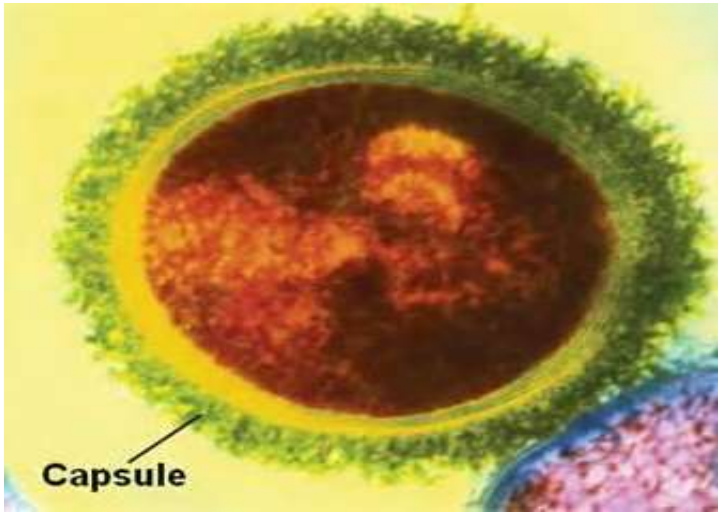


Structures internal to the cell wall:

- Cytoplasmic Membrane
- Mesosomes
- Ribosomes
- Cytoplasm
- Inclusion Bodies
- Chromosome (DNA)
- Plasmid
- Episome

Capsules

- Capsule consists of a network of fine strands.
- Capsules are divided into two groups:



Chemical composition:

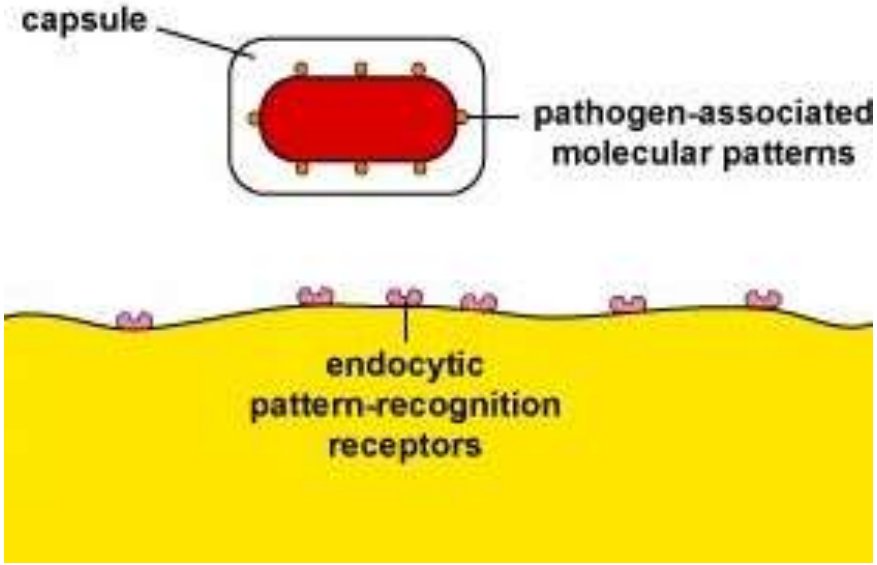
- They are made up of di- or polysaccharides or polypeptides.
- The polysaccharide may be homo-polysaccharide or heteropolysaccharide.

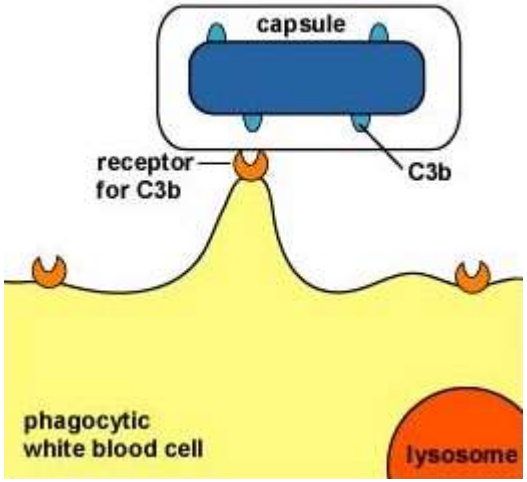
Functions

a. They provide protection against temporary drying by binding water molecules..

b. They are antiphagocytic until specific antibodies are produced

The antiphagocytic effect of capsule



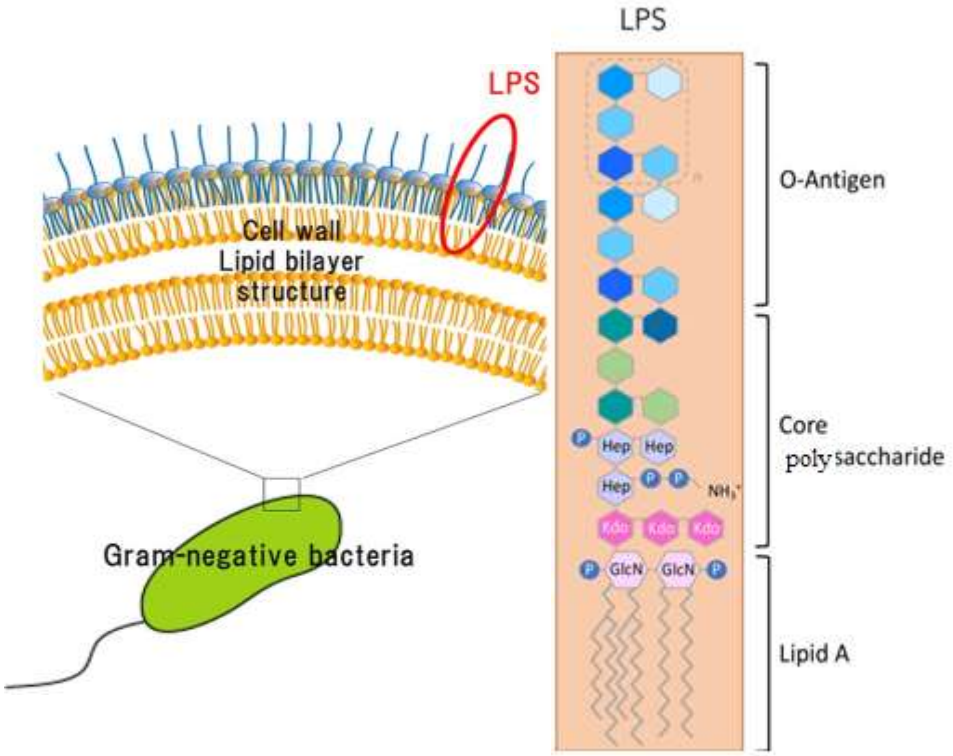


Capsules can resist unenhanced attachment by preventing pathogen-associated molecular patterns or PAMPs - components of common molecules such as peptidoglycan, teichoic acids, lipopolysaccharide, mannans, and glucans common in microbial cell walls from binding to endocytic pattern-recognition receptors on the surface of the phagocytes

Lipopolysaccharides (LPS)

Structures external to the cell wall of the Gram-negative bacteria

- Lipopolysaccharides (LPS) occur only in the outer layer of the membrane and are composed of three covalently linked parts :
  - i. Lipid A = firmly embedded in the membrane.
  - ii. Core polysaccharide = located at the membrane surface.
  - iii. O-antigens = which extend like whiskers from the membrane surface into the surrounding medium
- Many antigenic properties of gram -ve bacteria are attributable to O-antigens



The Cell Wall

Gram negative bacteria

Lipopolysaccharides (LPS)

Functions:

<u>O antigen:</u>

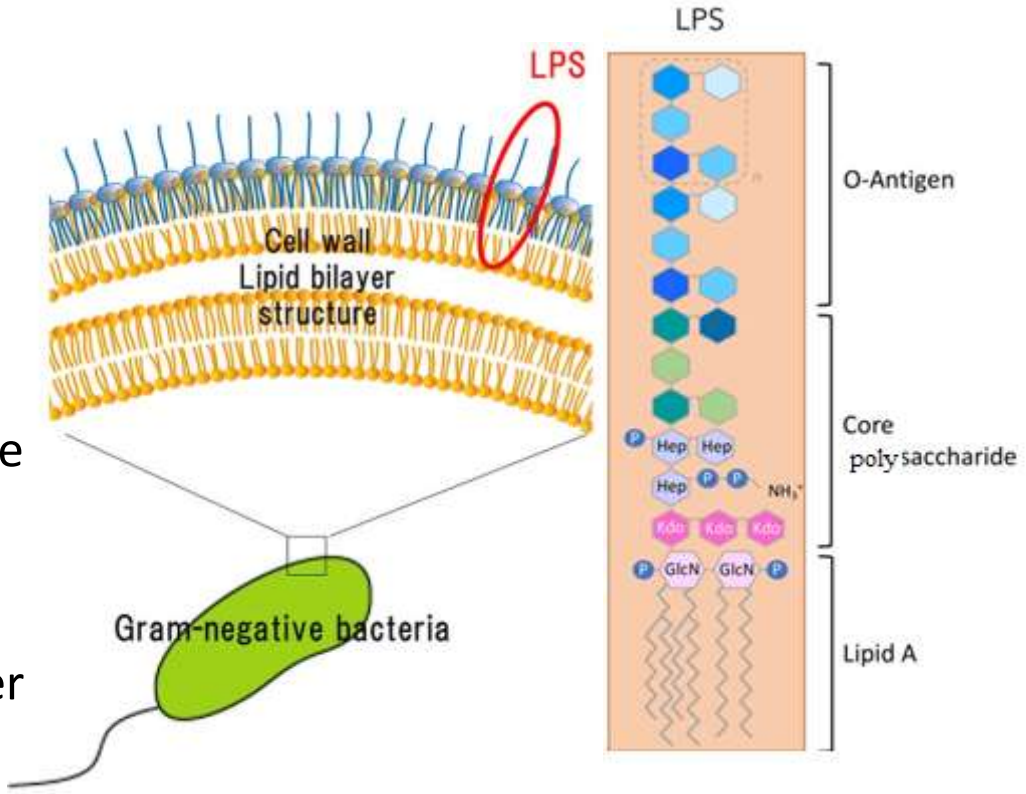
- Protection from host defenses

<u>Core polysaccharide</u>

- Contributes to the negative charge on the cell surface.

<u>lipid A:</u>

- Helps stabilize the outer membrane structure.
- Act as an endotoxin.



The Cell Wall

Gram negative bacteria

Pathogenic effect of LPS:

LPS has an endotoxin effect:

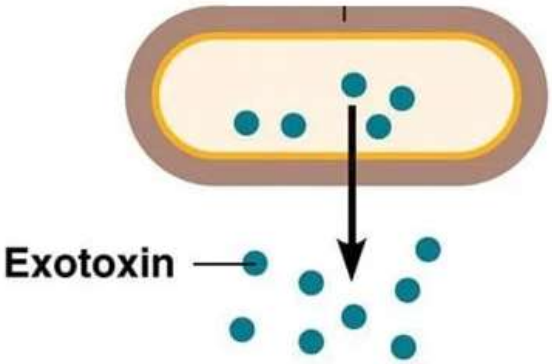
- Lipid A released when cells lyse
- Causes systemic effects – Fever, Shock, Blood coagulation, Weakness, Diarrhea, Inflammation, Intestinal hemorrhage, Fibrinolysis
- Activating white cells, especially macophages and monocytes

To remember the difference in the cell wall of Gram positive and negative bacteria

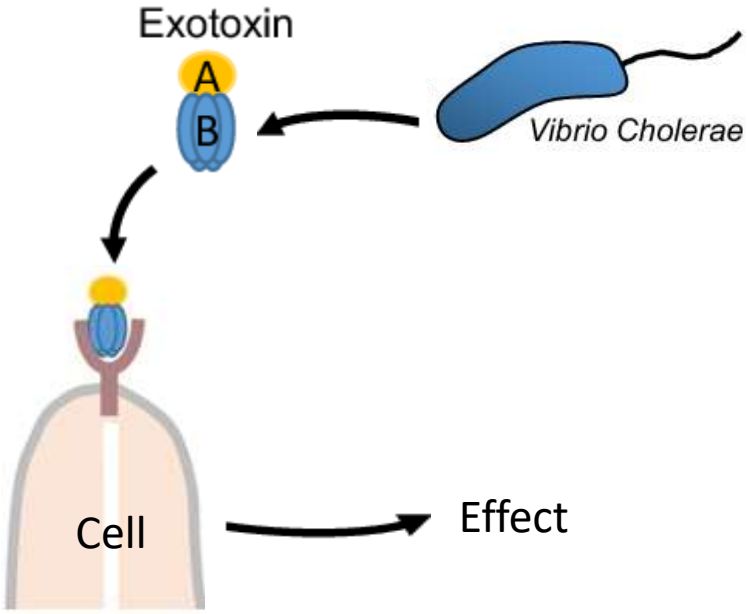
Lipopolysaccharide
Outer membrane
Negative
Gram?

Positive
Peptidoglycan (thick)
Teichoic acid

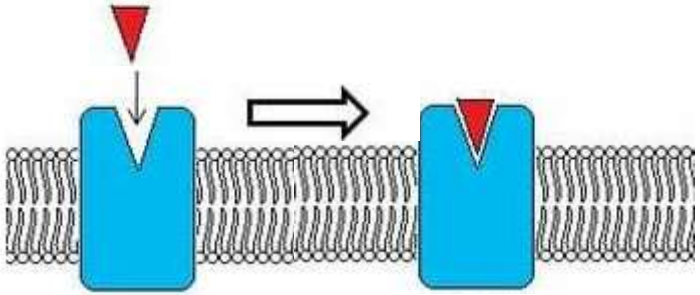
EXOTOXINS VS ENDOTOXINS



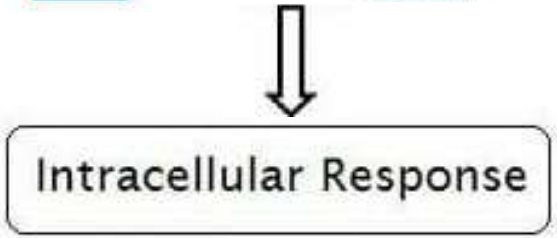
Example: Cholera exotoxin



LPS (Endotoxin)(after cell lysis)3



Immune cells



Cytokines and inflammatory mediators

Inflammation

Endotoxins vs. Exotoxins

Character	Endotoxins	Exotoxins
Definition	are the lipopolysaccharide-protein complexes, produced at the time of cell death.	are polypeptide proteins excreted by few species of bacteria
Location	It is a part of the cells and located on chromosomal genes	It is released from the cells and located on extrachromosomal genes (e.g. plasmids).
Toxicity	Endotoxin is moderately toxic	Exotoxin is highly toxic
Source	It is produced after the disintegration of the gram-negative bacteria	It is produced in the living gram-positive bacteria and gram-negative bacteria
Boiling	It does not get denatured on boiling	It gets denatured on boiling
Diseases	Meningococcemia, sepsis by gram-negative rods, etc.	Botulism, Diphtheria, Tetanus
Effects	general symptoms are fever, diarrhea, vomiting etc	cytotoxin, enterotoxin or neurotoxin with defined action on cells or tissues.
Neutralization	cannot be neutralized by antibodies	can be neutralized by antibodies
Vaccines	No effective vaccines are available	effective vaccines are available
Examples	Toxins produced by E.coli, Shigella, Vibrio cholera, Salmonella Typhi	Toxins produced by Staphylococcus aureus, Streptococcus pyogenes, Bacillus anthracis, Bacillus cereus.

Structure Internal to Cell Wall

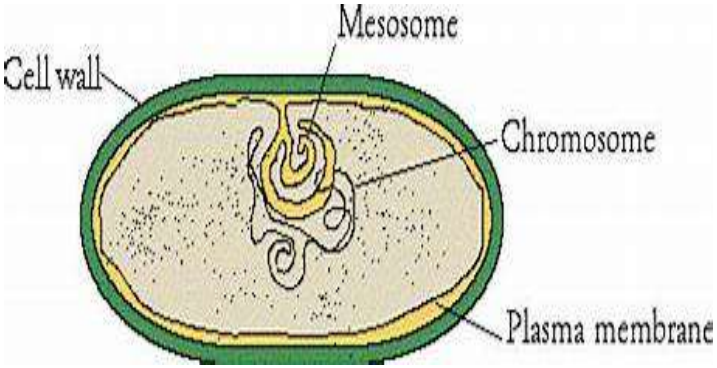
Structure Internal to Cell Wall

Cytoplasmic Membrane:

- Immediate below the cell wall is cytoplasmic membrane.
- Similar in both gram + ve and -ve bacteria.

Mesosomes:

- The mesosome was thought to increase the cell's surface area, aiding the cell in cellular respiration. This is analogous to cristae in the mitochondrion in eukaryotic cells, which are finger-like protrusions and help eukaryotic cells undergo cellular respiration. A site for oxidative phosphorylation



Structure Internal to Cell Wall

Inclusion Bodies:

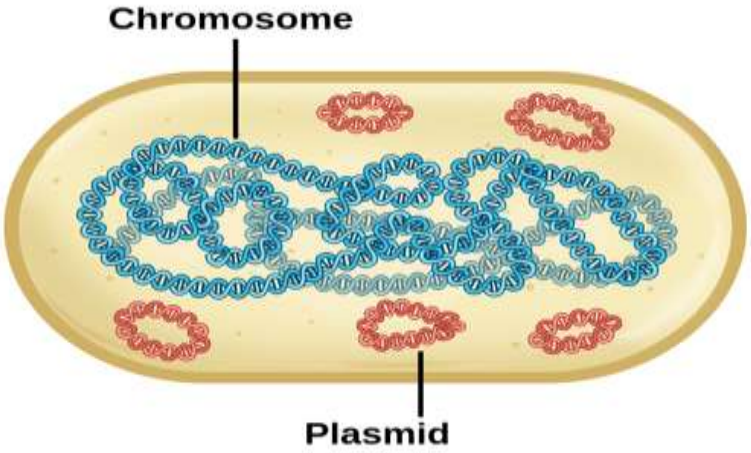
- Granules of organic or inorganic material that are stocked by the cell for future use.

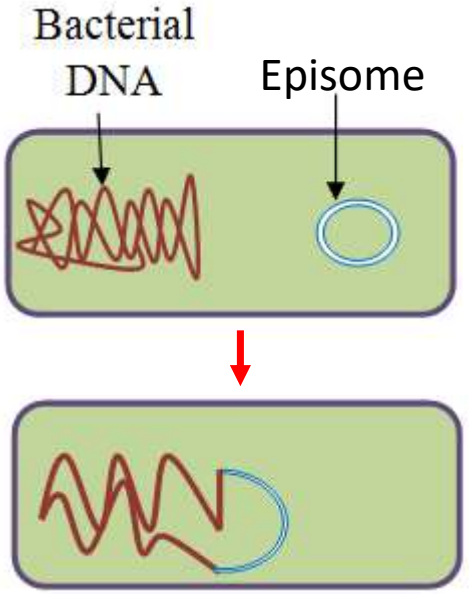
Inclusion	Composition	Function
Glycogen	poly-glucose	Reserve carbon and energy source
Poly-betahydroxybutyric acid (PHB)	lipid	Reserve carbon and energy source
Poly-phosphates	polymers of PO_4	Reserve phosphate, possibly high-energy PO_4
Sulfur globules	elemental S	Reserve energy and or electrons
Magnetosomes	magnetite (iron oxide)	Provide orientation in magnetic field
Gas vesicles	protein shells inflated with gases	Provide buoyancy in aquatic environments
Parasporal crystals	protein	Produced by endospore-forming Bacilli - toxic to insects

Structure Internal to Cell Wall

Episome vs. Plasmid:

- Plasmid and episome are two types of DNA elements which exist independently of the genome.
- The main difference between plasmid and episome is that plasmid does not integrate into the genome, whereas episome can integrate into the genome.





Nutrition

Microbial nutrition

Types of microbial nutrition

Bacteria are classified in two nutritional types on the basis of their carbon requirement into:

Autotrophic: that uses CO_2, an inorganic gas as its carbon source

- ✓ Photosynthetic bacteria.
- ✓ Chemosynthetic bacteria

Heterotrophic must obtain carbon in an organic form made by other living organisms

- ✓ Saprophytic
- ✓ Symbiotic
- ✓ Parasitic bacteria

Nutrition

Heterotrophic bacteria

Saprophytic bacteria

- They survive on dead and deteriorating organic compound.
- They convert the complex organic compound into soluble compound with the help of enzymes and then absorb them according to their requirement

Nutrition

Heterotrophic bacteria

Symbiotic bacteria

- Bacteria grow and develop in close beneficial partnership or association with other living organism
- A phenomenon is termed as symbiosis.
- For example, bacteria occur in the root
- nodules of certain plants where they fix free atmospheric nitrogen in the soil which is utilized by plants and plants in turn provide them carbohydrate and shelter for proper development .

Nutrition

Heterotrophic bacteria

Parasitic bacteria

- Those bacteria which feed themselves on living tissues (host) are called parasitic bacteria.
- They are transmitted to the host by means of air, water and food.

Reproduction in Bacteria

Reproduction in Bacteria

- Bacteria reproduce very commonly by vegetative (asexual mode of reproduction).
- No sexual reproduction was reporte.
- Reproduction in bacteria includes the following methods

Vegetative reproduction including (asexual reproduction):

i. Binary fission
ii. Budding
iii. Cyst
iv. Gonidia or segmentation
v. Endospore formation

Sexual Reproduction:

- transformation.
- Bacterial transduction.
- Bacterial conjugation.

Reproduction in Bacteria

Binary fission:

- The most common mode of bacterial division.
- The cell divides after developing a transverse septum (cross wall).

- Binary fission occurs in the following steps:
  a. Division of nuclear or genetic material.
  b. Division of cytoplasm and septum formation.

Reproduction in Bacteria

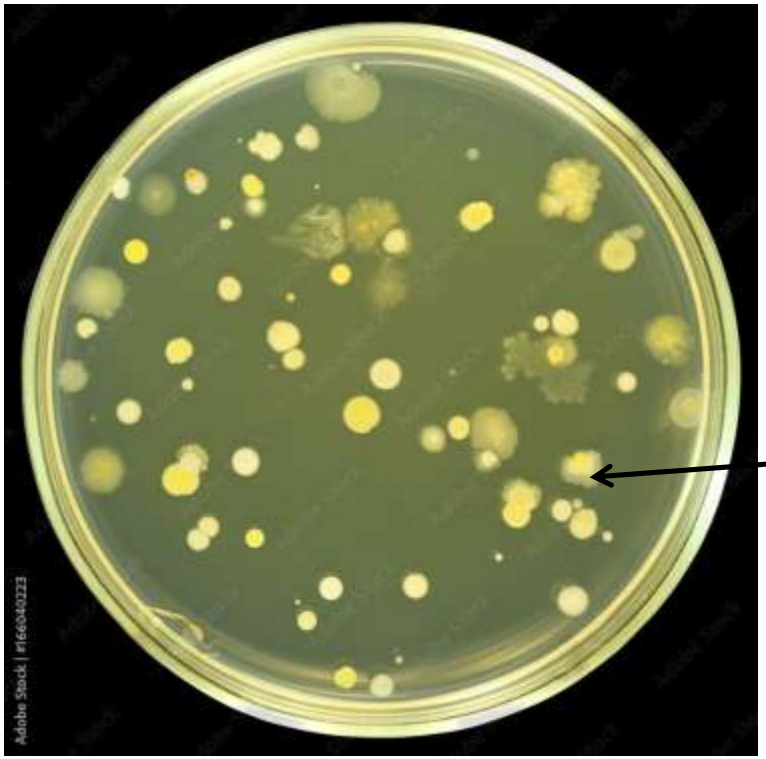
Binary fission:

- Under favourable conditions a single binary fission is completed within 18-20 minutes.
- Bacterial growth is inhibited due to following reasons :
  a. Lack of space, food, water, oxygen other salts and accumulation of their own harmful waste products in the medium.
  b. Environmental factors like light, temperature, moisture becomes unfavourable.
- Therefore survival rate of bacteria in nature is only 1 %.

Microbial Growth

Reproduction of microbes

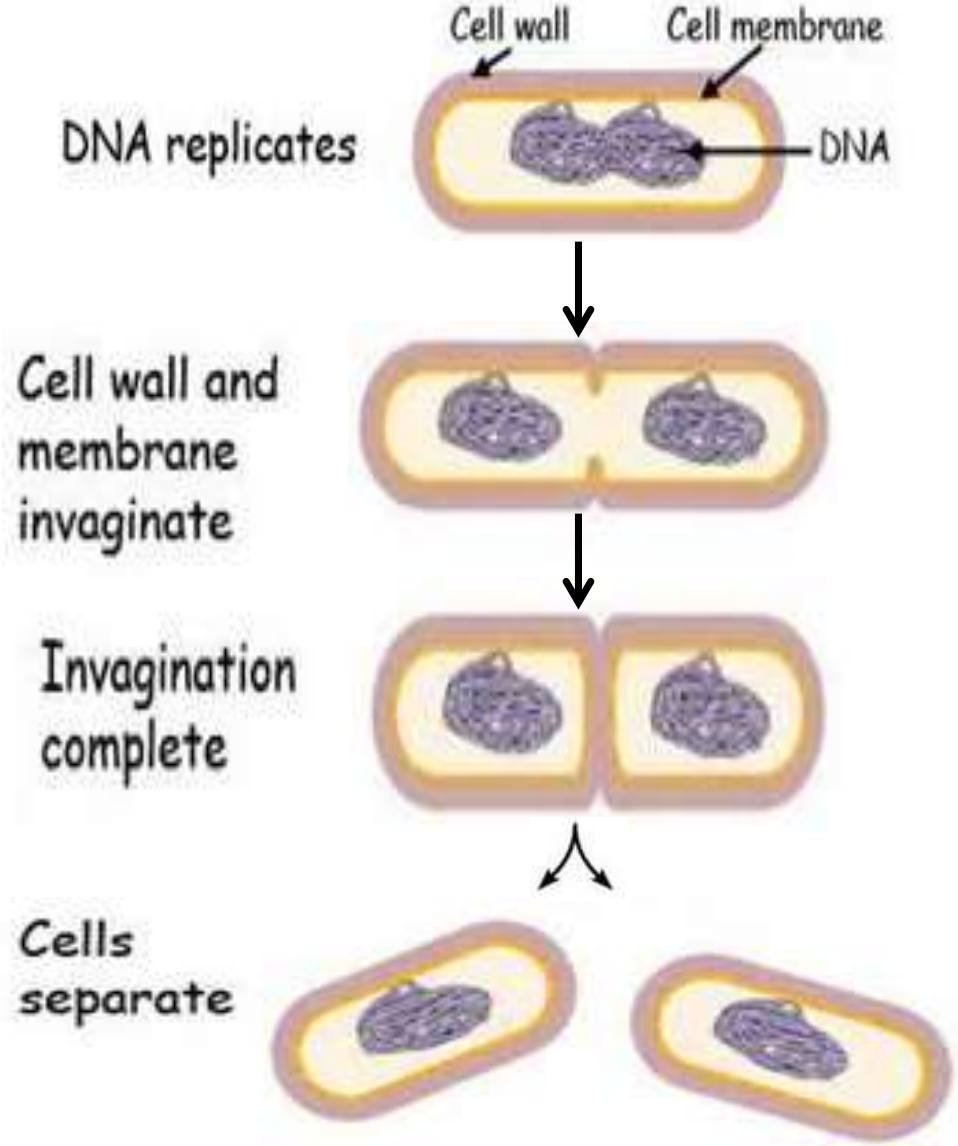
- Result of microbial growth is discrete colony – an aggregation of cells arising from single parent cell



Bacterial colony
(The result of one bacterial cell division)

Microbial Growth

Binary Division



Microbial Growth

Bacteria grow in four stages

1. **lag phase** – "flat" period of adjustment, enlargement; little growth
2. **exponential or log phase** – a period of maximum growth will continue as long as cells have adequate nutrients and a favorable environment
3. **stationary phase** – rate of cell growth equals rate of cell death caused by depleted nutrients and O_2, excretion of organic acids and pollutants
4. **death phase** – as limiting factors intensify, cells die exponentially in their own wastes

Bacterial physiology

Bacteria grow in four stages