Bacteria and Cyanobacteria

(Nostoc and Oscillatoria)

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General Characters

- Bacteria are prokaryotic, unicellular, ubiquitous, microscopic organisms. The study of Bacteria is called Bacteriology. Bacteria were first discovered by a Dutch scientist, Anton van Leeuwenhoek in 1676 and were called “animalcules”.
- They are Prokaryotic organisms and lack nuclear membrane and membrane bound organelles.
- The Genetic material is called **nucleoid** or **incipient nucleus**
- The cell wall is made up of Polysaccharides and proteins
- Most of them lack chlorophyll, hence they are heterotrophic (*Vibrio cholerae*) but some are autotrophic and possess Bacteriochlorophyll (*Chromatium*)
- They reproduce vegetatively by Binary fission and endospore formation.
- They exhibit variations which are due to genetic recombination and is achieved through conjugation, transformation and transduction.
- The shape and flagellation of the bacteria varies .

Structure of Bacterial Cell

The bacterial cell reveals three layers (i) Capsule (ii) Cell wall and (iii) Cytoplasm

Capsule

- Some bacteria are surrounded by a gelatinous substance which is composed of polysaccharides or polypeptide or both called **capsule**. It protects cell from desiccation and antibiotics. The sticky nature helps them to attach to substrates like plant root surfaces and tissues. It helps to retain the nutrients in bacterial cell.

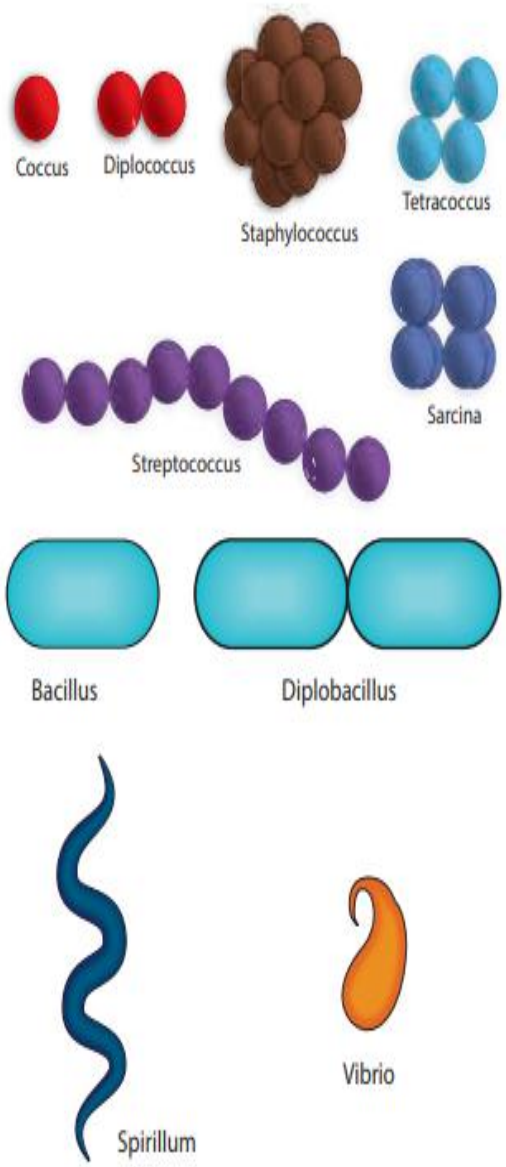
Cell wall

The bacterial cell wall is granular and is rigid. It provide protection and gives shape to the cell. The chemical composition of cell wall is rather complex and is made up of Peptidoglycan or mucopeptide . One of the most abundant polypeptide called porin is present .

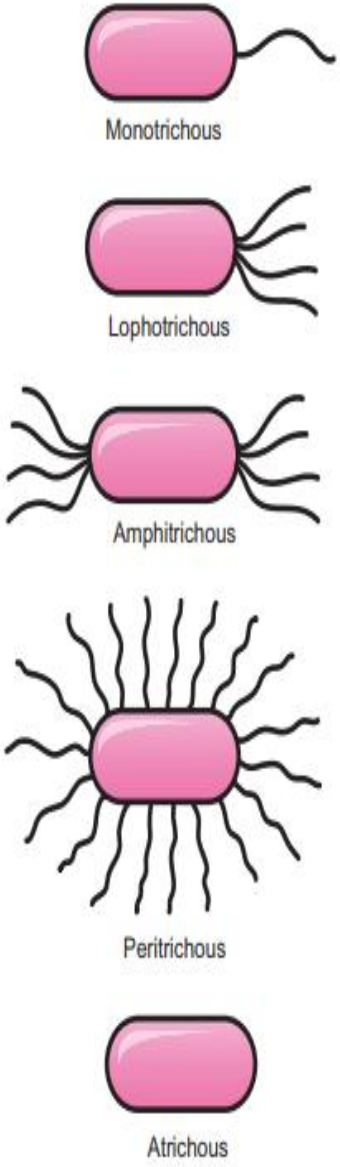
Plasma membrane

- The plasma membrane is made up of lipoprotein. It controls the entry and exit of small molecules and ions. The enzymes involved in the oxidation of metabolites (i.e., the respiratory chain) as well as the photosystems used in photosynthesis are present in the plasma membrane.

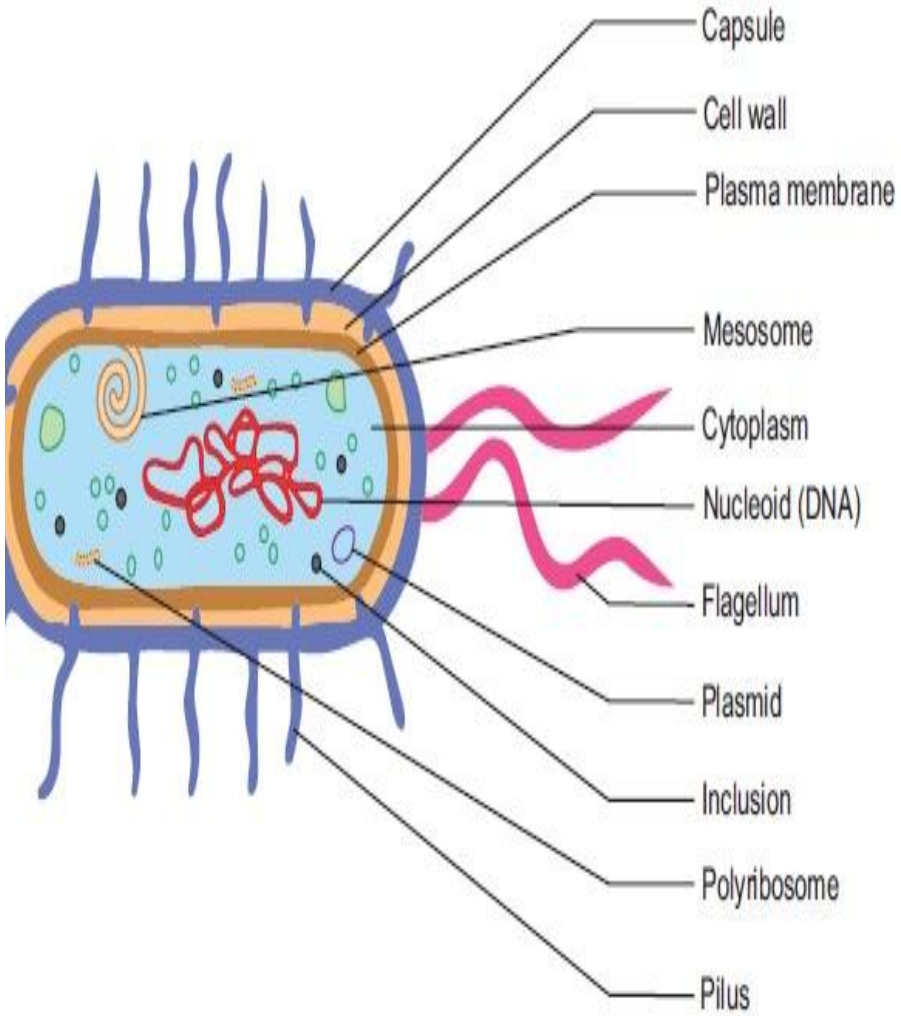
Cytoplasm is thick, semitransparent and contains ribosomes and other cell inclusions. like glycogen, poly-β-hydroxybutyrate granules, sulphur granules and gas vesicles are present.



Shapes of Bacterial cells



Flagellation in bacteria



Structure of bacterial cell

Bacterial chromosome

- The bacterial chromosome is a single circular DNA molecule, tightly coiled and is not enclosed in a membrane as in Eukaryotes. This genetic material is called **Nucleoid.** It is amazing to note that the DNA of *E.coli* which measures about 1mm long when uncoiled, contains all the genetic information of the organism.

Plasmid

- Plasmids are extra chromosomal double stranded, circular, self-replicating, autonomous elements. They contain genes for fertility, antibiotic resistant and heavy metals. It also help in the production of bacteriocins and toxins which are not found in bacterial chromosome. The size of a plasmid varies from 1 to 500 kb usually plasmids contribute to about 0.5 to 5.0% of the total DNA of bacteria.

Mesosomes

- These are localized infoldings of plasma membrane produced into the cell in the form of vesicles, tubules and lamellae. They are clumped and folded together to maximize their surface area and helps in respiration and in binary fission

Polyribosomes/Polysomes

- The ribosomes are the site of protein synthesis. The ribosomes are 70S type and consists of two subunits i.e. 50S and 30S formed of equal amount of RNA and Protein. The ribosomes are held together by mRNA and form polyribosomes or polysomes.

Flagella

- Certain motile bacteria have numerous thin hair like processes of variable length emerge from the cell wall called flagella. It is 20–30 µm in diameter and 15 µm in length. The flagella of Eukaryotic cells contain 9+2 microtubles but each flagellum in bacteria is made up of a single fibril. Flagella are used for locomotion. Based on the number and position of flagella there are different types of bacteria

Fimbriae or Pili

Pili or fimbriae are hair like appendages found on surface of cell wall of gram-negative bacteria (Example: *Enterobacterium*). The pili are 0.2 to 20 µm long with a diameter of about 0.025µm. In addition to normal pili there are special type of pili which help in conjugation called sex pili are also found.

Mesosome

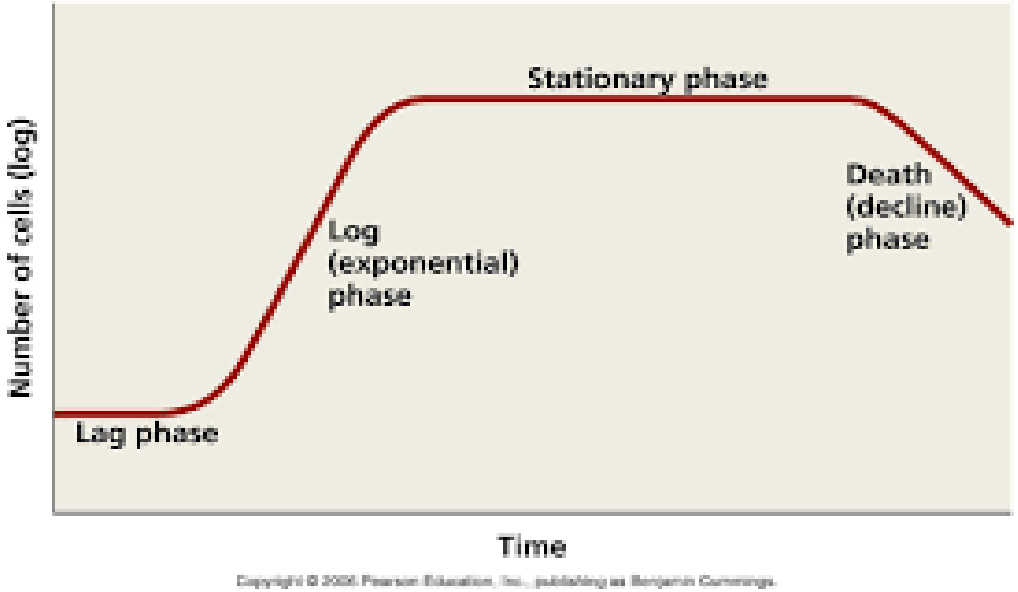
In-foldings of cell surface membrane. Appeared to be associated with DNA during cell division and separation during replication.

Spore or Cyst:

resistant bodies to heat, desiccation and radiation. Exospore, endospore

Growth curve of bacteria

- Lag phase
- Log phase
- Stationary phase
- Death/Decline phase



Reproduction in bacteria

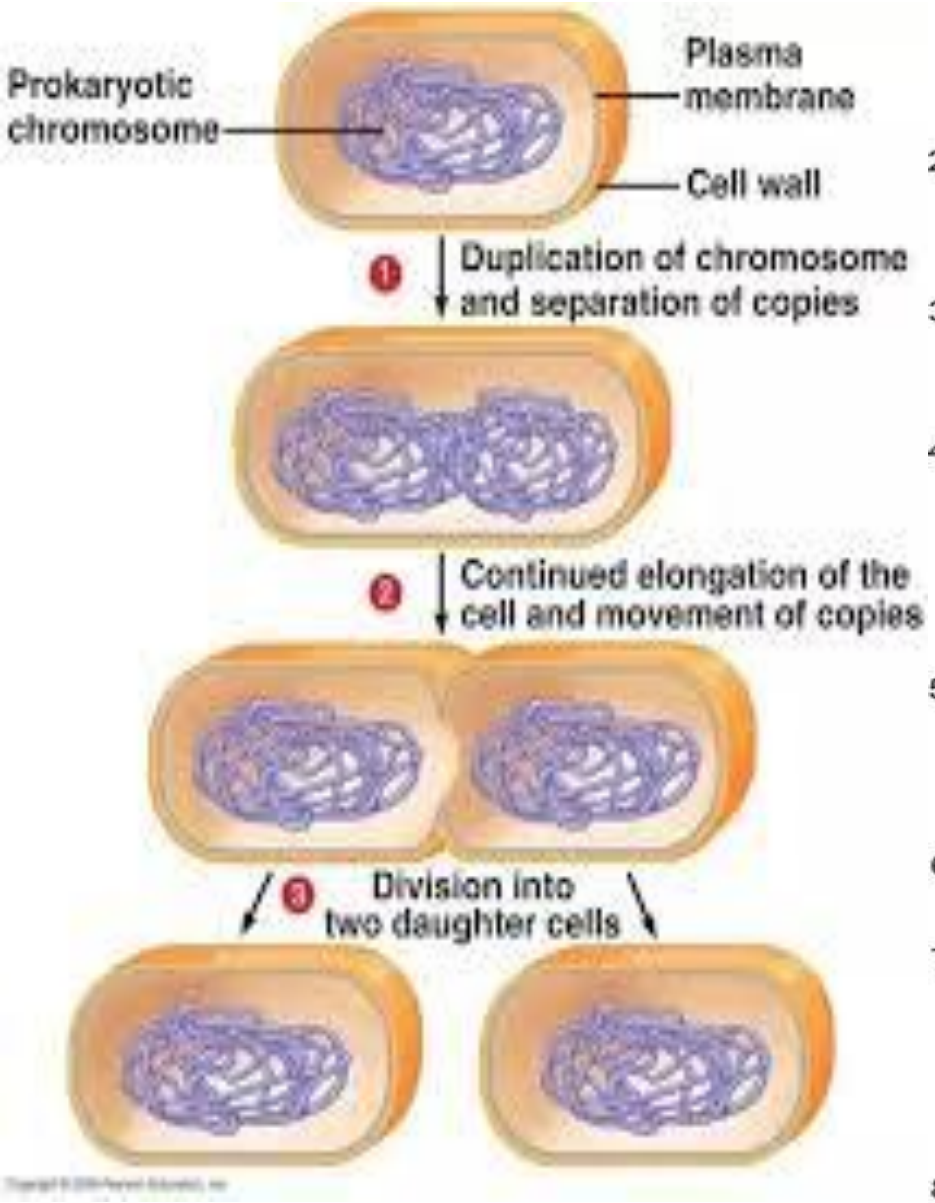
Asexual

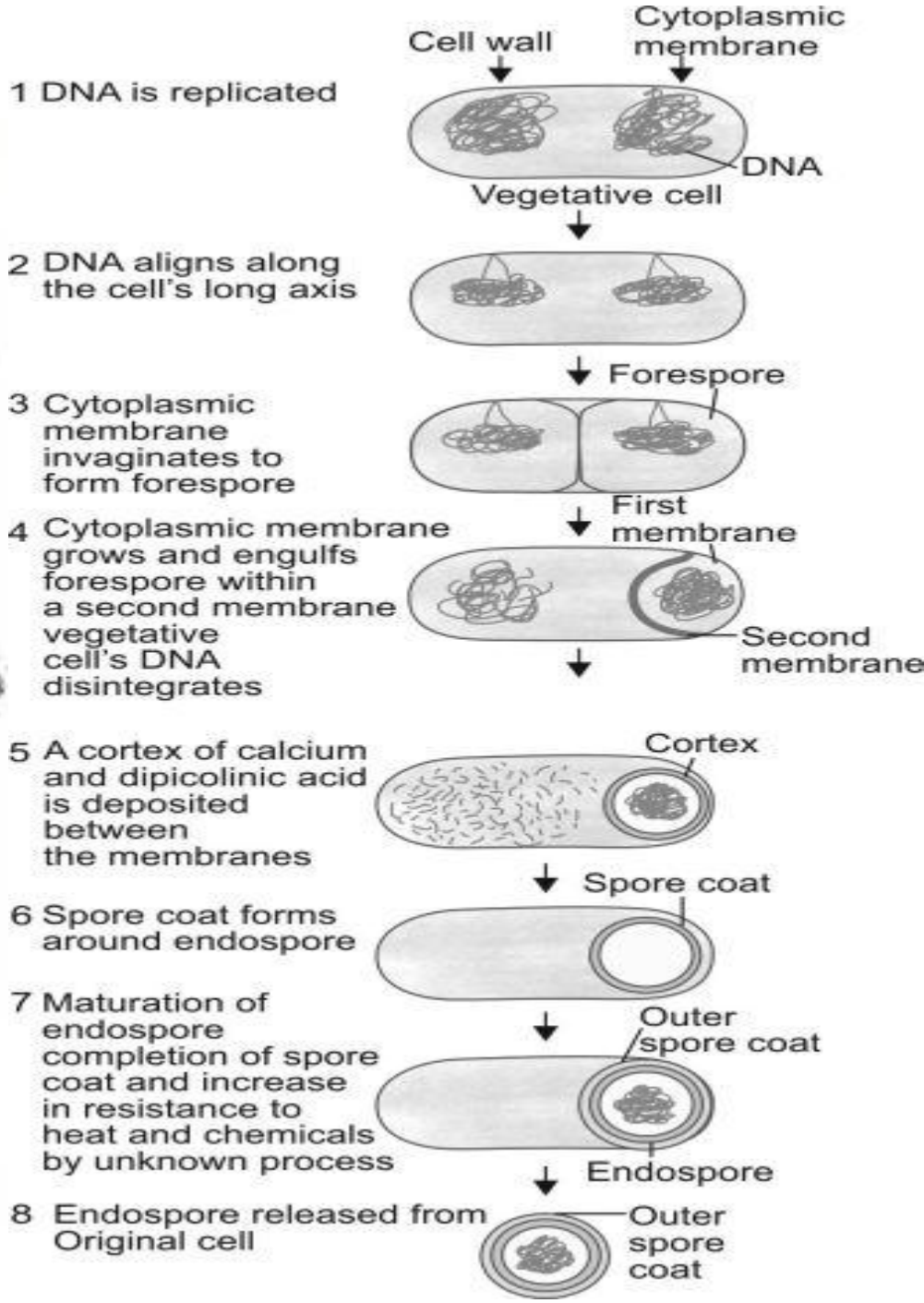
Binary fission, endospore formation

Sexual (Primitive type)/

Bacterial recombination

- Transformation
- Congugation
- Transduction


Prokaryotic chromosome
Plasma membrane
Cell wall
1 Duplication of chromosome and separation of copies
2 Continued elongation of the cell and movement of copies
3 Division into two daughter cells


1 DNA is replicated
Cell wall
Cytoplasmic membrane
DNA
Vegetative cell
2 DNA aligns along the cell's long axis
Forespore
3 Cytoplasmic membrane invaginates to form forespore
First membrane
4 Cytoplasmic membrane grows and engulfs forespore within a second membrane vegetative cell's DNA disintegrates
Second membrane
Cortex
5 A cortex of calcium and dipicolinic acid is deposited between the membranes
Spore coat
6 Spore coat forms around endospore
7 Maturation of endospore completion of spore coat and increase in resistance to heat and chemicals by unknown process
Outer spore coat
Endospore
8 Endospore released from Original cell
Outer spore coat

Transfomation

Transfer of DNA from one bacterium to another is called transformation. In 1928 the bacteriologist Frederick Griffith demonstrated transformation in Mice using *Diplococcus pneumoniae*. Two strains of this bacterium are present in wgich One strain produces smooth colonies and are virulent in nature (S-type) and other strain produce rough colonies and are avirulent (R-type). When S-type of cells were injected into the mouse, the mouse died. When R-type of cells were injected, the mouse survived. He injected heat killed S-type cells into the mouse the mouse did not die. When the mixture of heat killed S-type cells and R-type cells were injected into the mouse. The mouse died. The avirulent rough strain of *Diplococcus* had been transformed into S-type cells. The hereditary material of heat killed S-type cells had transformed R-type cell into virulent smooth strains. Thus the phenomenon of changing the character of one strain by transferring the DNA of another strain into the former is called Transformation.

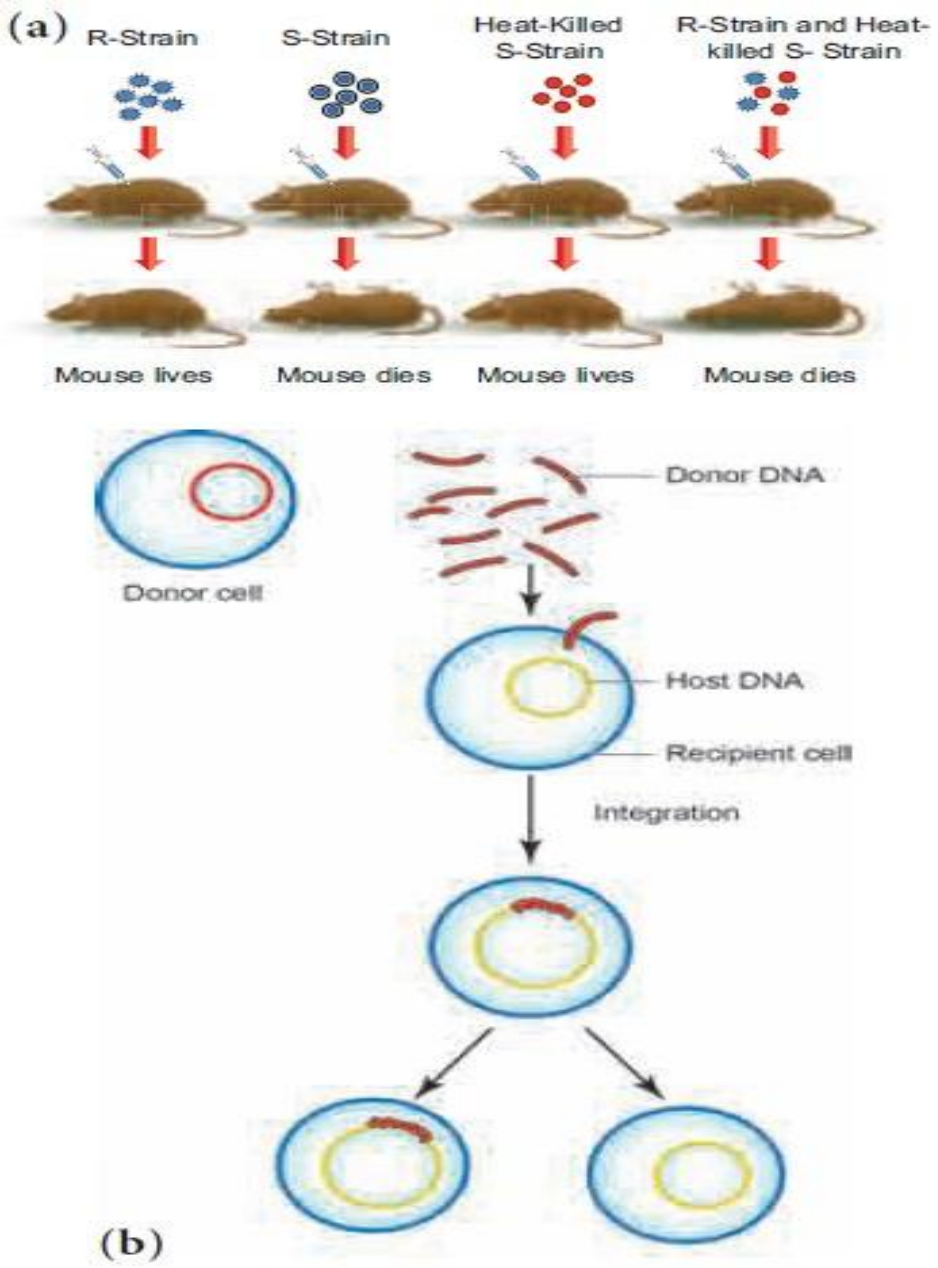
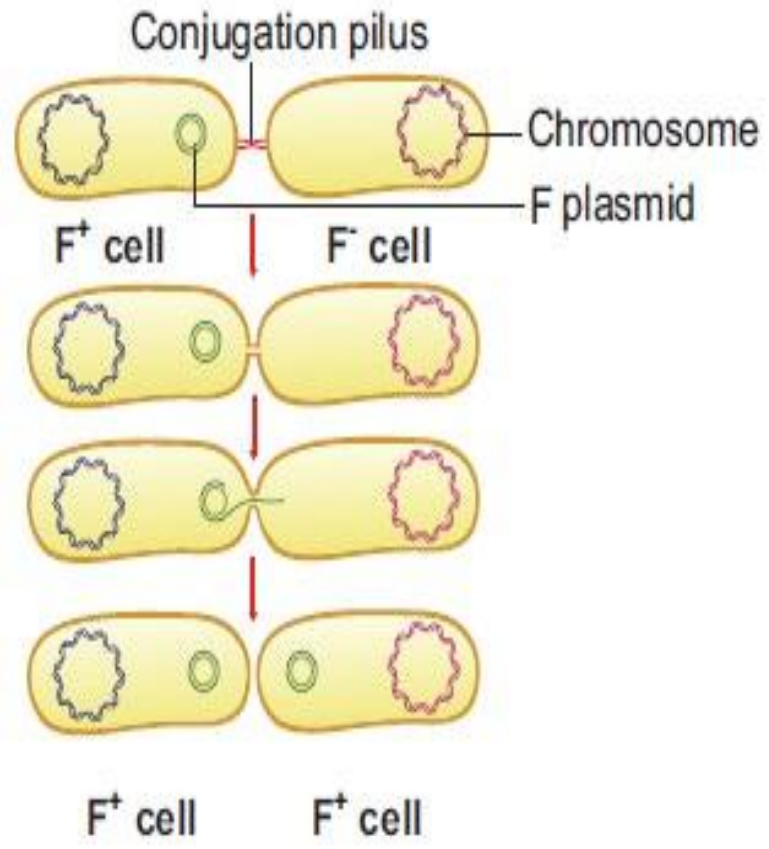


Figure 1.14: Transformation in Bacteria

Bacterial Conjugation

- J. Lederberg and Edward L. Tatum demon-strated conjugation in *E. coli*. in the year 1946. In this method of gene transfer the donor cell gets attached to the recipient cell with the help of pili. The pilus grows in size and forms the conjugation tube. The plas-mid of donor cell which has the F+ (fertility factor) undergoes replication. Only one strand of DNA is transferred to the recipient cell through conjugation tube. The recipient completes the structure of double stranded DNA by synthesizing the strand that complements the strand acquired from the donor.



Conjugation

Transduction

Zinder and Lederberg (1952) discovered Transduction in *S. typhimurum*. Phage mediated DNA transfer is called Transduction.

(i) Generalized Transduction
The ability of a bacteriophage to carry genetic material of any region of bacterial DNA is called Generalised transduction.

(ii) Specialized or Restricted Transduction

- The ability of the bacteriophage to carry only a specific region of the bacterial DNA is called specialized or restricted transduction.

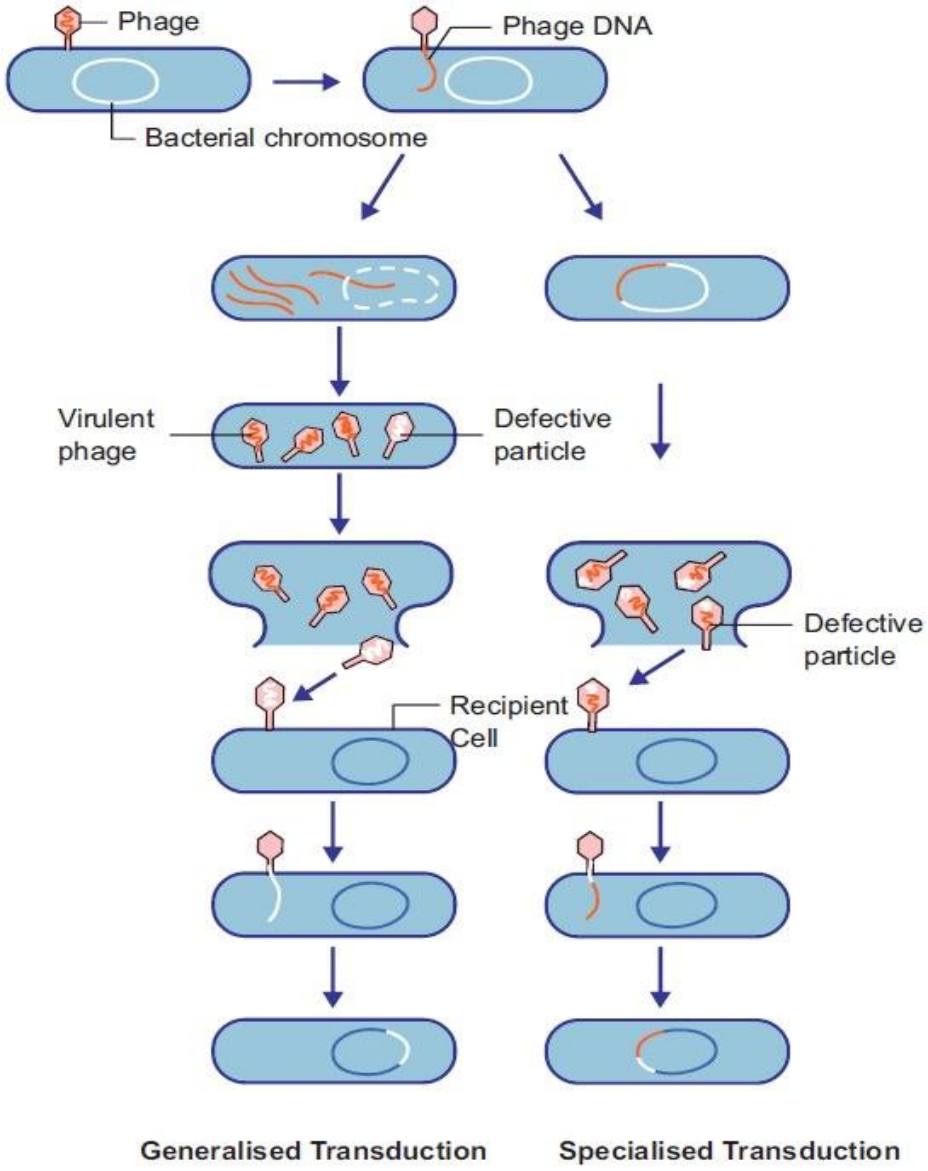


Figure 1.15: Transduction in Bacteria

Cyanobacteria
(Gr kyanos=blue+phyta= plants
Cyanophyta

- The division was named myxophyta (Gr Myxa= slime + phyton= a plant)--- single class cyanophyceae----characters same as bacteria----plced together in **Monera**
- Cyanobacteria resemble the eukaryotic algae in many ways, including morphological characteristics, liberation of O2, and ecological niches, and were at one time treated as algae, hence the common name of blue-green algae. Algae have since been reclassified as protists, and the prokaryotic nature of the blue-green algae has caused them to be classified with bacteria in the prokaryotic kingdom Monera.

Salient features

- The members of this group are prokaryotes and lack motile reproductive structures.
- The thallus imay be unicellular, Colonial or filamentous trichome as in *Nostoc*.
- Gliding movement is noticed in some species (*Oscillatoria*).
- The protoplasm is differentiated into central region called centroplasm and peripheral region bearing chromatophore called chromoplasm.
- The photosynthetic pigments include c-phyocyanin and c-phycoerythrin along with myxoxanthin and myxoxanthophyll.
- The reserve food material is Cyanophycean starch.
- In some forms a large colourless cell is found in the terminal or intercalary position called Heterocysts. They are involved in N2 fixation.
- They reproduce only through vegetative methods and produce Akinetes (thick wall dormant cell formed from vegetative cell), Hormogonia (a portion of filament get detached and reproduce by cell division), fission, Endospores.
- The presence of mucilage around the thallus is characteristic feature of this group. Therefore, this group is also called Myxophyceae
- Sexual reproduction is absent.

Nostoc

Nostoc, genus of blue green algae with cells arranged in beadlike chains that are grouped together in a gelatinous mass. Ranging from microscopic to walnut-sized, masses of *Nostoc* may be found on soil and floating in quiet water.

- Like most blue-green algae, *Nostoc* contains two pigments, blue phycocyanin and red phycoerythrin, as well as chlorophyll,
- the ability to fix N2 in specialized cells called heterocysts. A terrestrial species has been used as a supplementary food source in Asia.

Reproduction

- **Fragmentation, akinete** special thick-walled cell (**akinete**) has the ability to withstand desiccation for long periods of time. After 70 years of dry storage, the akinete of one spp. germinates into a filament when moistened.
- **Hormogonia** most common, filament of short length piecesdue to death decay of heterocyst or veg cells
- **Arthrospore** akinetes which are resting spores
- **Endospore** heterocyst contents divide to produce

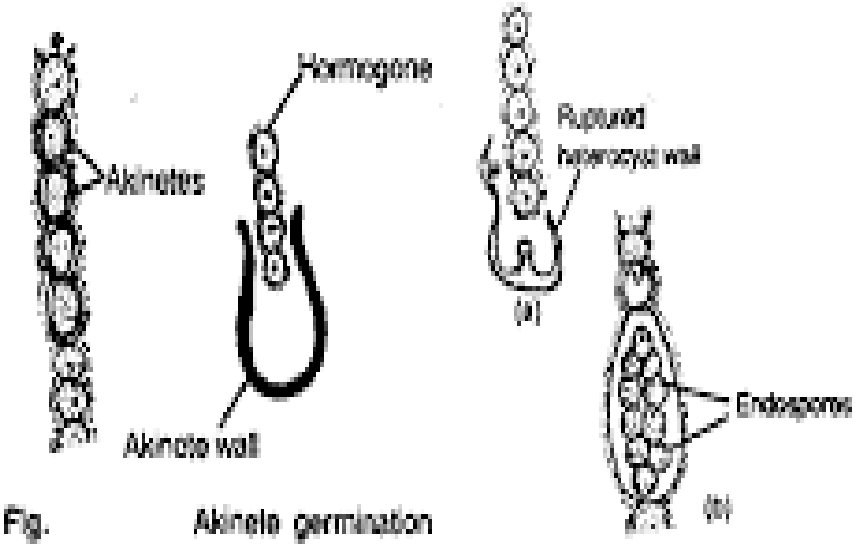


Fig. Akinete germination

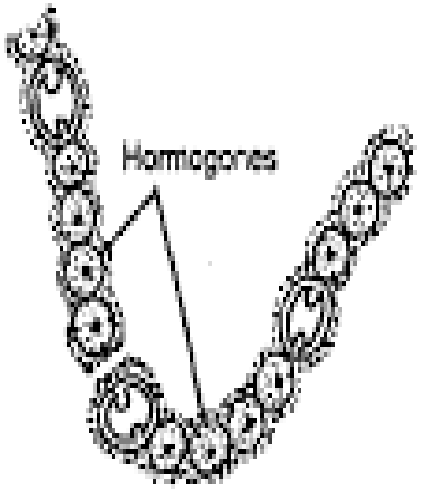


Fig. Hormogones

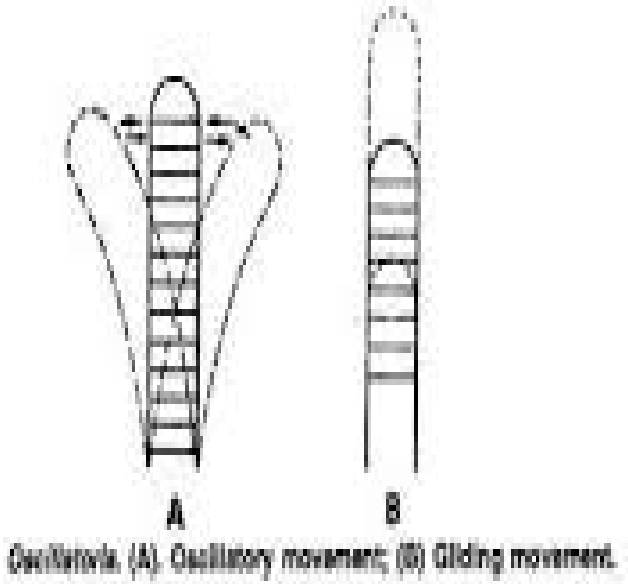
Oscillatoria

Filamentous cyanobacteria which is named after its oscillating movement. Filaments in the colonies can slide back and forth against each other until the whole mass is reoriented to its light source. It uses photosynthesis to survive and reproduce. Each filament consists of trichome which is made up of rows of cells. The tip of the trichome oscillates like a pendulum.

Habitat: It is commonly found in watering-troughs waters, and is mainly blue-green or brown-green. It occur in fresh water ponds.

Reproduction*:* takes place vegetatively

fragmentation, Hormogonia the filament breaks into a number of fragments called homogonia. Each consist of one or more cells and grow into a filament by cell division in one direction. **Necridia** Breaks in the filament usually occur where dead cells (necridia) are present..



Oscillatoria (A) Oscillatory movement; (B) Gliding movement.

Economic Importance of Bacteria and Cyanobacteria

Bio fertilizer and soil fertility

• Bacteria as Biofertilizers • Cultures of improved strains of beneficial bacteria which when applied to the seed or soil, colonize the rhizosphere or the interior of the plants and stimulate plant growth by increasing the availability of nutrients. • Improve cycling of nutrients and increase soil fertility . • Increase porosity and water holding capacity of the soil and provide protection against drought. • Enhance seed germination. • Increase crop yield to 20 – 30 % • Cheap, convenient and ecofriendly • Application of biofertilizers have considerable importance in sustainable agriculture. e.g. Species of *R. leguminosarum*.

Certain bacteria play an important role N2 fixation, ammonification , nitrification and thus help to increase the fertility of the soil. N_2 fixing bacteria • Plants can absorb N_2 only in the form of nitrates. N2 fixing bacteria can fix the free N2 of the atmosphere into absorbable form of nitrates. • N2 fixing bacteria are of two types viz. symbiotic N2 fixers and free living (asymbiotic) N2 fixers.

Symbiotic N2 fixing bacteria • Establish symbiotic relationship with leguminous plants and fix free N2 of the atmosphere into absorbable form of nitrates and increase the fertility of the soil. Infection of the roots of a leguminous plant with suitable species of these bacteria leads to the formation of root nodules. e.g. Bacteria like *R. leguminosarum*, etc.

N2 fixation by Cyanobacteria • Cyanobacteria like *Nostoc punctiforme*, etc. can also fix free N2 of the atmosphere by means of heterocysts and thus increase fertility of the soil. Ammonification • Species of bacteria like *B. subtilis*, *B. macerans*, Proteus terrae etc. degrade dead organic matter of plants, animals into simple compounds NH3 to enhance the fertility of the soil. Nitrification • Nitrifying bacteria like Nitrosomonas, Nitrosococcus etc. oxidise ammonia to nitrites and Nitrobacter species oxidise nitrites to nitrates and increase the fertility of the soil.

N2 fixation by Filamentous bacteria (Actinomycetes) • Form nodules in the roots of non –leguminous plants like Casuarina. e.g. Frankia Phosphorous solubilizers or Phosphobacteria • Solubilize different forms of insoluble phosphates by producing citric acid, succinic acid, fumaric acid etc. e.g. B. polymyxa

Industrial application

Role of Bacteria in food production Production of Curd , Butter, Cheese •Milk is inoculated with the starter culture and kept for a few hours. • Lactic acid bacteria like *L. acidophilus* grow in milk and ferment lactose in milk into lactic acid results in coagulation of casein to the curd and also in the production of butter, cheese etc. Production of Yoghurt • The main (starter) cultures in yogurt are *Lactobacillus bulgaricus.* Production of Vinegar • Ethyl alcohol is oxidized into acetic acid by acetic acid bacteria, Acetobacter aceti, etc. Probiotics • Live microorganisms when administered in adequate amounts, confer a health benefit on the host . The most commonly used probiotic bacteria belong to the heterogeneous group of Lactic Acid Bacteria e.g. yoghurt and other fermented milk products include *L. acidophillus.*

Production of Fermented foods : • They are serving as process organisms and transform the chemical constituents of raw materials of plant/animal sources during fermentation. Bacteria for the production of medically useful enzymes • Streptokinase - a thrombolytic enzyme used to dissolve blood clots - produced by Streptococci bacteria , vitamin B12

Role of Bacteria in Bioremediation • Disposal of sewage and agrowastes - The bacterium Sphaerotilus natans , popularly known as sewage fungus , play an important role in the degradation of organic matter in sewage. Bacteria for Pesticide degradation: Klebsiella and *B. subtilis*. Oil-degrading microorganisms include Pseudomonas etc. • genetically engineered super bug, Pseudomonas putida capable of degrading Petroleum Bacterium as a biocontrol agent • The bacterium *B. thuringiensis* can be used as a biocontrol agent. 8. Agrobacterium mediated gene transfer technique • The soil bacterium , *A. tumefaciens*, known as natural plant genetic engineer is used to produce many genetically modified plants Bt crops • Bt gene (cry gene Bt crops - e.g. Bt cotton, Bt corn, Bt brinjal etc. which are resistant to insects. Production of biogas • Several bacteria are involved in the production of bio gas (methane – biofuel) from cow dung, animal wastes, etc. Biodegradable plastics • Poly β-hydroxybutyrate is used for the production of biodegradable plastic. Uses of genetically engineered bacteria: *E. coli* • Used for the production of human insulin .e.g. 'Humulin' and human growth hormone Somatotropin to treat dwarfism ; production of biofuels e.g. Bioethanol.

Pathogenecity

Harmful aspects of Bacteria :Reduction in soil fertility by denitrifying bacteria. Denitrifying bacteria like *Thiobacillus denitrificans* convert the nitrates of the soil into free Nitrogen of the atmosphere and thus reduce the fertility of the soil.

Parasitic bacteria are pathogens cause various diseases in plants and animals including man. e.g. Blight disease of Paddy caused by *Xanthomonas oryzae*

Citrus canker • caused by *Xanthomonas axonopodis*

Bacterial diseases in man Diphtheria - *Corynebacterium diphtheriae*. Cholera - *Vibrio cholera*e Pneumonia - *Streptococcus pneumoniae* etc.

food spoilage : Food spoilage is the undesirable change in the food. • Spoilage causes changes in the appearance of food, formation of unpleasant odour and unpalatable taste. A large number of bacteria cause spoilage of • Vegetables and fruits Bacillus Staphylococcus, Streptococcus etc. • Cereals Micrococcus, Bacillus, Pseudomonas etc. • Meat – Bacillus, Clostridium, Escherichia, Pseudomonas etc. • Egg Salmonella , Micrococcus, Pseudomonas etc. Poultry: Bacillus, Enterobacter , Escherichia, Salmonella etc. • Fish – Alcaligenes, Micrococcus, Pseudomonas etc. • Processed foods – *B. subtilis*, *B. licheniformis* etc. Bacteria causes food poisoning - Botulism • An anaerobic bacterium, *Clostridium botulinum* produces a neurotoxin botulin (an exotoxin) which produces food poisoning called botulism.

Biowar/Bioterrorism: The improved variety of infective agents (bioweapons) are widely been used as an agent of effective weapon of bioterrorism. e.g. *Bacillus anthracis* - causes Anthrax, *Clostridium botulinum* (botulism) etc.