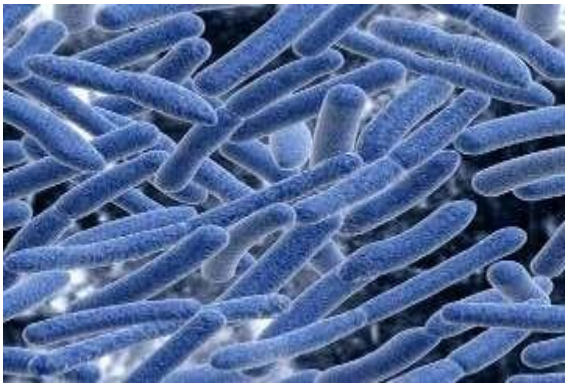
Bacteria:

Bacteria are single cellular microscopic organisms. The study of bacteria is known as bacteriology and it is a branch of microbiology. The singular world of bacteria is bacterium.Bacteria have been grouped into prokaryotic, which means absence of nucleus.

Structure of Bacteria



Characteristics of Bacteria

→→ There are 3 types of bacteria based on their shapes such as: Bacteria grow in number not in size, but they make copies of themselves by dividing into half. There are three basic shapes of bacteria:

- Rod shaped bacteria called as bacilli.
- Spherical shaped bacteria called as cocci.
- Curved shaped bacteria called as spirilla.

Some of the bacteria exist as single cells, others exist as cluster together.

Respiration in bacteria:

Anaerobic bacteria: does not require oxygen for respiration.

Aerobic bacteria: require oxygen for respiration.

Gram staining bacteria are a method of differentiating bacterial species into two large groups, which are based on their chemical and physical properties of their cell wall.

Gram positive bacteria: Those bacteria when they are stained in gram stain results in purple colour.

Gram negative bacteria: Those bacteria when they are stained in gram stain results in pink colour.

locomotion of bacteria

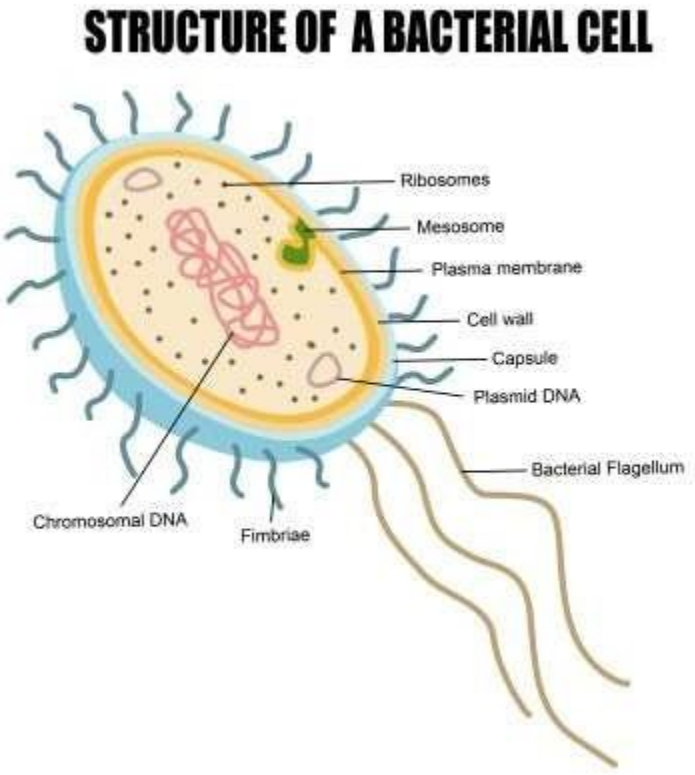
They move around by using their locomotion organs such as cilia and flagella.

Nutrition of bacteria:

They exhibits different modes of nutrition level such as-

- ***Autotrophic bacteria:*** These bacteria are able to synthesize their own food. For e.g.: Phototropic bacteria and chemosynthetic bacteria
- ***Heterotrophic bacteria:*** These bacteria are unable to synthesize their own food, hence they depends on other organic materials. For e.g.: saprophytic bacteria-these bacteria feeds on dead and decaying matter.
- ***Symbiotic bacteria:*** These bacteria have a mutual benefit from other organisms. For e.g.: nitrogen fixing bacteria (or) rhizobium.
- ***Parasitic bacteria:*** These bacteria are present in plants, animals and human beings. These bacteria feeds on host cells and causes harm to the host.

Bacterial Cell Structures



Cell Wall:

- Cell walls of bacteria are made up of glycoprotein murein.
- The main function of cell wall is it helps in providing support, mechanical strength and rigidity to cell.
- It protects cell from bursting in a hypotonic medium.

Plasma Membrane:

- It is also known as cytoplasmic membrane (or) cell membrane.
- It is composed of phospholipids, proteins and carbohydrates, forming a fluid-mosaic.
- It helps in transportation of substances including removal of wastes from the body.
- It helps in providing a mechanical barrier to the cell.
- Plasma membrane acts as a semi permeable membrane, which allows only selected material to move inside and outside of the cell.

Cytoplasm:

- Helps in cellular growth, metabolism and replication.
- Cytoplasm is the store houses of all the chemicals and components that are used to sustain the life of a bacterium.

Ribosome:

- A tiny granule made up of RNA and proteins.
- They are the site of protein synthesis.
- They are freely floating structures that helps in transferring the genetic code.
-

Plasmid:

- Plasmids are small circle of DNA.
- Bacterial cells have many plasmids.
- Plasmids are used to exchange DNA between the bacterial cells.

Flagella:

- This is a rigid rotating tail.
- It helps the cell to move in clockwise and anticlockwise, forward and also helps the cell to spin.
- The rotation is powered by H+ gradient across the cell membrane.

Pilli:

- Short protein appendages.
- Smaller than flagella.
- Fixes bacteria to surfaces.
- It also helps in reproduction during conjugation.

Capsule:

- Capsule is a kind of slime layer, which covers the outside of the cell wall.
- They are composed of a thick polysaccharide.
- It is used to stick cells together and works as a food reserve.
- It protects the cell from dryness and from chemicals.

Reproduction in Bacteria:

The reproduction in bacteria is mainly by cell division and binary fission. In some cases few bacteria also reproduce by budding.

Bacteria reproduce by **Vegetative, asexual and sexual** methods.

Vegetative reproduction includes **Budding, Fragmentation** and **Binary fission**

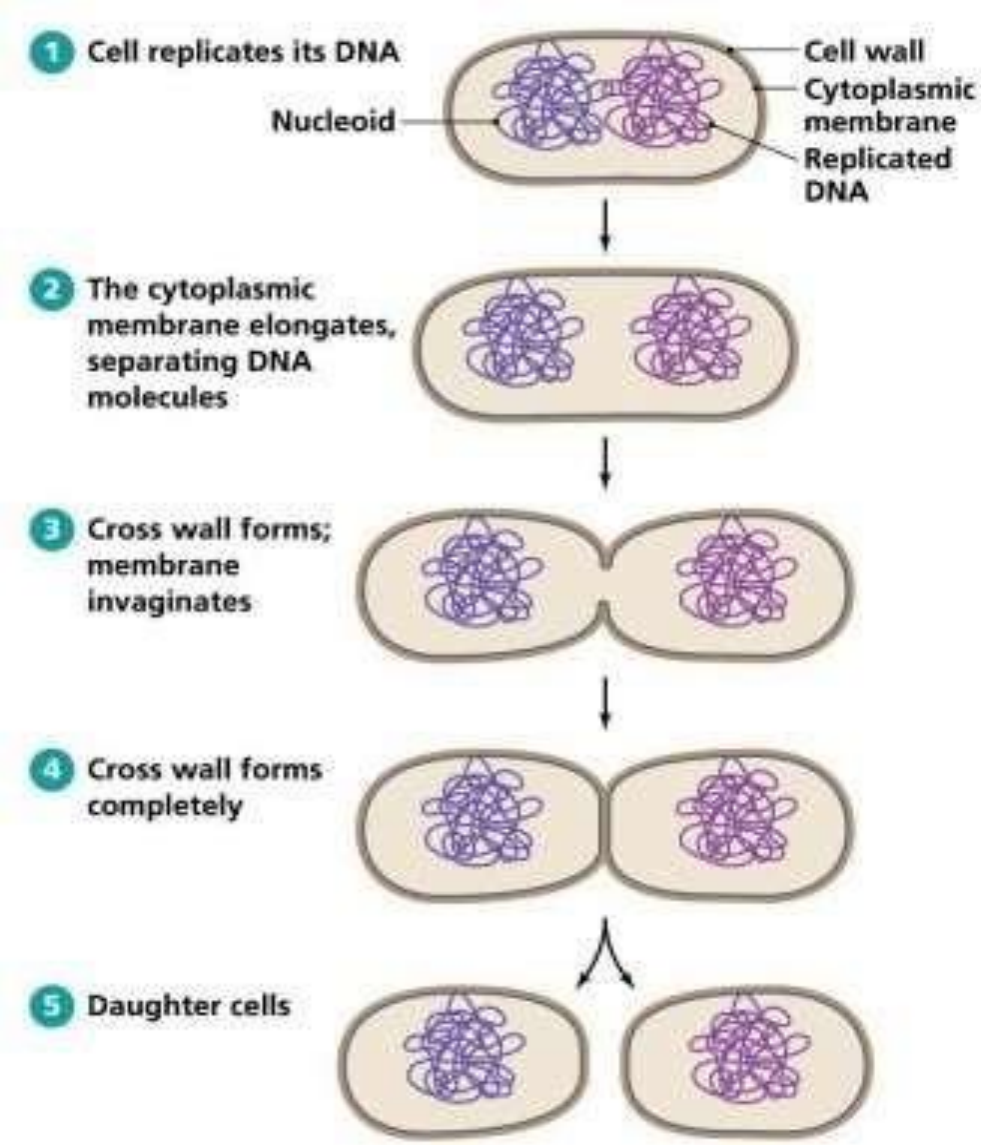
Budding:

- In this case, a small protuberance, called bud, develops at one end of the cell. Genome replication follows, and one copy of the genome gets into the bud. Then the bud enlarges, eventually become a daughter cell and finally gets separated from the parent cell.
- **Fragmentation: Mostly during unfavourable conditions bacterioprotoplasm** undergoes compartmentalization and subsequent fragmentation, forming minute bodies called **gonidia.** Under favorable conditions, each gonidium grows to a new bacterium. It becomes apparent that prior to fragmentation the bacterial genome has to undergo repeated replication so that each fragment gets a copy of it.

Binary fission:

- It is the commonest type of reproduction under favorable conditions in which cell divides into two similar daughter cells. During the process, the bacterial chromosomes get attached to the cell membrane and replicates to the bacterial chromosomes. As the cell enlarges the daughter chromosomes gets separated. A cross wall is formed between the separating daughter

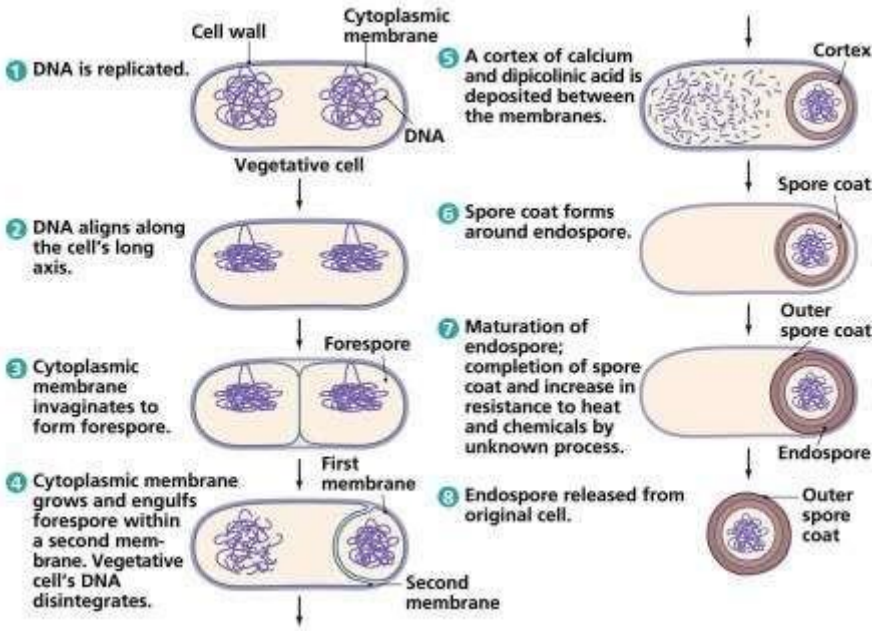
chromosomes. It divides the cell into two daughter cells. The daughter cells soon grow to maturity within 20-30 minutes. Under favorable conditions many bacteria divide once in 20-30 minutes.



Binary Fission

Asexual reproduction takes place by endospore formation, conidia and zoo spores.

- **Endospore formation:** Endospore are resting spores formed in some gram positive bacteria (Bacillus and Clostridium) during unfavourable conditions. They are formed within the cells. During this process a part of the protoplast becomes concentrated around the chromosome. A hard resistant wall is secreted around it. The rest of the bacterial cell degenerates; Endospore are very resistant to extreme physical conditions and chemicals. During favourable conditions the spore wall gets ruptured and the protoplasmic mass gives rise to a new bacterium.



Endospore Formation

Types of Sexual Reproduction that occurs in Bacteria:

Types of sexual reproduction that occurs in bacteria are as follows-

Cytologic observations and genetic studies indicate something like sexual reproduction, involving the fusion of two different cells and a transfer of hereditary factors occurs in bacteria although infrequently. Genetic recombination occurs in those bacteria that have been carefully studied and presumably occurs in other species as well.

F+ which can itself be transferred to a female, thereby converting One of the most intensively studied species of bacteria, Escherichia coli has been shown to have sex-some act as males and

transfer genetic information by direct contact with females. This ability to transfer genes is regulated by a fertility factor her into a male.

The usual vegetative bacterial cells are haploid and in sexual reproduction part or all of the chromosome passes from the male cell to the female cell, yielding a cell, i.e., partly or completely diploid. Crossing over then occurs between the female chromosome and the male chromosome or fragment, followed by a process of segregation that yields haploid progeny cells.

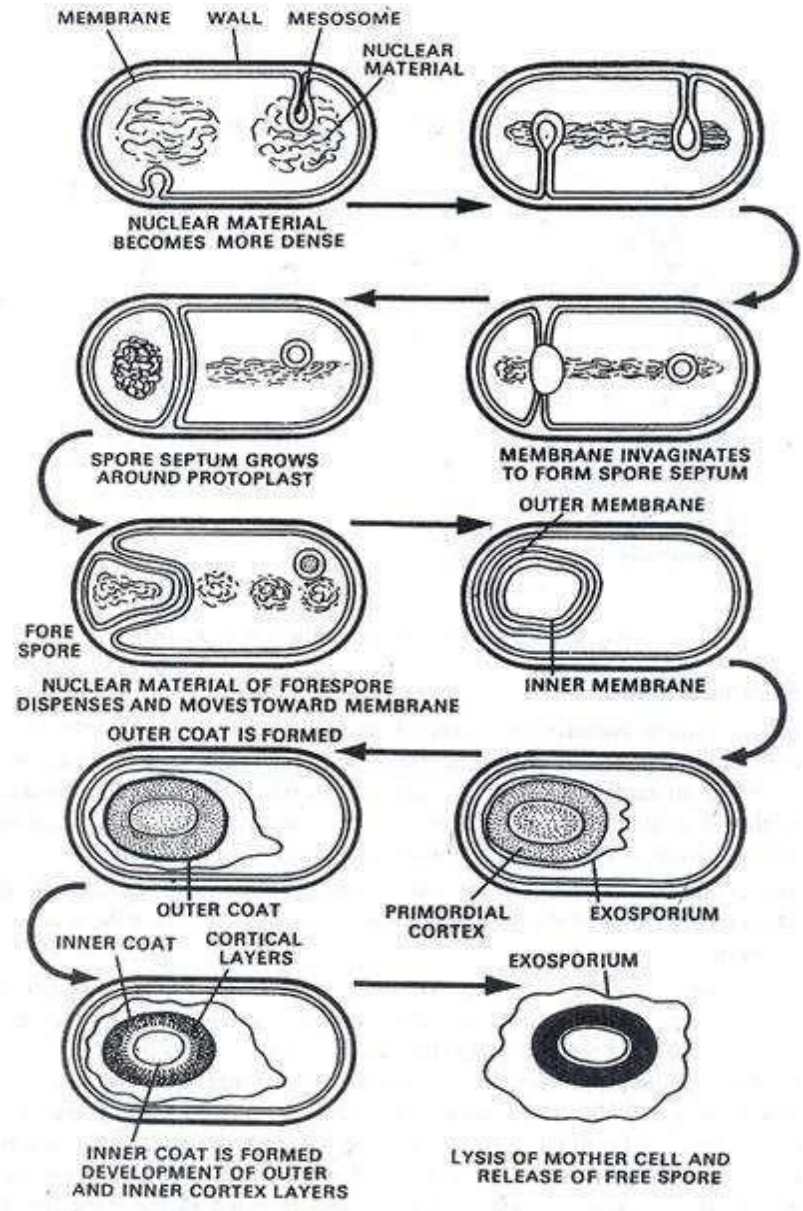


Fig. 2.13. Bacteria. Formation of endospore in a bacterial cell.

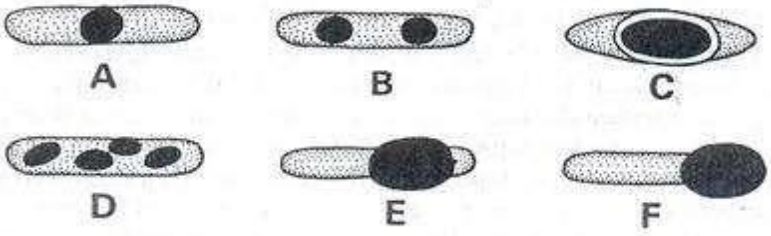


Fig. 2.14. Bacteria. Various stages of endospore formation (A–F).

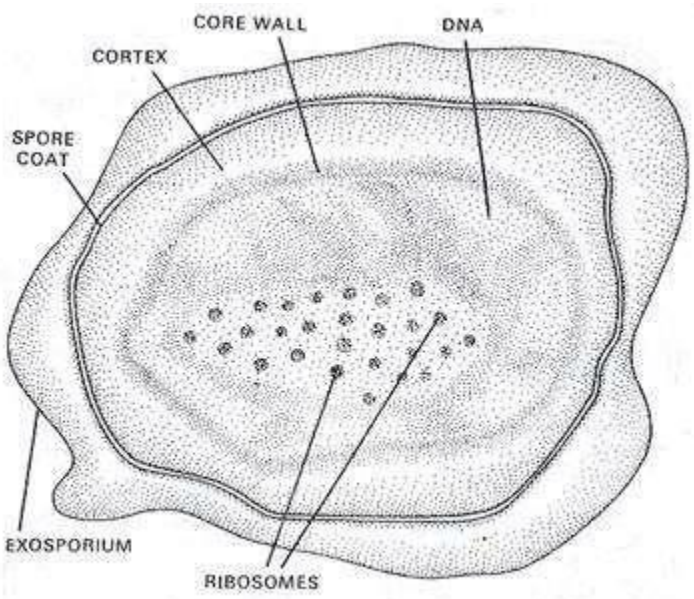


Fig. 2.15. Bacteria. Structure of endospore.

1. Bacterial Transformation:

The genetic transfer in bacteria also occurs by transformation, in which the DNA molecule of the donor cell, when liberated by its disintegration, is taken up by another recipient cell and its offspring inherit some characters of the donor cell. When different strains of bacteria are found in a mixed state either in culture or in nature, some of the resultant offspring possess a combination of characters of the parent strains. This phenomenon is known as recombination . The phenomenon of transformation was first recorded by Griffith (1928). Avery, Macleod and McCarty (1944) demonstrated that the transforming principle being DNA in the sequence of events in bacterial transformation.

The lines of inquiry that led to an understanding of the chemical nature of genetic material arose from a study of the pestilent organism Diplococcus pneumoniae. This bacterium causes pneumonia in males. In 1928, Frederick Griffith found that there are two strains of D. pneumoniae, one that forms smooth colonies protected by a capsule, and the other one that formed irregular or rough colonies without a capsule when grown on a suitable medium in petri dishes.

When injected into mice (A) only capsulated smooth cells (virulent) produced the disease, but not the non-virulent rough cells (B). On the other hand when the heat killed capsulated (virulent)

smooth cells were mixed with non-virulent rough cells (D) and then were injected in the mice the

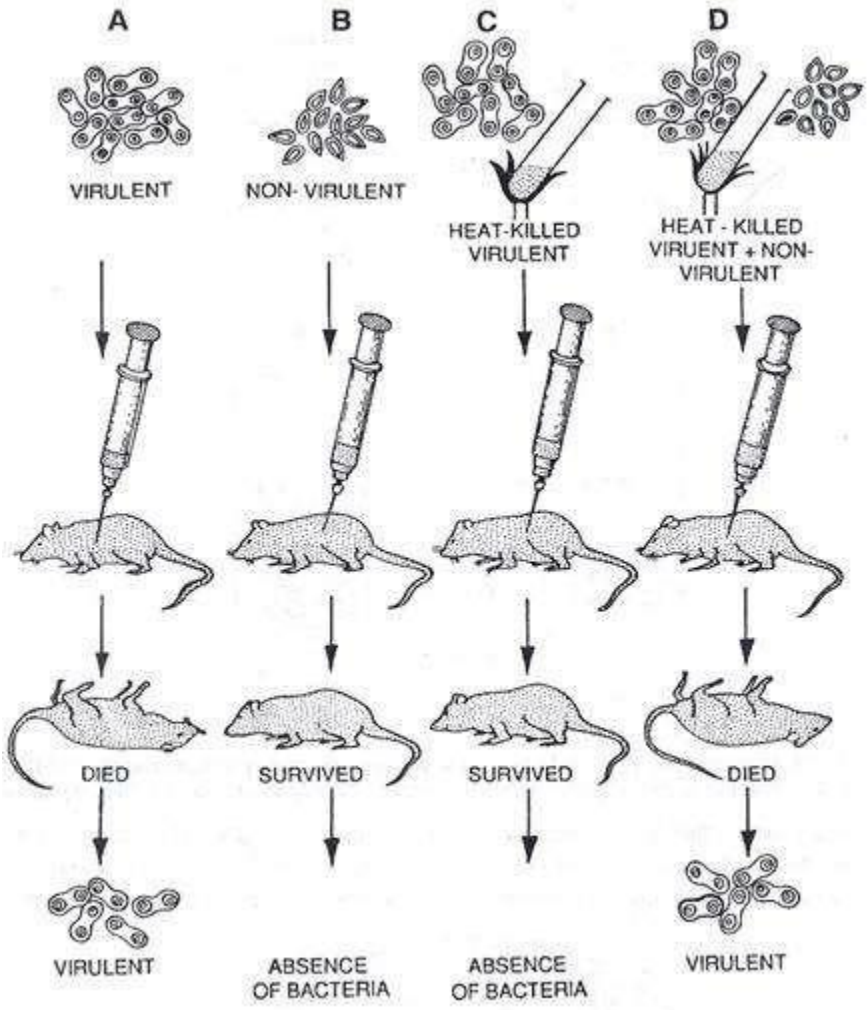


Fig. 2.16. Griffith's experiments with *Diplococcus pneumoniae* and mice.

Viral-infecting agent is DNA::

A bacteriophage (T_2 virus) infects the bacterium Escherichia coli. After infection, the virus multiplies and T_2 phages are released with the lysis of the bacterial cells. As we know, the T_2 phage contains both DNA and proteins. Now the question arises, which of the two components has the information to programme for the multiplication of more viral particles.

To solve this problem Hershey and Chase (1952) devised an experiment with two different preparations of T_2 phage. In one preparation they made protein part radioactive and in the other preparation the DNA was made radioactive. Thereafter a culture of E. coli was made infected by these two phage preparations. Immediately after infection and before lysis of bacteria the E. coli cells were gently agitated in a mixer so that the adhering phage particles were loosened and then

the culture was centrifuged. With the result the heavier pellets of infected bacterial cells were

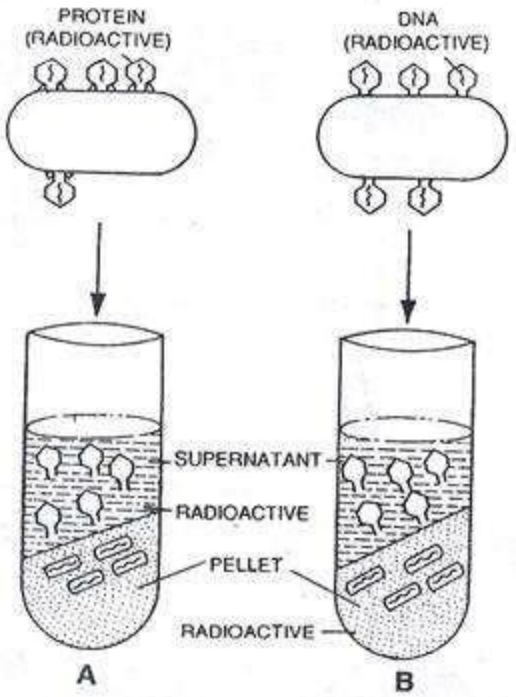


Fig. 2.17. The viral infecting agent is DNA. A, the viral protein coat is radioactive; B, viral DNA is radioactive. The infected bactetrial pellet picks up radioactivity only when the viral DNA is radioactive.

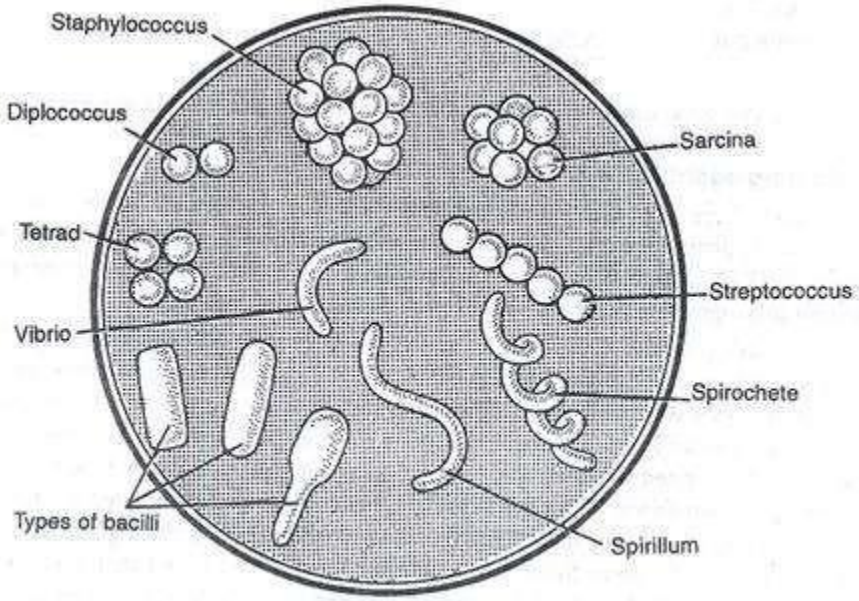


Fig. 2.18. Different types of bacteria.

that it is the viral DNA and not protein that contains information for the production of more T_2 phage particles hence DNA is genetic material. However, in some viruses (e.g., TMV, influenza virus and polio virus) RNA serves as genetic material,

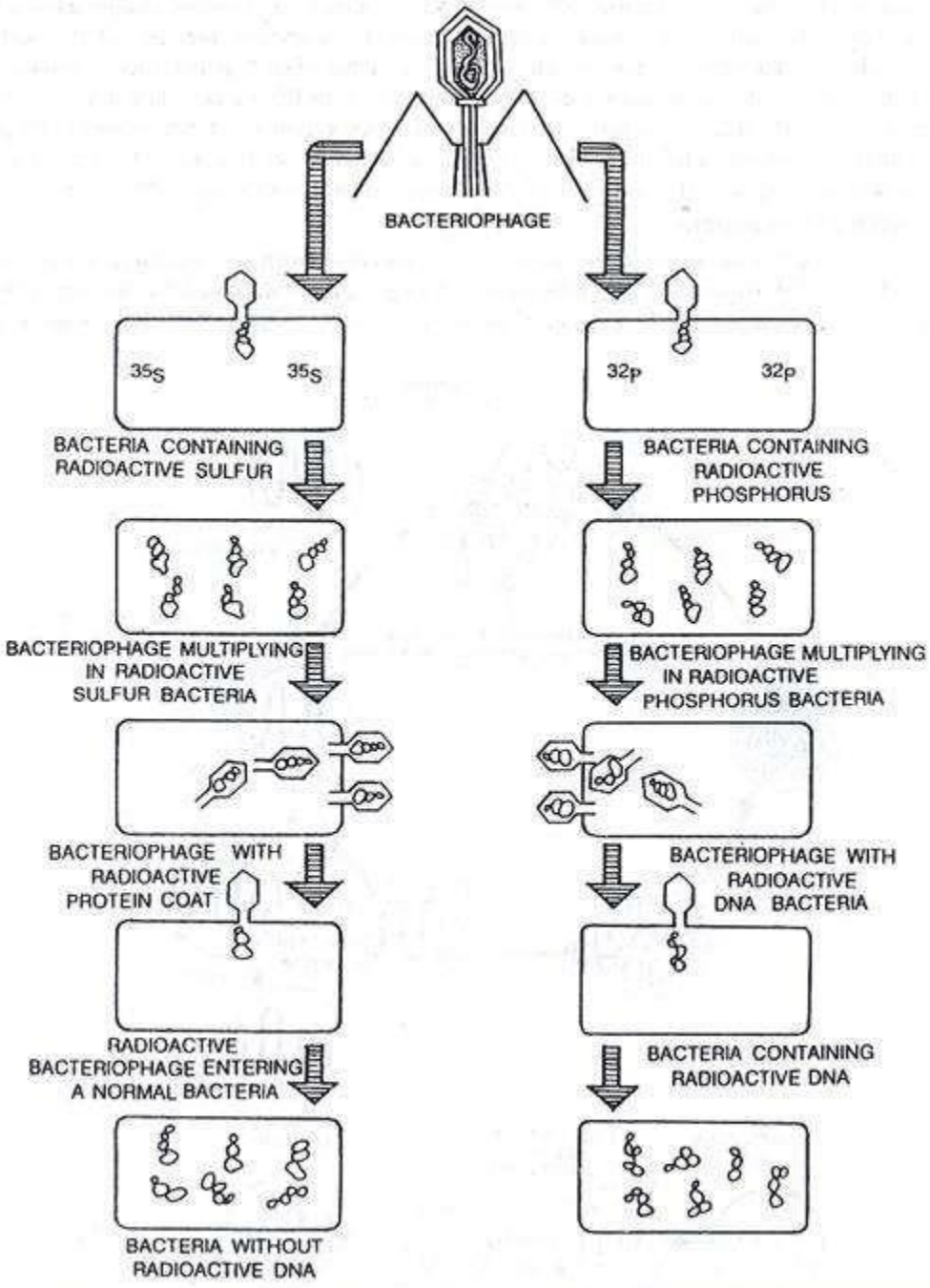


Fig. 2.19. Hershey and Chase's experiments show that DNA is hereditary material in bacteriophages.

Hershey and Chase conducted two experiments. In one experiment E. coli was given in a medium containing the radio-isotope S^{35} and in the other experiment E. coli was grown in a medium containing the radio-istope P^{32}. In these experiments E. coli cells were made infected with T_2 phage released from E. coli cells grown in S^{35} medium have S^{35} in their protein capsid, and those from P^{32} medium had P^{32} in their DNA.

When these phages were used to infect new E. coli cells in normal medium, the bacterial cells which had infection by S^{35} labelled phages showed the radioactivity in their cell wall and not in cytoplasm. Whereas the bacteria infected with P^{32} labelled phages had shown the reverse condition.

Thus it can be said that when T_2 phage infects the bacterial cell, its protein capsid remains outside of the bacterial cell but its DNA enters the cytoplasm of the bacterium. When the infected cells of bacteria get lysed, new complete viral particles (T_2 phages) are formed. This proves that viral DNA carries the information for synthesis of more copies of DNA and protein capsids. This shows that DNA is genetic material,.

2. Bacterial Transduction:

The genetic transfer in bacteria is achieved by a process known as transduction. Lederberg and Zinder's (1952) experiment in U-tube Salmonella typhimurium indicated that bacterial viruses or phages are responsible for the transfer of genetic material from one to the other lysogenic and

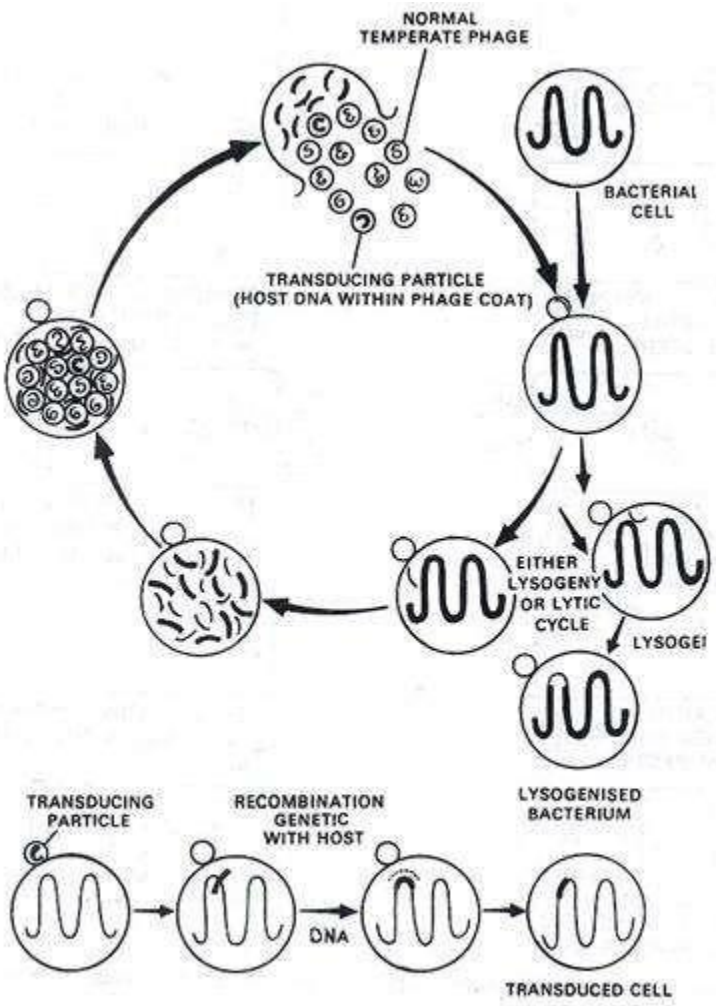


Fig. 2.20. Bacteria. Upper diagram: transduction mechanism where phage particles containing host can be formed. Lower diagram: genetic recombination with transducing particles.

lytic phages. Thus the host acquires a new genotype. Transduction has been demonstrated in many bacteria.

In this process, the DNA molecule that carries the hereditary characters of the donor bacterium is being transferred to the recipient cell through the agency of the phage particle. In this process very few closely linked characters can be transferred by each particle. Thus the bacteriophage brings about genetic changes in those bacteria which survive the phage attack.

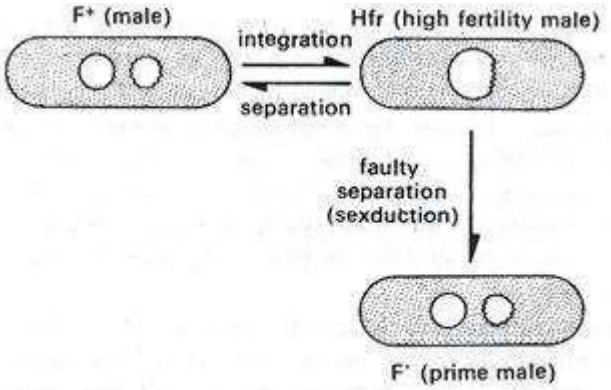


Fig. 2.21. Bacteria. Transduction.

When a bacterial cell is being infected with a temperate virus either lytic-cycle or lysogeny starts. Thereafter, host DNA breaks down into small fragments along with the multiplication of virus.Some of these DNA fragments are incorporated with the virus" particles becoming transducing one. When bacteria lyse these particles along with normal virus particles are released

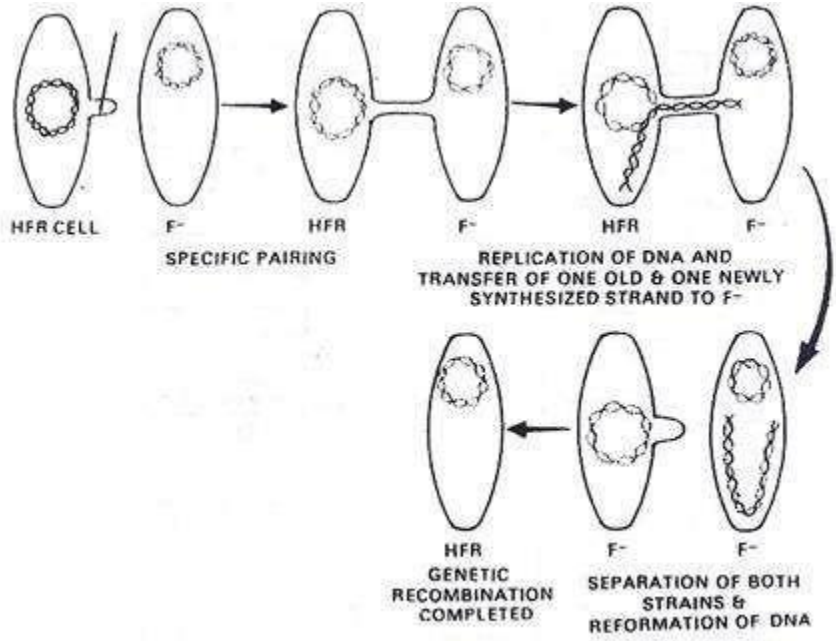


Fig. 2.22. Bacteria, Diagrammatic representation of possible mechanism of conjugation.

when this mixture of transducing and normal virus particles is allowed to infect the population of recipient cells, most of the bacteria are infected with normal virus particles and with the result lysogeny or lytic-cycle occurs again. A few bacteria are infected with transducing particles, transduction takes place and the DNA of virus particles undergo genetic recombinations with the bacterial DNA.

3. Bacterial Conjugation:

Wollman and Jacob (1956) have described conjugation in which two bacteria lie side by side for as much as half an hour. During this period of time a portion of genetic material is slowly passed from one bacterium which is designated as a male to a recipient designated as a female. This was established that the male material entered the female in a linear series.

The genetic recombination between donor and recipient cells takes place as follows: The Hfr DNA after leaving a part in fragment to recipient cell again reforms in circular manner. In F strain genetic recombination takes place between donor fragment and recipient DNA. Gene transfer is a sequential process and a given Hfr strain always donates genes in a specific order. A single stranded donor DNA (F factor) is integrated in the host chromosome with the help of nuclease enzyme, (see figs. 2.21 and 2.22).

In bacterial conjugation the transfer of genetic material (DNA) takes place by cell to cell contact of donor and recipient cells. During the process of conjugation large portion of the genome is transferred, while in transformation and transduction only small fragment of DNA is transferred. The process of conjugation was discovered by Lederberg and Tatum (1944) in a single strain of Escherichia coli. Conjugation has also been demonstrated in Salmonella, Pseudomonas and Vibrio.

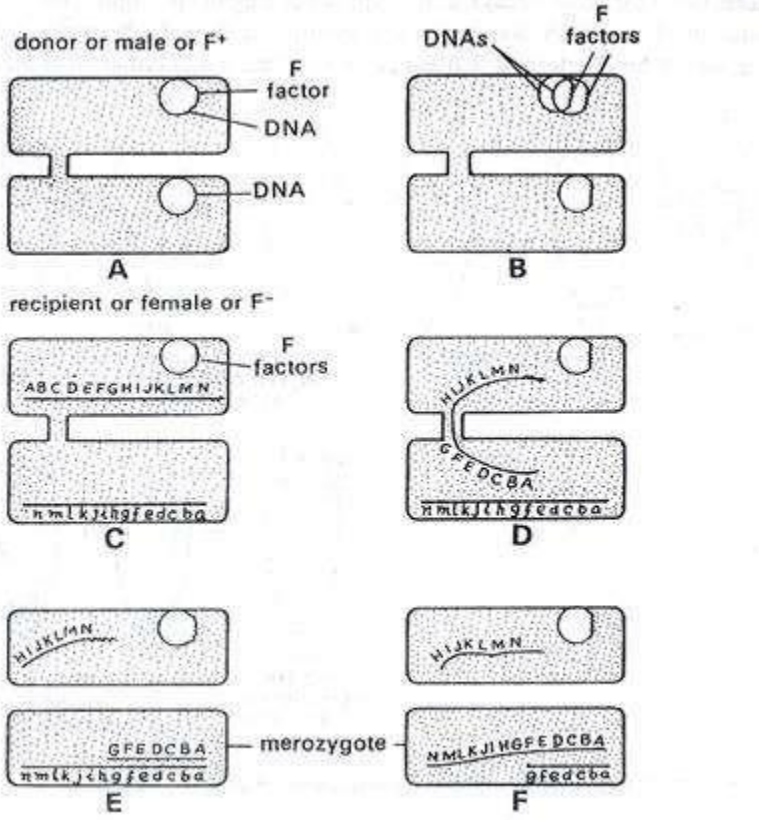


Fig. 2.23. Bacteria. Conjugation between sterile male and female of *Escherichia coli*.

In conjugation one way transfer of genetic material takes place from donor to recipient strain. The donor and recipient strains are always determined genetically. Recipient strain is designated as F, while donor strains are of two kinds and are designated as F^+ and H fr (high frequency of recombination). If the strain donates only a small portion of its genome it is called F^+, and if it donates large amount of genome it is called H fr. These F^+ and H fr factors are called episomes.

Strains F^+ and Hfr are characterised by the presence of specific flagellum like structures, the so called sex pilus. The sex pilus is absent in F^+ strains, and is responsible for bacterial mating. Sex pili of F^+ and H fr touch the opposite mating type of cells specifically to transfer the genetic material.

Sex pilus has a hole of 2.5µm diameter which is large enough for a DNA molecule to pass through it lengthwise. At the time of pairing DNA of H frstrain (donor) is transferred to F^- strain (recipient) immediately. The circular DNA of H fr cells opens and replicates but during transfer, one strand of DNA is newly synthesized, whereas the other strand is derived from a pre-existing strand of H fr strain. After transfer of DNA both the cells are separated from each other.

The H fr DNA after leaving apart its fragment to recipient cell again reforms in circular manner. In F^- strain genetic recombination takes place between donor fragment and recipient DNA. Gene transfer is a sequential process a given H fr strain always donates genes in a specific order. If F^- and H fr strains are allowed to mix in a suspension, different genes in a sequence of time are transferred from the genome of H fr to F^- strain. Genes that enter early, always appear in larger percentage of the recombinations than do genes that enter late, (see figs. 2.22, 2.23 and 2.24).

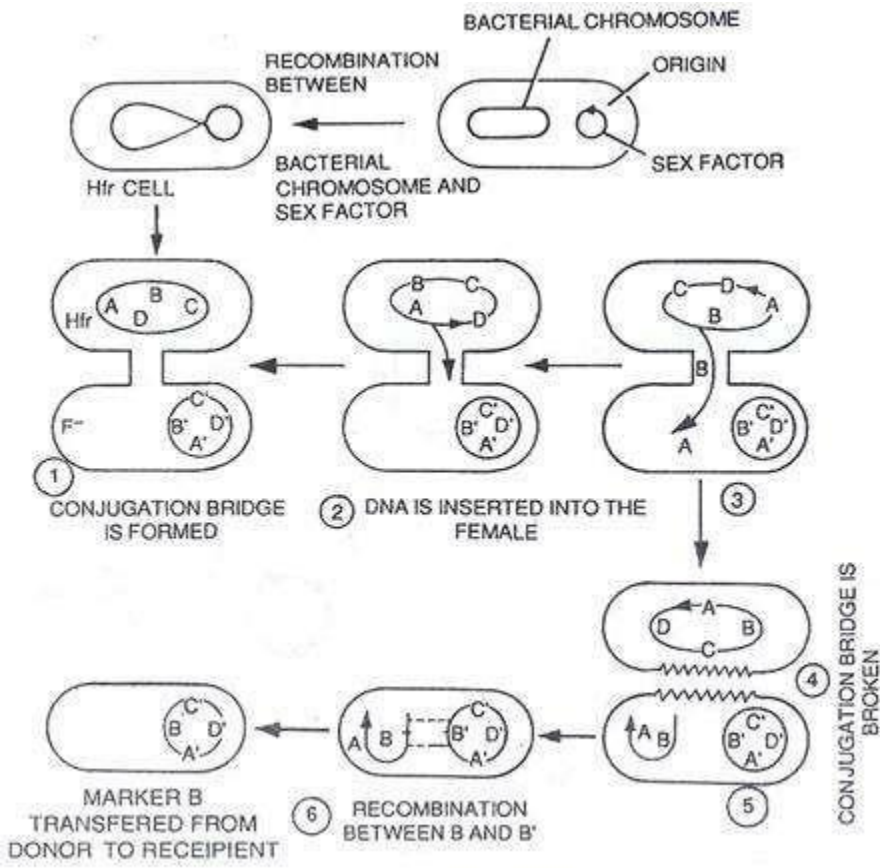


Fig. 2.24. Bacterial conjugation

Conjugation results in a number of recombinants in a suspension of F^+ and H fr cells. These recombinants are variable in their genotypic constitution and so also in their phenotypic expression. These recombinants are entirely new and different from their parents.

Economic Importance of Bacteria:

Bacteria play very important role in the continuous sustenance of life. They are man's best friends as well as enemy. There are many useful as well as harmful bacteria around us. Economic importances of bacteria are studied under two headings they are Beneficial activities and Harmful activities. Beneficial Activities are studied under three headings.

A.Agricultural Importance:

i) Dead and decay of organic matter-saprophytic bacteria eg. *Clostridium*, *Staphylo*, Coccus, salmonella etc acts upon the organic matter and disintegrates them converting valuable fertilizer.

ii) Nitrification:- It is a process of conversion of organic substance into nitrate form which are utilized by green plants easily. EgNitrifying bacteria like ammonia salts (*nitrosomes* and nitrococcus) to nitrites (nitrobacter) – Nitrates

iii) Nitrogen fixation- in the air present 78% of nitrogen, but atmospheric nitrogen cannot be utilized by plants directly. The process of conversion of atmospheric nitrogen into molecular nitrogen by bacteria.Eg*Rhizobium*, Azobactor, Clostridium is called Nitrogen fixation.

iv) Soil fertility- soil bacteria plays important role for the soil fertility. When soil will be fertile, automatically agricultural production will be increased. Eg- Fusarium and other soil bacteria.

v) Manure- saprophytic bacteria acts on animal dung, farm refuse and organic wastage of industrial house resulting manure which is the best for agricultural production.

vi) Ensilage

vii) GobarGasPlant

B) IndustrialImportance

i) Milk is converted into curd by the action lactic acid bacteria.

ii) Cheese- Milk first coagulated by chemical reagent and converted into spongy, soft, tasty cheese.

iii) Vinegar Production- Mycoderm bacteria converts sugar and sugary substance into acetic acid or vinegar.

iv) Alcohol and acetone production.

Molases (Sugary substance)--------(fermentation/Clostriduim)---- Acetone + Alcohol

v) Curing and ripening of tea and tobacco leaves- when harvested leaves and hung in shed, they will be acted by bacteria micrococcus resulting flavor and tasty.

vi) Fibre retting- the intact firbres of jute, hemp, flax,etc are separated by bacterial action. Fibre

plant when immersed in water acted by bacteria dissolves pactic substances of middle la,ella and yiekdsfibres, which are used for many commercial uses e.g. Making different kinds of ropes bags,shoesetc

vii) Leather tanning-bacteria are used to convert skin of animal (hide) into leather. Recently replaced by chemical for tanning.

C) Medicinal Importance

i) Vitamin B- Riboflavin obtained from clostridium

ii) Antibiotics-Different antibiotics are obtained from bacteria's like Thyromicin antibiotic by bacillus brevis bacteria. Subtilin antibiotics obtained by bacillus substises.

Harmful Activities of Bacteria:

About 90% of human and disease are caused by bacteria

1) Animal Diseasei)

i) Cholera- Vibrio cholera

ii) Tuberclosis- Mycobaterium tuberculosis

iii) Leprosy- Mycobacterium leprae

iv) Typhoid- Bacillus typhosus

v) Tetanus- Clostridium tetani

vi) Pneumania-Dilplococcuspnemoniae

Plant diseases caused by bacteria

i) Citrus Canker- Xanthomonascitri

ii) Leaf blight of rice- Xanthomonasoryzae

iii) Bacteria blight of bean- Xanthomonasphaseoli

2) Spoilage of food stuff- Sporophytic bacteria acts upon different food stuff resulting unfit for eating.

3) Food poisoning- Some bacteria like Staphylococcus aureus secrets toxic substance due to which food becomes poisonous resulting even death too.

4) Deterioration of Domestic articles- Wooden articles, fibres, leather deteriorate by action of bacteria eg (Spirochaetecytophaga)

5) Denitrification and desulphurification of soil-plants can absorb NO3 and SO¬4 form of

nitrogen and sulphur by the process of nitrification and sulphurificarion. But there are some harmful bacteria which convert NO3 and SO4 form of nitrogen and sulphur into NO2 and H2S which are not utilized. Hence, bacteria are our friend as well as enemy.