ENTRI

MICROBIOLOGY

BACTERIA

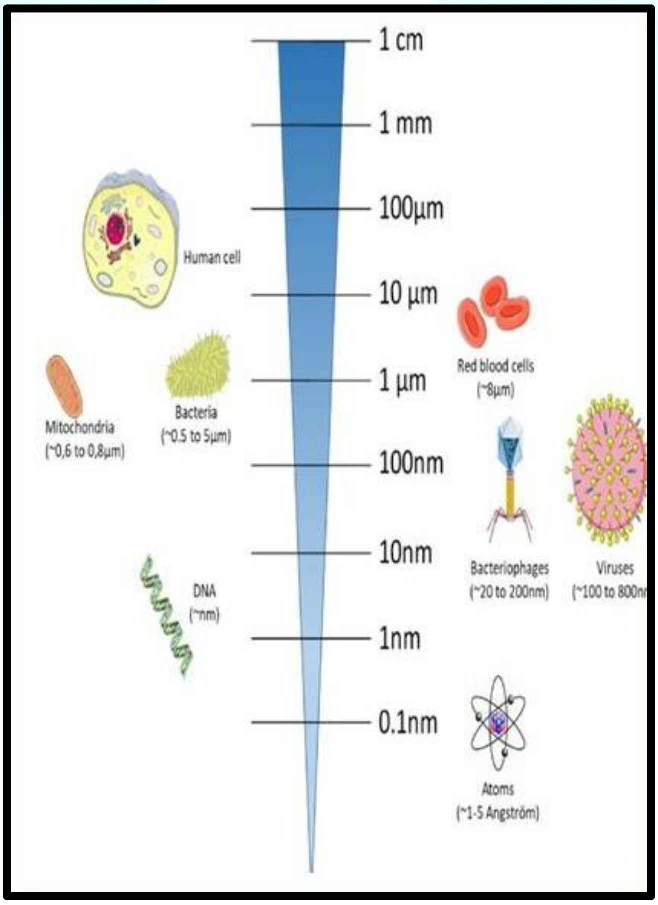
MORPHOLOGY OF BACTERIA

SIZE:

- Bacteria are prokaryotic, unicellular microorganisms, which lacking chlorophyll.
- The cell structure is simpler than that of other organisms as there is no nucleus or membrane bound organelles.
- Due to the presence of a rigid cell wall, bacteria maintain a definite shape, though they vary as shape, size and structure.
- In general, bacteria are between 0.2 and 2.0 µm - the average size of most bacteria.
- *E. coli*, a bacillus of about average size is 1.1 to 1.5 µm wide by 2.0 to 6.0 µm long.
- Spirochaetes occasionally reach 500 µm in length and the cyanobacterium.
- *Oscillatoria* is about 7 µm in diameter.
- The bacterium, *Epulosiscium fishelsoni* , can be seen with the naked eye (600 µm long by 80 µm in diameter).
- One group of bacteria, called the Mycoplasmas, have individuals with size much smaller than these dimensions.
- They measure about 0.25 µ and are the smallest cells known so far. They were formerly known as pleuropneumonia-likeorganisms (PPLO).
- *Mycoplasma gallicepticum, with* a size of approximately 200 to 300 nm are thought to be the world smallest bacteria.
- *Thiomargarita namibiensis* is world's largest bacteria, a gram-negative.
- Proteobacterium found in the ocean sediments off the coast of Namibia.
- Usually it is 0.1—0.3 mm (100—300 µm) across, but bigger cells have

been observed up to 0.75 mm (750 µm).

- Research studies have shown their size to play an important role in survival over time.
- Due to their small size, bacteria are able to exploit and thrive in various microenvironments.
- The small size of bacteria is also beneficial for parasitism and oligotrophy.
- Bacteria can continue relying on a range of hosts (large and small) for their nutrition. In addition, they can also live and survive in environments that contain a low concentration of nutrients.
- Bacteria have a high surface area to volume ratio that allows them to take up as many nutrients as possible for survival. In the process, they are able to continue growing and reproducing at a steady rate.



SHAPES AND ARRANGMENT

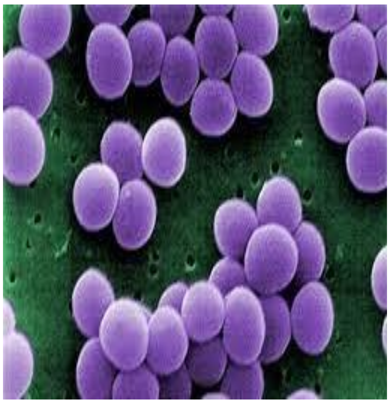
❖ Due to the presence of a rigid cell wall, bacteria maintain a definite shape, though they vary as shape size, structure and arrangement.

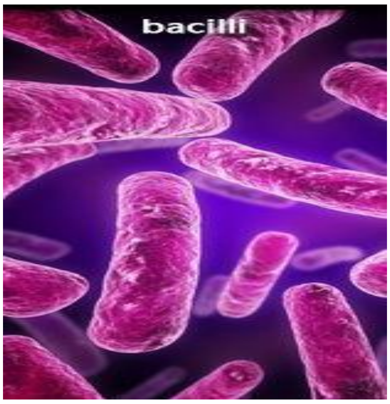
SHAPES:

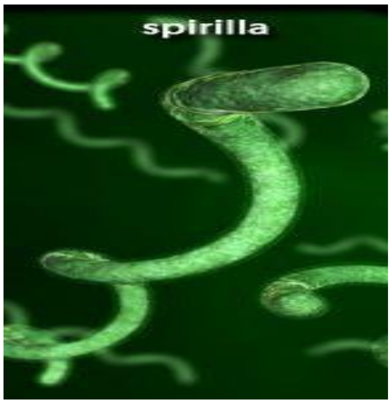
❖ When viewed under light microscope, most bacteria appear in variations of three major shapes:

1. Cocci
2. Bacilli
3. Spirilla

	NAME	SHAPE & HABIT
1.	Cocci (coccus for single cell)	• Round cells. • sometimes slightly flattened when they are adjacent to one another.
2.	Bacilli (Bacillus for a single cell)	• Rod-shaped bacteria.
3.	Spirilla (Spirillum for a single cell)	• Curved bacteria which can range from a gently curved shape to a corkscrew-like spiral. • Many spirilla are rigid and capable of movement. • A special group of spirilla known as spirochetes are long, slender, and flexible.







ARRANGEMENTS

❖ So far as the arrangement is concerned, it may Paired (diplo), Grape-like clusters (staphylo) or Chains (strepto).

1. Arrangement of Cocci

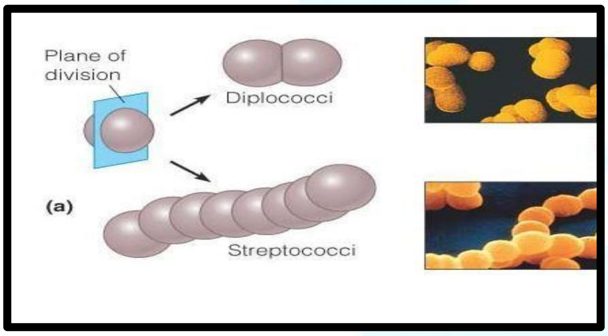
❖ Cocci bacteria can exist singly, in pairs (as diplococci), in groups of four (as tetrads), in chains (as streptococci), in clusters (as staphylococci), or in cubes consisting of eight cells (as sarcinae).

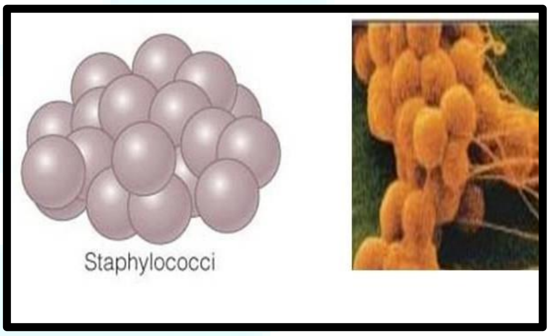
❖ Cocci may be oval, elongated, or flattened on one side. Cocci may remain attached after cell division. These group characteristics are often used to help identify certain cocci.

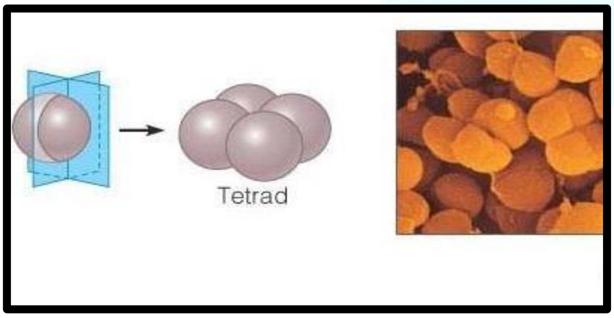
1. Diplococci
2. Streptococci
3. Tetrads
4. Sarcinae
5. Staphylococci

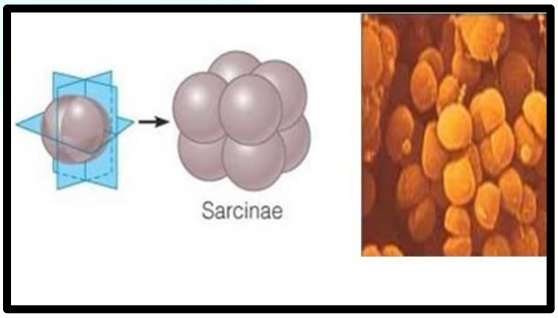
NAME	ARRANGEMENT	EXAMPLES
1. Diplococci	• The cocci are arranged in pairs.	*Streptococcus pneumoniae, Moraxella catarrhalis, Neisseria gonorrhoeae,* etc.
2. Streptococci	• The cocci are arranged in chains, as the cells divide in one plane.	*Streptococcus pyogenes, Streptococcus agalactiae*
3. Tetrads	• The cocci are arranged in packets of four cells, as the cells divide in two plains. • Following division, the cells remain attached and grow in this attachment.	*Aerococcus, Pediococcus Tetragenococcus*
4. Sarcinae	• The cocci are arranged in a cuboidal manner, as the cells are formed by regular cell divisions in three planes. • Cocci that divide in three planes and remain in groups cube like groups of eight. • Some of the characteristics	*Sarcina ventriculi, Sarcina ureae, etc.*

	associated with these bacteria include being strict anaerobes, Gram-positive bacteria and that measure between 1.5 and 3.0 um.	
5. Staphylococci	• The cocci are arranged in grape-like clusters formed by irregular cell divisions in three plain. • As members of the family Streptococcaceae, this group of bacteria is characterized by being non-motile, Gram-positive organisms	*Staphylococcus aureus*







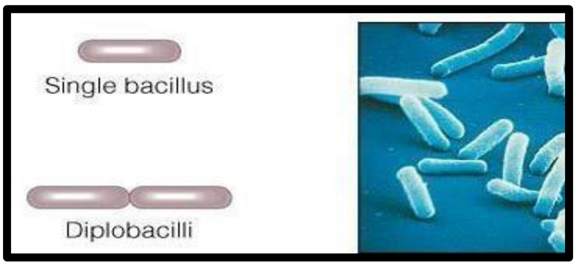


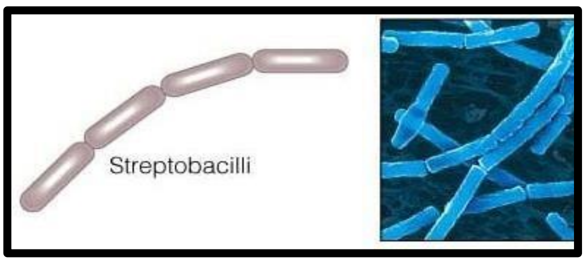
2. Arrangement of Bacilli

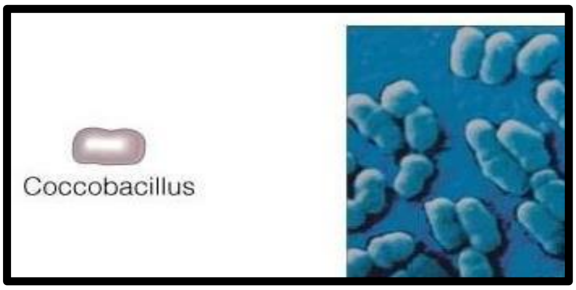
❖ The cylindrical or rod-shaped bacteria are called 'bacillus' (plural: bacilli). These group characteristics are often used to help identify certain bacilli.

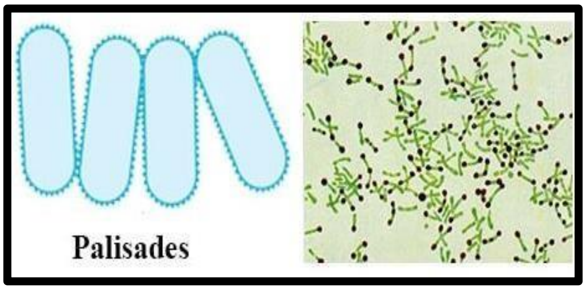
1. Diplobacilli
2. Streptobacilli
3. Coccobacilli
4. Palisades

NAME	ARRANGEMENT	EXAMPLES
1. Diplobacilli	• Like Diplococci bacteria, Diplobacilli occur in pairs. • Following cell division, the two cells do not separate and continue existing as a pair.	Single Rod: *Bacillus cereus.* Diplobacilli: *Coxiella burnetii, Moraxella bovis, Klebsiella rhinoscleromatis,* etc.
2. Streptobacilli	• The bacilli are arranged in chains, as the cells divide in one plane.	*Streptobacillus moniliformis*
3. Coccobacilli	• These are so short and stumpy that they appear ovoid. • They look like coccus and bacillus.	*Haemophilus influenzae*, *Gardnerella vaginalis*, and *Chlamydia trachomatis.*
4. Palisades	• The bacilli bend at the points of division following the cell divisions, resulting in a palisade arrangement resembling a picket fence and angular patterns that look like Chinese letters.	*Corynebacterium diphtheriae*









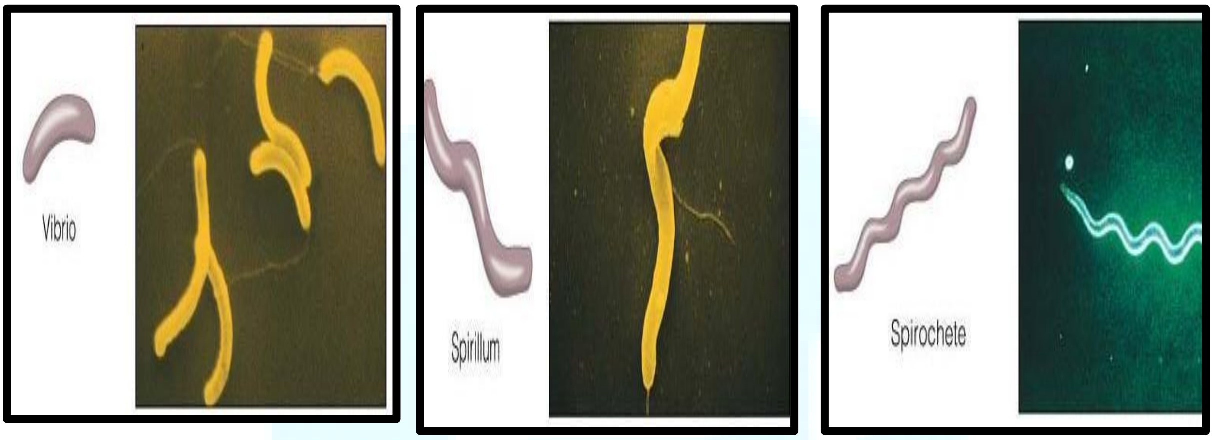
3. Arrangement of Spiral Bacteria

❖ Spirilla: (or spirillum for a single cell) are curved bacteria which can range from a gently curved shape to a corkscrew-like spiral. Many spirilla are rigid and capable of movement. A special group of spirilla known as spirochetes are long, slender, and flexible.

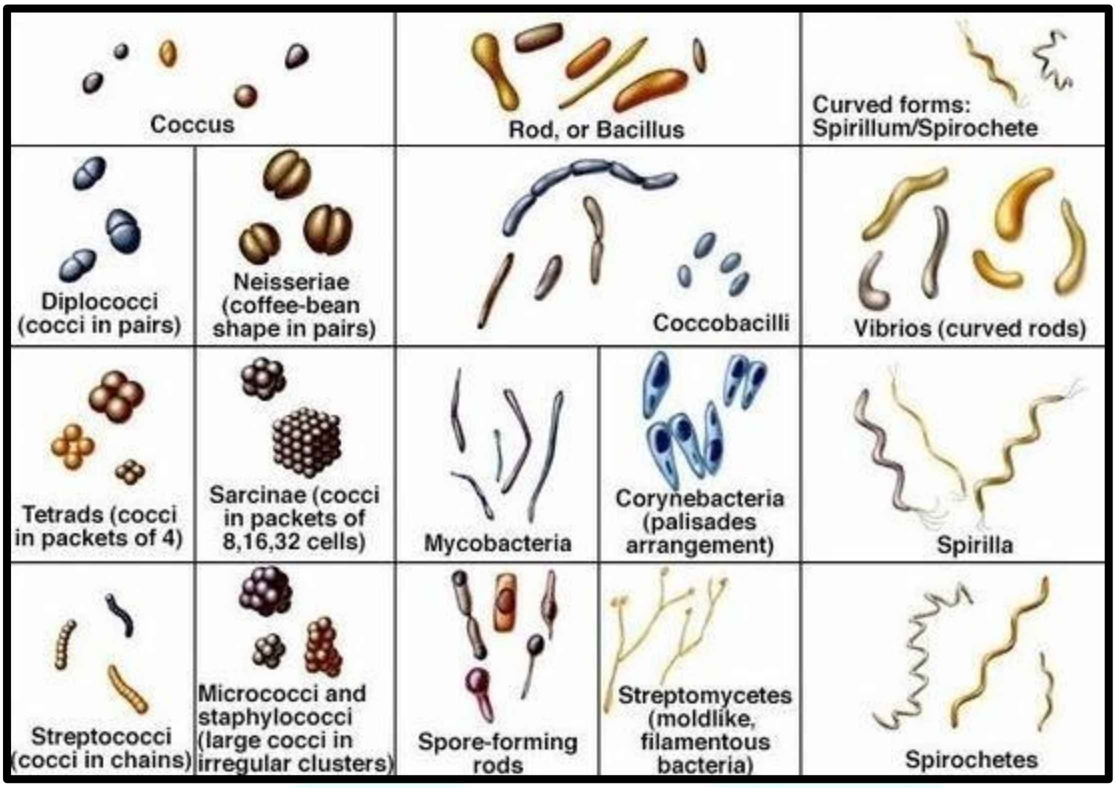
1. Vibrio
2. Spirilla
3. Spirochetes

NAME	ARRANGEMENT	EXAMPLES
Vibrio	• They are comma-shaped bacteria with less than one complete turn or twist in the cell.	*Vibrio cholerae*
Spirilla	• They have rigid spiral structure. • Spirillum with many turns can superficially resemble spirochetes. • They do not have outer sheath and endoflagella, but have typical bacterial flagella	*Campylobacter jejuni*, *Helicobacter pylori*, *Spirillum winogradskyi.*
Spirochetes	• They have a helical shape and flexible bodies. • Spirochetes move by means of axial filaments, which look	*Leptospira* species, *Treponema pallidum*, *Borrelia recurrentis*

	like flagella contained beneath a flexible external sheath but lack typical bacterial flagella. ● The movement involves the use of axial filaments, which is one of the distinguishing features between the bacteria and other types of bacteria	

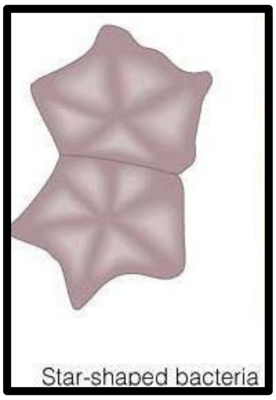


SHAPE AND ARRANGMENT OF BACTERIA



Others Shapes and Arrangements of Bacteria;

NAME	ARRANGMENT	EXAMPLES
Filamentous Bacteria	They are very long thin filament-shaped bacteria. Some of them form branching filaments resulting in a network of filaments called 'mycelium'.	*Candidatus Savagella*
Star Shaped Bacteria	Look like stars (star-shaped)	*Stella humosa*
Rectangular Bacteria	They are rectangular in shaped.	*Haloarcula* spp
Pleomorphic Bacteria	These bacteria do not have any characteristic shape unlike all others described above. They can change their shape. In pure cultures, they can be observed to have different shapes	*Mycoplasma pneumoniae, M. genitaliu*



ULTRA STRUCTURE OF BACTERIA

❖ Like other living plant cell, bacterial cell comprises a cell wall and protoplast.

1. Slime layer/ Capsule:

- Slime layer is a gelatinous layer present on the outer surface of cell wall, composed of polysaccharides and polypeptide chain of amino acids.
- When its constituents are only polysaccharides which form a viscous layer, it is called slime layer, but when nitrogenous substances (i.e., amino acids) are also present along with polysaccharides, then it is called capsule.
- The capsulated cells are drought resistant. Association of polysaccharides with others makes it antigenetically important (used in serology).
- Mucopolysaccharieds help bacteria to remain in body without damage. Mucopolysaccharides have virulence (bacteria genetically capable of producing capsule if are pathogenic).
- If capsule is removed the cells will die. It means that for survival capsule is must.
- Mucopolysaccharides are sometimes associated with Ca^{2+}, Mg^{2+} ions for holding higher amount of water.
- The capsule is removed by chelating polysaccharides like EDTA or EDTA + NaCl in which cells after shaking, shed off capsule.
- In *Streptococci*, *Staphylococci* mucilage capsule is present only

when cells are dividing rapidly. Slime/ Capsule protects cells from lysozyme activity.

2. Cell wall:

- In the electron micrograph the cell wall is seen as thin, sharply defined enveloped around the protoplast.
- It range in thickness around 0.02µ. The cell wall is tough though flexible.
- The inert and somewhat rigid cell wall limits the volume occupied by the protoplast and thus gives rigidity and shape to the bacterial cell. It show granular and lacks microfibrils.

(a) Structure of cell wall:

- The bacterial cell wall is composed by 4 layers. Of these two are of higher electron density.

- The outer layer (L4) is wavy. Within it is the lighter layer of low electron density (L3).

- Next comes the inner dense or darker layer (L2), is considered to be mucopeptide followed by the innermost layer of low electron density (L1).

(b) Chemical composition of cell wall:

- The three main constituents of cell wall are: (i) N-acetyl glucosamine (NAG), (ii) N-acetyl muramic acid (NAM), and (iii) a peptide chain of four or five amino acids.
- These together form a polymer called peptidoglycan or mucopeptide.
- The NAG and NAM molecules which are arranged alternatively, run in one direction and the peptide chain run crosswise.
- The rigidity of bacterial cell wall is due to the presence of this polymer. Besides above mentioned three constituents, some other chemicals such as teichoic acid, protein polysaccharides, lipoproteins. Lipopolysaccharides are also deposited on it.

- The Gram stain, developed in 1884 by Hans Christian Gram, characterizes bacteria based on the structural characteristics of their cell walls as; Gram positive and gram negative.
- The thick layers of peptidoglycan in the "gram-positive" cell wall stain purple, while the thin "gram-negative" cell wall appears pink. A comparison between Gram-positive and Gram-negative bacteria is given:

Characteristics	Gram-positive bacteria	Gram-negative bacteria
Cell wall structure	• Single layered and 150-200A° thick	Triple layered and 75-120A° thick
Outer membrane	• Absent	• Present
Periplasmic space	• Present in some	• Present in all
Chemical compositio n	• Peptidoglycans accounts about 80% of the cell wall. • The rest are polysaccharides, teichoic acid present, low in lipid (1-4%), highly responsive to triphenylmethane, resistant to alkalies and insoluble in 1% KOH solution.	• Peptidoglycans accounts only 3-12% of the cell wall. • Mainly composed of lipoproteins and lipid polysaccharides, teichoic acid absent. • High in lipid (11-22%), little response to triphenyl methane, show sensitivity to alkalies and soluble in 1% KOH solution.
Rigidity	• Highly rigid due to high proportion of peptidoglycans	• Elastic due to plastic nature of lipoprotein-polysaccharide mixture.
Susceptibility	• High susceptibility	• Low susceptibility

Nutritional requirement	• Relatively complex in many species	• Relatively simple
Permeability	• More penetrable	• Less penetrable

3. Protoplast:

- A living, slightly viscous stuff called protoplast is differentiated into:

a) *Cytoplasmic membrane:*

- Inner to cell wall, a semipermeable cytoplasmic membrane is present which is about 75 A^{o} thick.
- Chemically it is composed of a double layer of phospholipid molecules. Proteins are found embedded in the lipid bilayers.
- The cytoplasmic membrane has many folded structures called mesosomes which are associated with number of activities like seat for protein synthesis, respiratory function, multiplication of chromosomal DNA, and DNA.
- Plasma membrane contains special receptor molecules that help bacteria detect and respond to chemicals in their surroundings. It also controls the entry of organic and inorganic molecules.

b)Cytoplasm:

- Bacterial cytoplasm is a complex mixture of carbohydrates, proteins, lipids, minerals, nucleic acids and water.
- It stores organic material in the form of glycogen, rolutin and poly-β-hydroxy butyrate. Besides fluid portion and storage particles, the bacterial cytoplasm also contain chromatic or nuclear area and some other inclusions.
- The bacterial cell is devoid cell organelles but the photosynthetic bacteria have chromatophores in their cytoplasm.

❖ Ribosomes are the sites of protein synthesis and suspended freely in cytoplasm. Their number varies from 10,000 to 15,000 in a cell.

❖ Bacterial ribosmoes are 70s type (50s and 30s subunits) consists of two subunits. Mesosomes are complex localized infoldings of the cytoplasmic membrane and higher in bacteria which show high respiratory activity, such as nitrifying bacteria.

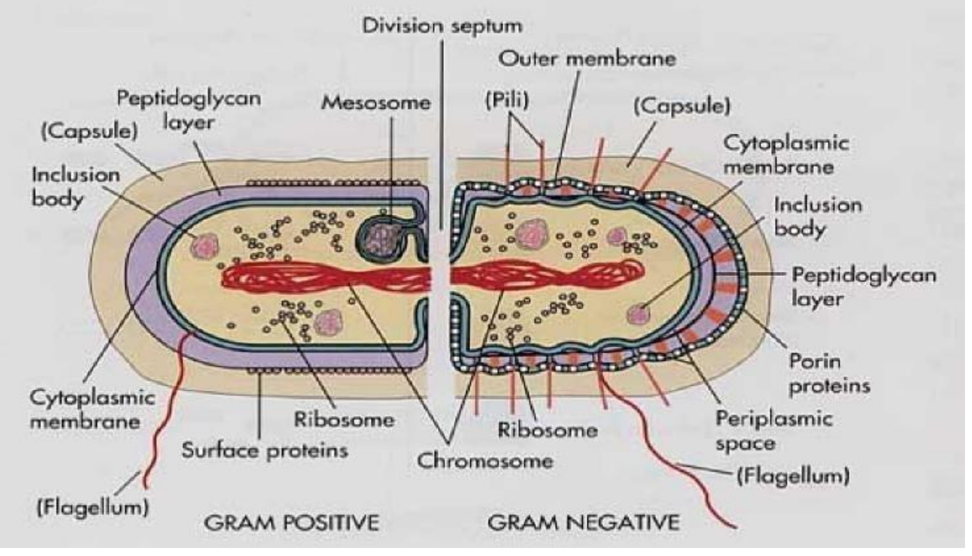
- ❖ It has been suggested that mesosomes serves to accommodate more centres of respiration. But the absence of enzymes like ATPase, dehydrogenase and cytochrome in mesosome indicates that they are not the sites of respiration.
- ❖ They probably participate in the formation of transverse septum during cell division.

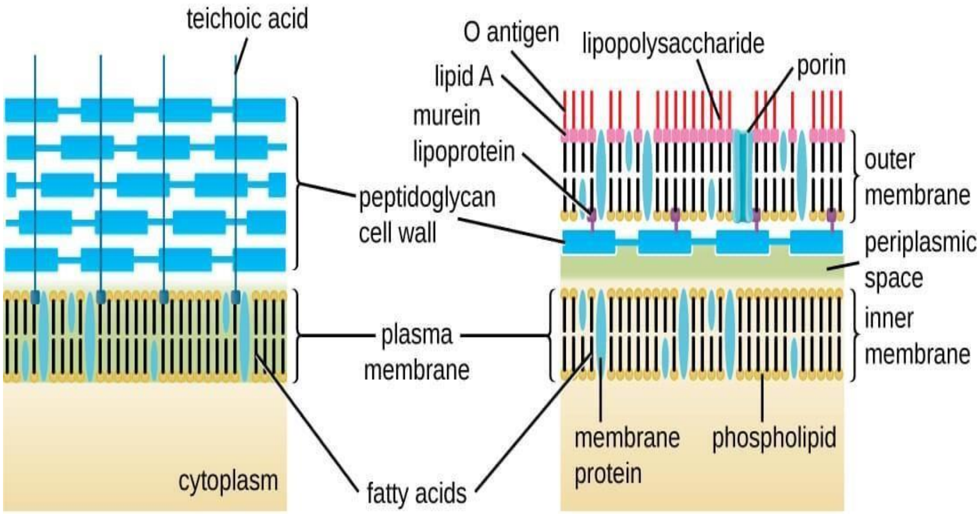
(c) The nuclear apparatus:

- The bacterial nucleus devoid of nuclear membrane, nucleolus, chromonemata and nuclear sap, such structure is called nucleoid or genophore.
- The DNA molecule (may be double or single) is approximately 1,000 μm long, usually forming ring like structure or sometimes remain diffused throughout the cytoplasm of the cell.
- The Bacterial DNA is devoid of histones and referred as bacterial chromosome. Bacterial cells also contain some extrachromosomal heredity determinants which are either independent of bacterial chromosomes or are intergrated with them called plasmid.
- Extranuclear materials called as episome are present which may be linear, circular, covalent coiled circular. Lederberg (1952) gave the term plasmid to those extragenophoral genetic materials.
- The replication of plasmid seems self controlled. They contain different non- essential characters.
- Based on host properties, the plasmids are classified into different types as:
    - F-factor for fertility
    - Col-factor for colicinogeny
    - R-factor for resistance
    - Tumor inducing plasmid (*Agrobacterium*)
    - Degradative plasmid (*Pseudomonas*)
    - Pathogenicity to mammals
    - Penicillase plasmid (*Staphylococcus*)
    - Mercury resistance
    - Cryptic plasmids

- Two important genes are associated with plasmids *ori* (origin of replicon) and *tra* (transfer).

ULTRA STRUTURE OF BACTERIA





LOCOMOTION IN BACTERIA

- Some bacteria are self motile. They are swim through the liquid in which they live. They can't crawl over dry surface or f ly through the air. Motility is universal among the spirilla, common among the bacilli but lacking or rare in cocci forms.
- The organ of the locomotion is small whips or hair like appendages called flagella.

Flagellation

- The flagella are distributed over the surface of the bacterial cell in a characteristic manner. Their number, position and arrangement varies with the species. On the basis of the flagellation and arrangement the bacterial cell can be classified as;

(a) Polar flagellation:

- This type of flagellation is restricted to a rather homogenous group of bacilli and spirilla. They are all gram negative. These are the following type;

1. **Monotrichous**

2. **Amphitrichous**

3. **Cephalotrichous**

4. **Lophotrichous**

NAME	HABIT	EXAMPLES
Monotrichous	One f lagella at one end.	*Vibrio chlolerae, Pseudomonas*
Amphitrichous	One f lagella at each end.	*Nitosomonas, Spirillum*
Cephalotrichous	Two or more f lagella at one end only.	*Pseudomonas fluorescens*
Lophotrichous	Tufts of f lagella at both the ends.	*Spirillum volutans*

(c) Non-polar flagellation:

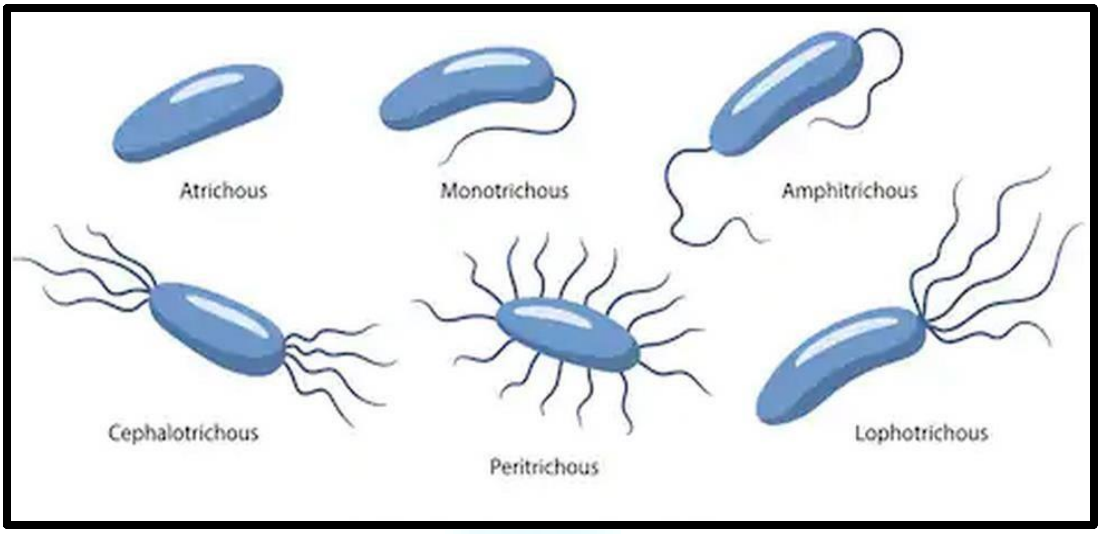
- In this case f lagella distributed uniformly all over the body surface.

1. **Peritrichous:** Flagella distributed evenly all over the body. Eg:- *Proteus vulgaris*.

2. **Atrichous:** Bacteia which lack f lagella. Eg. *Lactobacillus*

ARRANGMENT AND STRUCTURE OF FLAGELLA

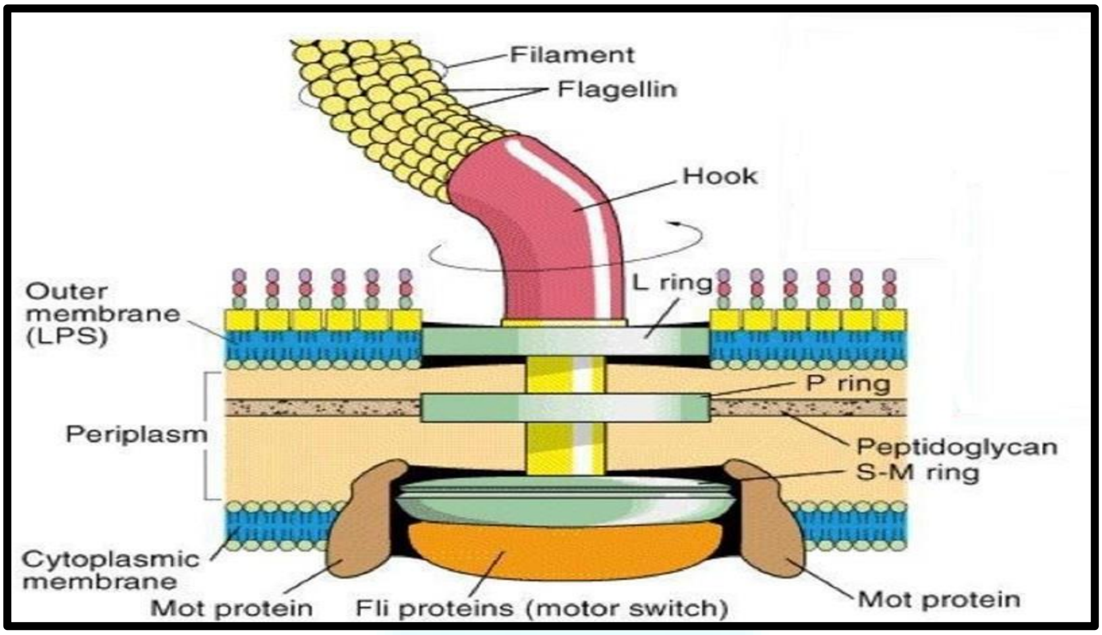
STRUCTURE OF FLAGELLUM



- Flagella in bacteria has special significance (a) a hook is always present and is never straight (b) eukaryotic flagella has 9+2 arrangements of microtubules with association to each other have protein attachments called spokes.

- Laterals of peripheral tubules are made of protein dinein; but in prokaryotes like bacteria flagella organization is simple. Flagellum is made up of contractile protein called flagellin.

- There are polymers of this attached laterally/longitudinally by special bondage with the result that there may be 5-6 subunits arranged in spirals creating hollow in centre.



- Basal body structure in both eukaryotes and prokaryotes are different. In prokaryotes the basal subunits has only 4 discs. Through hook flagellum passes and whole structure is joined by a f lagellin rod.

- A sort of lever system is provided by these rings. A fixed position of rod L, P, S have a hollow centre through which rod passes and act as bearings of movement of flagella. Periplasmic space provides the force for rotation by ionic strength and the source of motion is not ATP.

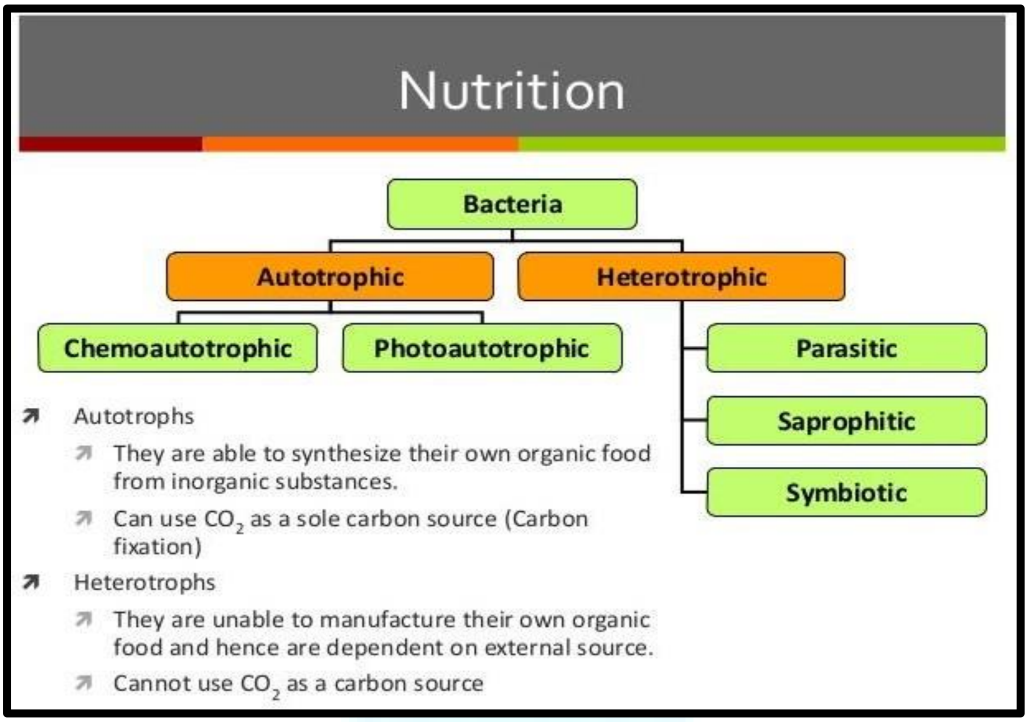
- In gram negative bacterium peptidoglycan layer is very small and only 2 rings are available and hook is not as rigid. If bacterium is present in water, the resistance to the cell is very large.

- Thus for movement very high force is required, usually the movement is anticlockwise. With this movement the cell is pushed forward. This rotation is not constant. After sometime the cell either stops or f lagella changes its direction to clockwise movement.

- Thus the movement of bacteria is zig-zag or Brownian movement. Rotation of flagella is unique. Motion is controlled by ionic balance in periplasmic space.

NUTRITION IN BACTERIA

- Most of the bacteria do not contain chlorophyll. They are unable to synthesize their own food, but a small group of bacteria are capable of synthesizing their own food.
- So, nutrition in bacteria is both autotrophic and heterotrophic.



1) Autotrophic bacteria:

- The bacteria which synthesis their own food (organic compound) necessary for structure and metabolism from the simple inorganic compound, is called autotrophic.
- They are further divided into 2 types, photosynthetic and chemosynthetic according to the energy utilization. Thus the former called photosynthetic autotrophs and the later non- photosynthetic autotrophs.

a. Photosynthetic Bacteria:

- They can prepare their food by using solar energy in the presence of photosynthetic pigment bacteriochlorophyll and chlorobium chlorophyll. Photosynthesis in bacteria differs from other green plants because there is no release of oxygen in photosynthesis. Such photosynthesis is called anoxygenic photosynthesis. It is of following types:

    i. Green sulphur bacteria: The photosynthetic pigment is chlorobium chlorophyll and sulphur is by- product. e.g: *Chlorobium*.

    ii. Purple sulphur bacteria: The photosynthetic pigment is bacteriochlorophyll and sulphur is by- product. e.g: *Chromatium*.

    iii. Non-sulphur bacteria: The photosynthetic pigment bacteriochlorophyll and sulphur is not a by-product. e.g: *Rhodopseudomonas*.

b. Chemosynthetic Bacteria:

- These bacteria prepare their food by using chemical energy in the absence of photosynthetic pigment. They get energy for food synthesis by the oxidation of certain inorganic substances such as ammonia, nitrites, nitrate, ferrous iron, hydrogen sulphides and a number of metalic or non matelic materials avialable in the environment.
- The bacteria absorb inorganic molecules of the substance into the body where the chemical reaction takes place . In this reaction the chemical bonds are broken and energy is resleased. This energy is used by the bacteria and this process is called chemosynthesis. It is following types:

    i. **Sulphur bacteria:** They use chemical energy while there is oxidation of sulphur compound. E.g: *Thiobacillus*

    $$2H_2S \text{ or } S_2 + O_2 \Longrightarrow 2S + 2H_2O + \text{energy}$$

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ii. **Iron bacteria:** They use chemical energy while there is oxidation compound (Fe^{2+} to Fe^{3+}). E.g: *Leptothrix, Ferobacillus, Cladothrix*

$4FeCO_3 + O_2 + 6H_2O \Longrightarrow 4Fe(OH)_3 + 4CO_2 + \text{Energy}$

iii. **Hydrogen bacteria:** They use chemical energy while there is oxidation of molecular hydrogen. E.g: *Pseudomonas, Hydrogenomonas, Bacillus pectotrophus.*

$H_2 + \frac{1}{2} O_2 \Longrightarrow H_2O + \text{Energy}$

iv. **Nitrifying bacteria:** They use chemical energy while there is oxidation of nitrogen compound. E.g: *Nitrosomonas, Nitrobacter*

$2NO_2 + O_2 \Longrightarrow 2NO_3 + \text{Energy}$

DIFFERENCE BETWEEN CHEMOSYNTHESIS AND PHOTOSYNTHESIS

Parameters	Chemosynthesis	Photosynthesis
Amount of energy	The amount of energy available in the chemosynthesis is much less as compare with photosynthesis	The amount of energy available in the photosynthesis is much more as compare with chemosynthesis
Gain of energy	There is no gain of energy from outside the planet	There is distinct gain of energy from the outside the planet.
Energy input	No light is involve in the process	It take place in the present of sun light

Type of energy	Reaction are all exothermic. Energy required for the process is obtained by the oxidation of certain inorganic substances available in the environment	The reactions are endothermic. Solar energy trapped by the pigment is process
Pigments	No pigments are required	Bacteriochlorophyll, chlorobium chlorophyll
Bacteria	Purple sulphur bacteria and green sulphur bacteria. E.g., Pseudomonas, Thiobacillus	Sulphur bacteria, iron bacteria, nitrifying bacteria, hydrogen bacteria. E.g., Rhodospirillum, Chlorobium
Example	$H_2S + CO_2$ ======è(CH_2O) + S + H2O (in the presence of sun light, pigment)	$4FeCO_3 + O_2 + 6H_2O$=======è$Fe(OH)_3 + 4CO_2$ + Energy

2) Heterotrophic bacteria:

- The heterotrophic bacteria which form the majority cannot synthesized organic compounds from the simple inorganic substances. Lacking the pigment they can not capture the solar energy which is essential for the synthesis the substances they need as food. Thus these type of bacteria live where the organic food is readily available either from living organism.

A.Saprophytic bacteria:

- They grow in dead, decaying organic material and live by digesting and absorbing them. These bacteria gradually break down complex organic compounds into simpler products. For doing so they secreting the enzymes.

- The break down of carbohydrate is called fermentation (e.g., Lactic acid bacteria). The break down of protein material called putrefaction (nitrifying bacteria.

B. Parasitic bacteria:

- Parasitic bacteria live on and within other organisms (host) and they obtain their nutrition from the host. They live on or within the organisms both plants and animals.
- If the parasitic bacteria cause diseases and are harmful for their host they are called pathogenic. If the parasitic bacteria cannot cause diseases and are harmless for their host they are called non- pathogenic. e.g.: *Vibrio cholerae, Diplococcus pneumoniae*.
- Many diseases including plant and animal including the man are caused by the pathogenic bacteria.

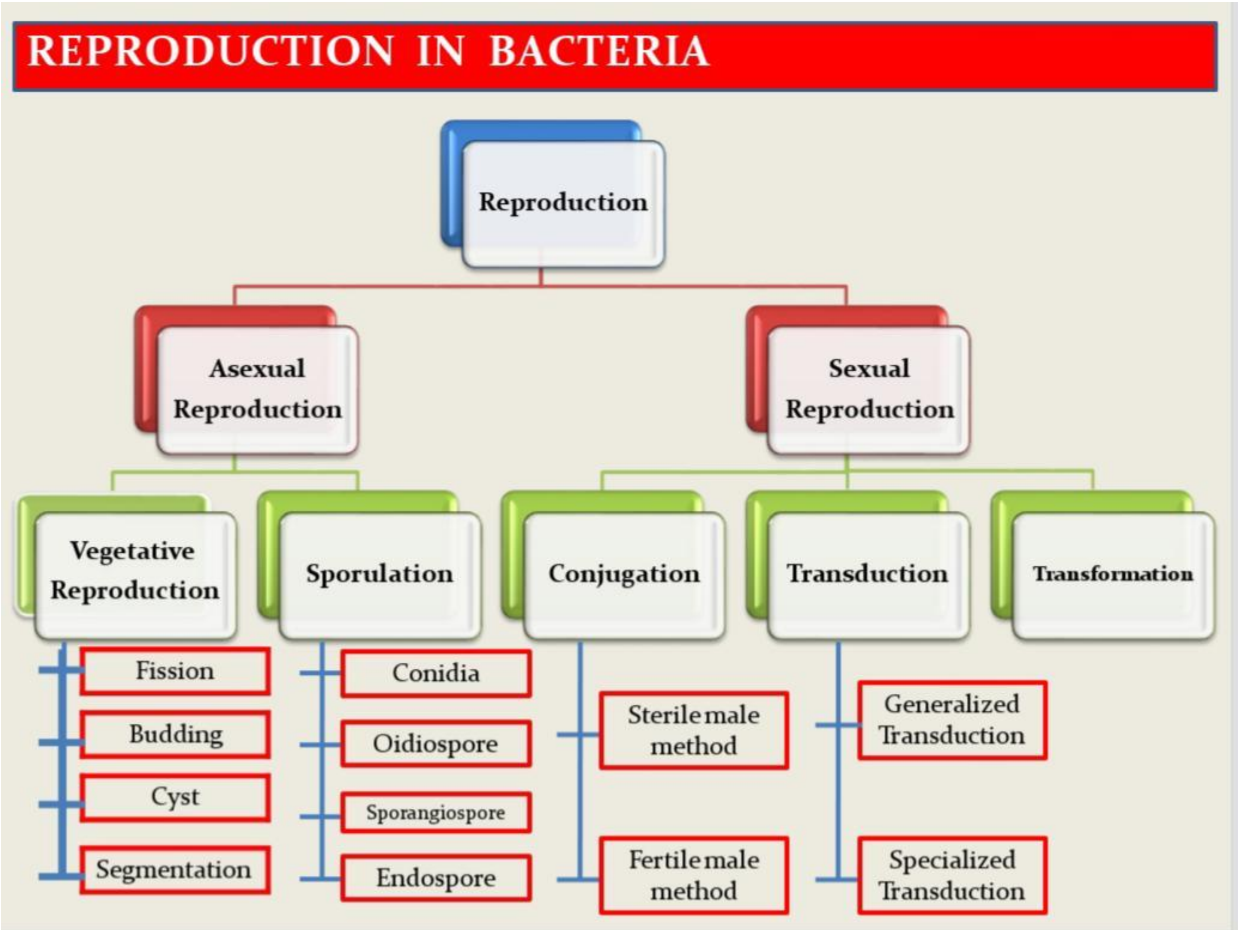
C. Symbiotic bacteria:

- Symbiotic bacteria live in close association with other living organisms so that they both are benefited to each other, neither of them is harmed. e.g.: *Rhizobium*.

- Certain plants establish a symbiotic relationship with bacteria, enabling them to produce nodules that facilitate the conversion of atmospheric nitrogen to ammonia.

- It appears that not only must the plant have a need for nitrogen fixing bacteria, but they must also be able to synthesize cytokinins which promote the production of root nodules, required for nitrogen fixation.

<u>REPRODUCTION IN BACTERIA</u>



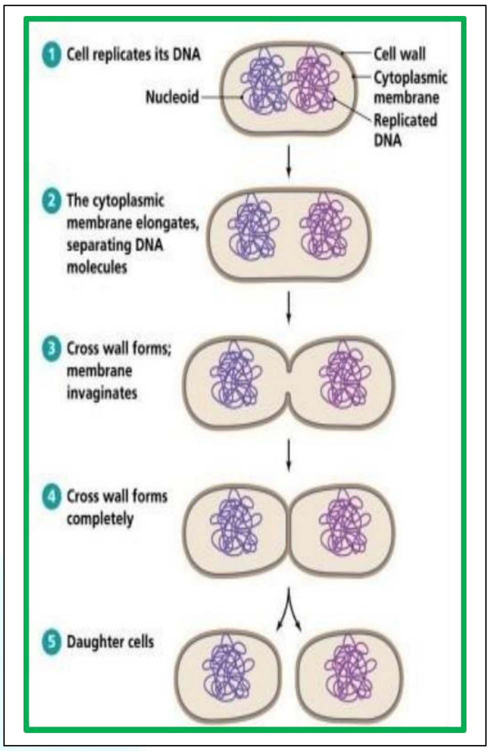
- Asexual reproduction is characteristic of all bacteria. Sexual reproduction was long through to be absent but investigation with the help of electron microscope have clearly demonstrated the exchange of genetic material in some species of bacteria.

1. ASEXUAL REPRODUCTION

- It take place by two methods: (i) Vegetative, (ii) Sporulation.

Vegetative reproduction: It take place by the following methods.

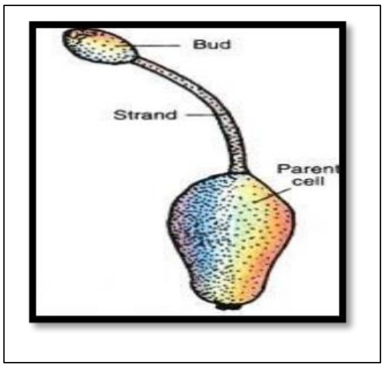
➢ Binary Fission:



- The most common way by which the bacteria reproduce itself is the Binary Process. It is a process by which a single bacterial cell simply divides into two in half an hour time.
- The various events of binary fission are as follows: The nucleoid gradually become elongated in size and form dumbel-shaped structure.
- They still remain attached to the plasma membrane with the help of mesosome.
- The duplication of DNA and mesosome takes place and get separate from each other.
- The daughter mesosomes and nucleoids migrate towards the opposite poles.
- The plasma membrane invaginates at the center and the parent cell is divided into two identical cells.

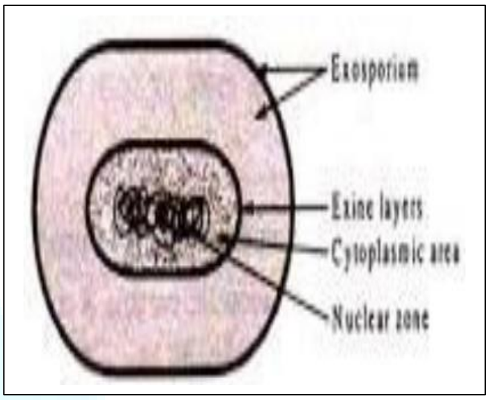
➢ Budding:

- 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.



- It is comparatively rare process observed in few bacteria like *Rhodopseudomonas, Hyphomicrobium, Pedomicrobium, Hyphomonas* etc. Hyphomicrobeales, commonly called the budding bacteria, a branch strand of cell wall material may be initiated prior to the separation of a bud.

➢ Cysts:



- In certain bacteria the entire protoplast of the cell recedes from the cell wall and becomes rounded.

- A thick wall is then secreted around it to form resistant structure somewhat similar to the endospore. It is called the cyst. These are formed in certain species of *Azobacter*.

- Under suitable environment conditions the cyst germinate to produce the new bacterium.

➢ Segmentation:

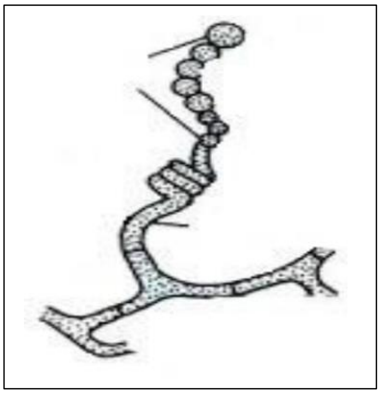
- In some other species of bacteria reproduce vegetative called segmentation. In this case the protoplast of the bacterium cell at some stage , divides to form very tiny body called gonidia.

- The cell wall ruptured and the librated tiny gonidia grow into new bacterium cell under suitable conditions

➢ Sporulation:

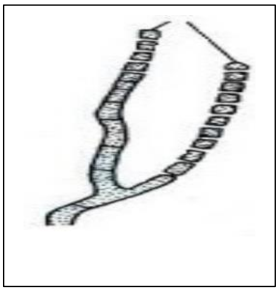
- Some bacteria produce   non   motile spores which are of the following types:

➢ Conidia:



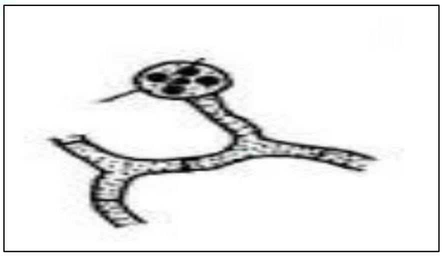
- Many filamentous bacteria (e.g., *Streptomyces*) form chains of small, spherical spore- like conidia at the tips of the filaments.
- A conidium develops by the formation of a transverse wall at the tip of the filament. The filament bearing conidia are known as conidiophores.
- After liberation each conidium gives rise to a new filamentous bacterium, provided conditions for germination are favourable.

➢ Oidiospores:



- In an another member Actinomyces he hypha instead of obstructing spore in succession at the free end, undergoes additional separation through its length to form numerous small reproductive units known as oidiospores.
- Each oidiospores on germination produces, a filamentous bacterium.

➢ Sporangiospores:

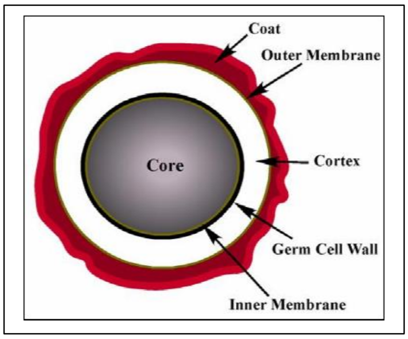


- In some branching bacteria sporangia like structure may developed at the end of certain hyphae. The protoplast of the sporangia may divided to form tiny sporangiospores.
- On liberation of these spores germinate under suitable condition, each producing a filamentous bacterium.

➢ Endospore

- During the unfavorable condition, eubacteria have the ability to become endospores. In this state, the bacteria can tolerate exceedingly high and low temperatures, acidic and basic conditions, and large amounts of radiation.

- Endospores are extremely hard to kill. Surprisingly, they can be boiled for hours and still survive.
- Endospores can only be made by Gram-positive bacteria. Within the endospore remains the bacterial DNA, but the cytoplasm has a decreased water concentration.

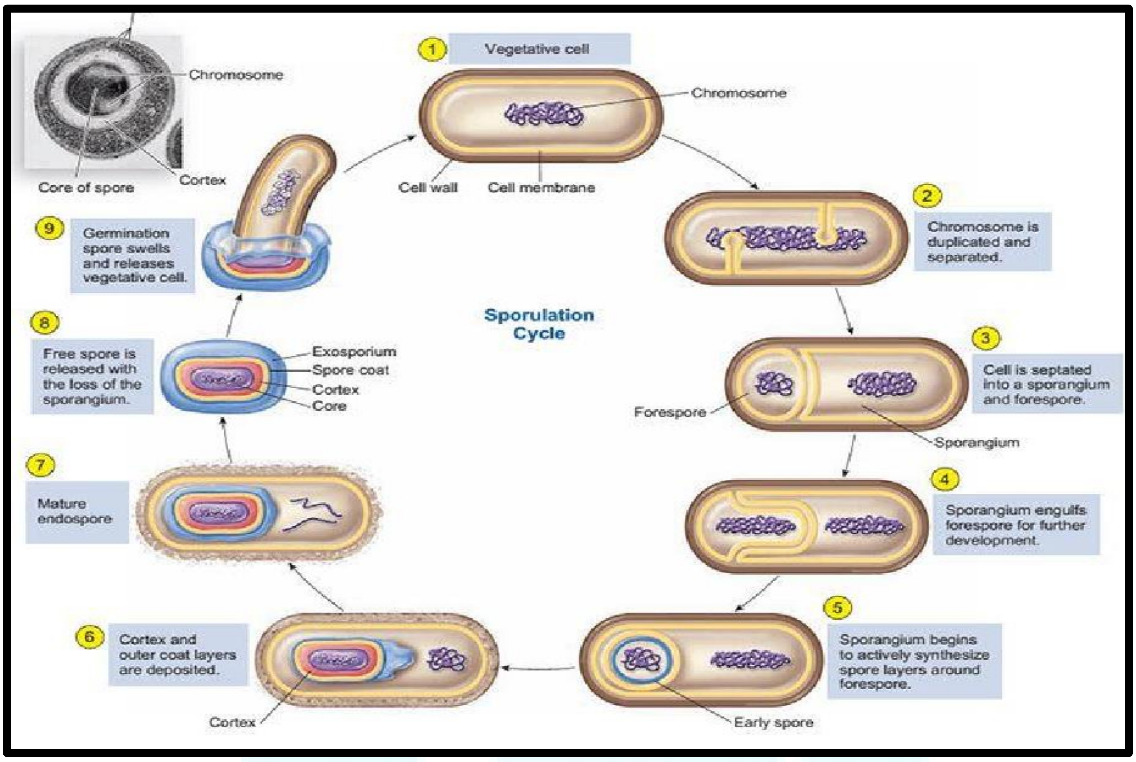


- This is thought to help in protecting against high heat.
- The bacteria will take on a tough coating composed of calcium and dipicolinic acid, creating a dense and impregnable barrier to stabilize the DNA within the cell.
- DNA repair enzymes are also still active, aiding in the resistance of the endospore.

➢ Endospore formation:

- These are specialized structures produced for the cells tiding over unfavorable conditions to the extent that they are heat resistant even at 80°C for 10 minutes (during pasteurization).
- They can withstand draught and can survive for years (200 years). They can survive in radiation also and can withstand acid treatments (conc. H_2SO_4).
- Their presence is very widely distributed among various groups of bacteria and almost all those bacteria which show endospores are gram positive except one *Archebacterium*.
- These spores are formed in both aerobic and anaerobic forms. Spore formation is observed under conditions of restricted growth starting with accumulation of protein rich content in spore forming region.
- Numerous metabolic conversions occurs during spore formation sometimes at the expense of PHBA and as well as polysaccharide during anaerobic.
- During first hour protein of specific nature is formed the reserve food gets depleted. Dipicolenic acid is synthesized which is not usually associated and accumulated.
- These 2 diamino pimalic acid and Ca^{2+} acts as chelate and makes upto

10-15% of dry weight.



- ❖ Equal division starts from periphery of the plasma membrane. Two cells are specifically formed, one small and other large.

- ❖ As soon as it occurs, the large cell starts engulfing the smaller one so that the spore becomes embedded in the original cell. It is at this stage that spore coat is laid down.

- ❖ Spore coat becomes double walled structures with DPA accumulated in cortex region.

- ❖ Outer spore envelope is formed by mother cell and is formed of polysaccharide which may remain as such or additionally a exosporium may be laid in *B. cerius* which is also formed of mother cell.

- This exosporium remains as loose, discrete structure in mature spore. As mature one is getting investing by cortical region much of the water is lost.

- This state is reached in 7-8 hours which results in completion of endospore formation.

2. SEXUAL REPRODUCTION:

- The following points highlight the methods of sexual Reproduction (Para Sexuality) in Bacteria, i.e., Conjugation, Transformation and Transduction.

Conjugation:

- It was first discovered in *Escherichia coli* by Lederberg and Tatum (1946). They found that two different types of auxotroph (nutritional mutants) grown together on minimal medium produced an occasional prototroph (wild type).

- Cell contact was required for this change. Anderson (1957) observed conjugation between two such bacteria under electron microscope. Conjugation was later reported in a number of other bacteria. Bacteria showing conjugation are dimorphic, i.e., they have two types of cells, male (F^+) or donor and female (F-) or recipient.

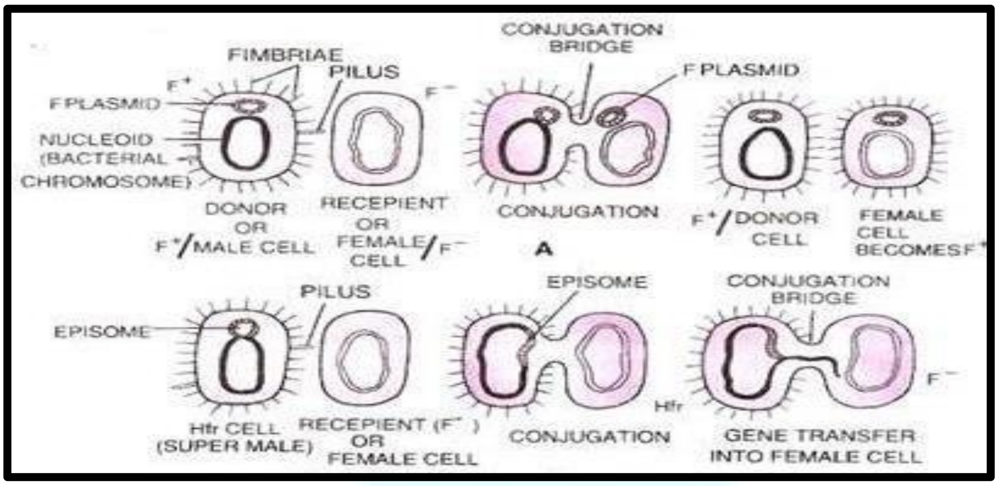
- The male or donor cell possesses 1-4 sex pili on the surface and fertility factor (transfer factor, sex factor) in its plasmid. Fertility factor contains genes for producing sex pili and other characters needed for gene transfer.

- Sex pili are 1- 4 narrow protoplasmic outgrowths. Both sex pili and fertility factor are absent in female or recipient cells.

- If these two types of cells happen to come nearer, a piles of male cell establishes a protoplasmic bridge or conjugation tube with the female cell. It takes 6-8 minutes. Gene exchange can occur by two methods;

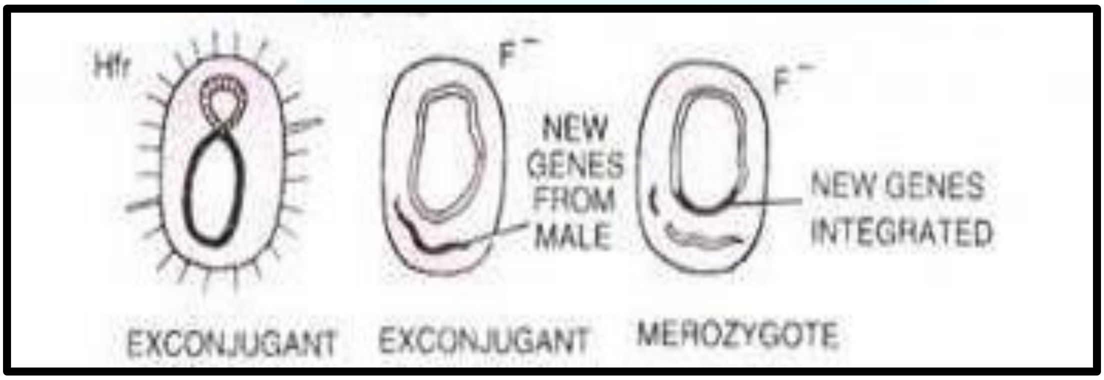
Sterile Male Method (F^+ x $F^- \rightarrow F^-$ becomes F^+):

- The plasmid having fertility factor replicates. A copy of it gets transferred to the recipient cell through the conjugation tube. The recipient cell also becomes donor. The phenomenon of reversibility of sex is called sexduction.



Fertile Male Method (Hfr x $F^- \rightarrow F^-$ remains F^-):

- The F^+ plasmid or fertility factor of the donor cell gets integrated to bacterial chromosome or DNA. The attachable plasmid is known as episome.



- The point at which plasmid gets integrated to bacterial chromosome differs in different strains. Integration is possible because certain nucleotide sequences present in bacterial chromosome are compatible with sequences in plasmid DNA.

- The donor cell having fertility factor integrated to its chromosome is called Hfr (high frequency of recombination), meta male or super male because it has a recombination frequency of 1000 times more as compared to normal F^+.

- Non-integrated F^+ plasmids disintegrate in her cells. The integrated $F+$ factor breaks the bacterial chromosome at one end of its attachment. The bacterial chromosome now undergoes replication.

- A copy of the freed end of bacterial chromosome (end distal to F^+ factor, also called zero end) passes into the recipient cell through the conjugation tube. Fertility factor is the last to do so.

- Generally whole of bacterial chromosome does not pass into recipient cell. F^+ factor is very rarely transferred as conjugation is maintained for a brief period. Only a few genes are transferred, one in seven minutes, two in nine minutes, three in ten minutes, four in eleven minutes, etc.

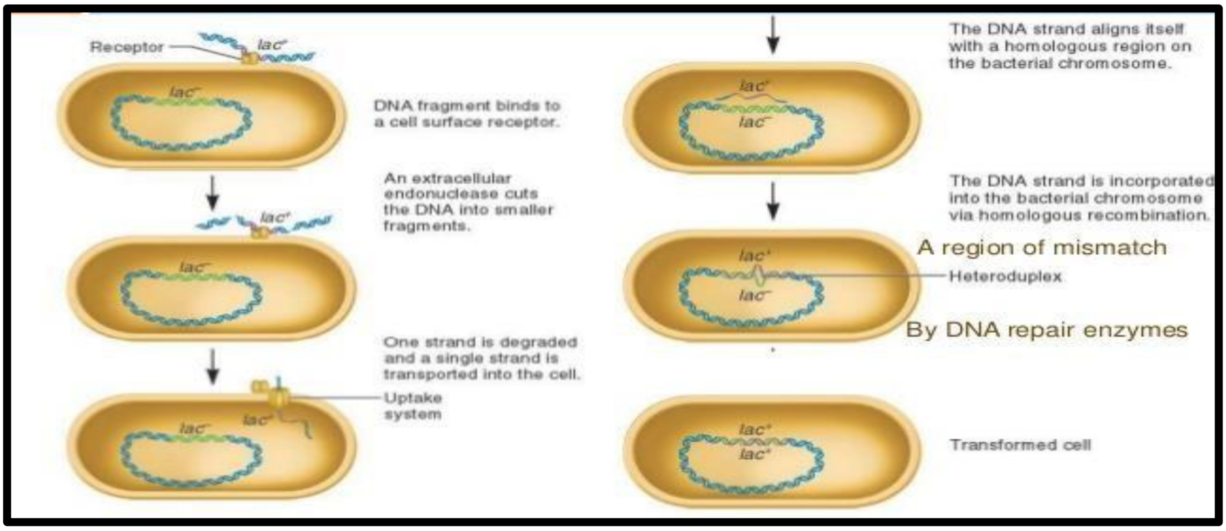
- Conjugation produces an incompletely diploid "zygote" known as mesozygote or partial zygote. The new genes may replace the genes present in the recipient cells (those of the recipient cells disintegrate) or get added to them.

Transformation:

- It is the absorption of DNA segment from the surrounding medium by a living bacterium. The phenomenon was discovered by Griffith in 1928. Its mechanism was worked out by Avery (1944).

- In transformation, a bacterium takes in DNA from its environment, often DNA that's been shed by other bacteria. If the DNA is in the form of a circular DNA called a plasmid, it can be copied in the receiving cell and passed on to its descendants.

- Receptivity for transformation is present for a brief period when the cells have reached the end period of active growth. At this time they develop specific receptor sites in the wall. Normally E. coli does not pick up foreign DNA but it can do so in the presence of calcium chloride.



Transduction:

- It is the transfer of foreign genes by means of viruses. Transduction was first discovered by Zinder and his teacher Lederberg (1952) in *Salmonella typhimurium.*

- Such a virus is never virulent. It passes over the gene of the previous host to the new host. Transducing viruses may carry the same genes (restricted transduction) or different genes (generalized transduction) at different times.

- The genetic recombination in which genetic material is transferred by phage virus between two bacteria is called transduction. It has two forms:

➢ Generalized transduction:

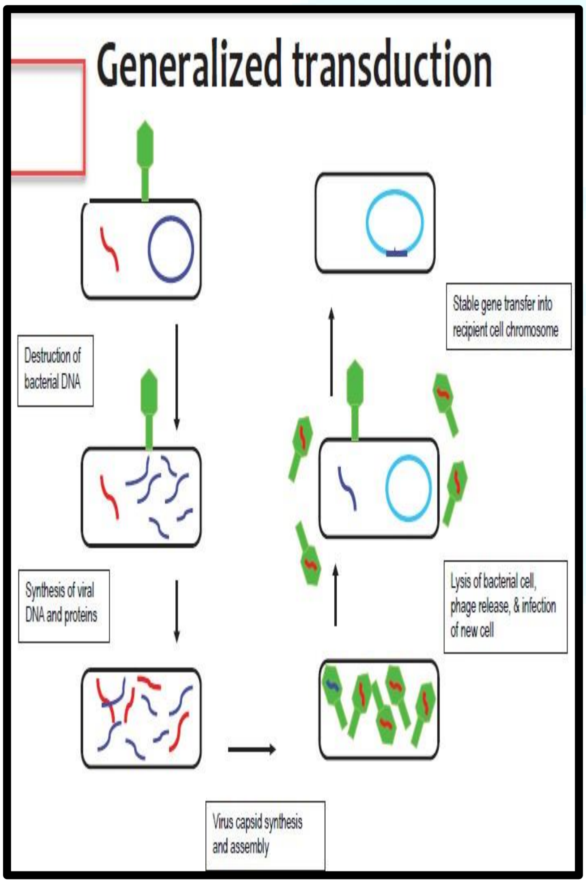
- It occurs in lytic cycle of phage virus. DNA of phages virus enter into *E. coli* bacteria. This DNA replicates and develops many new DNA and capsids.

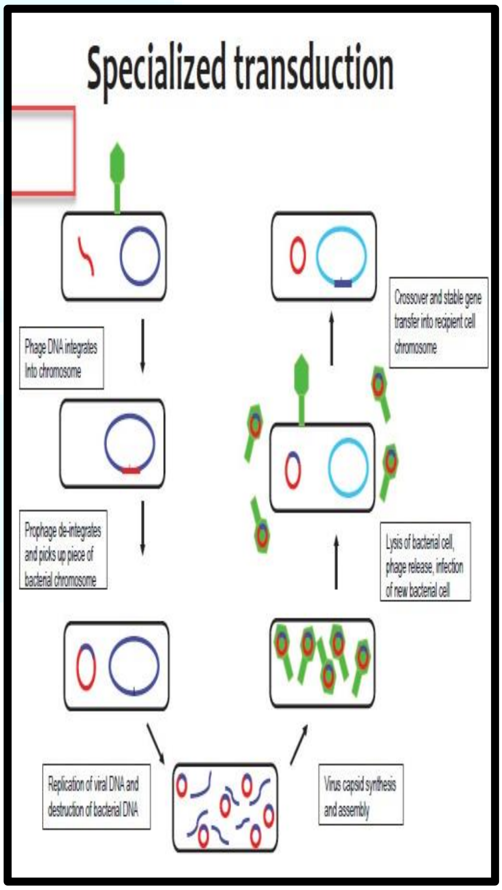
- The DNA of bacteria is broken. Some pieces of DNA also enter into capsid of virus. Bacteria burst and release new phage viruses. Now this phage enters into recipient bacteria and transfer DNA of donor bacteria into the DNA of recipient bacteria.

- Bacterial endonucleases enzymes destroy the phage virus. Now these bacteria incorporate genes of donor bacteria and replicates.

- **Specialized transduction:**

  - It occurs in Lysogenic cycle of phage virus. In this cycle viral DNA incorporate into bacterial DNA as prophage.
  - It remains peacefully there. But sometime, it becomes lytic. It comes out of bacterial DNA.
  - Some part of bacterial DNA remain attach with it.
  - Viral DNA with a piece of bacterial DNA replicates and develops new capsids. Bacteria burst. Virus infects other bacteria and transfer genes of donor.





<u>VIRUSES</u>

- Viruses are simple and acellular infectious agents.

- Viruses are infectious agents having both the characteristics of living and nonliving.

- Viruses are microscopic obligate cellular parasites, generally much smaller than bacteria. They lack the capacity to thrive and reproduce outside of a host body.

- Viruses are infective agent that typically consists of a nucleic acid molecule in a protein coat, is too small to be seen by light microscopy, and is able to multiply only within the living cells of a host.

- The branch of science which deals with the study of viruses is called virology.

- The term "virus" is derived from the Latin word *vīrus* referring to poison and other noxious liquids.

- Viruses can infect all types of life forms including multicellular organisms to unicellular organisms.

CHARACTERS AND PROPERTIES OF VIRUSES

- Viruses are a cellular, non-cytoplasmic infectious agents. Therefore, a unit of virus is referred to as 'a virus particle' rather than 'a virus cell'.

- They are smaller than bacteria and can pass through bacteriological filter.

- They are consisting mainly of a nucleic acid surrounded by a protein envelope called capsid.

- They are devoid of the sophisticated enzymatic and biosynthetic machinery essential for independent activities of cellular life. Therefore, they can grow only inside suitable living cells.

- These viruses do not grow, neither respire nor metabolize, but they reproduce.

- Viruses may even be crystallized much like molecules although some kind of viruses can only be purified but not crystallized .

- A virus cannot contain both DNA and RNA. Therefore, virus is called either 'DNA virus' or 'RNA virus' depending on whether it contains the nucleic acid DNA or RNA.

- Viruses are transmissible from disease to healthy organisms.

- All viruses are obligate parasites and can multiply only within the living host cells.

- Viruses are host specific that they infect only a single species and definite cells of the host.

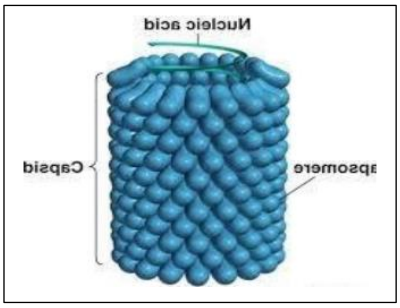
- They are highly resistant to germicides and extremes of physical conditions.

- Viruses are called connective link between living and non living.

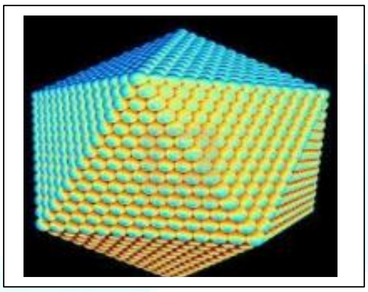
ULTRASTRUCTURE OF VIRUSES

- Viruses may be classified into various morphological types on the basis of their capsid architecture:

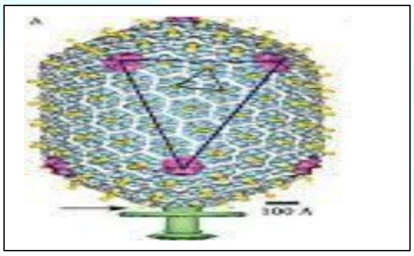
    1. Helical viruses : Composed of a single type of capsomer stacked around a central axis to form a helical structure, which may have a central cavity, or hollow tube. E.g: TMV



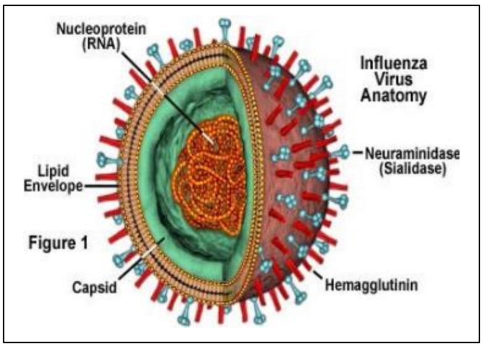
2. **Icosahedral:** Most animal viruses are icosahedral or near-spherical with icosahedral symmetry. E.g: *Adenovirus*



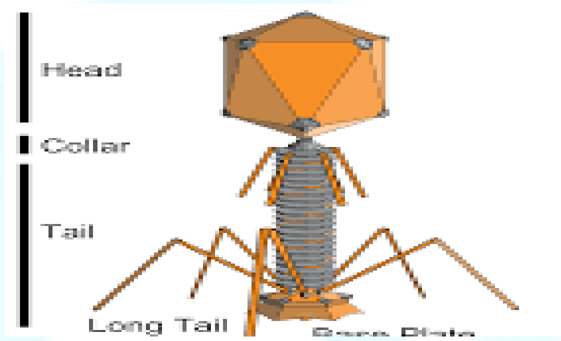
3. **Prolate:** This is an isosahedron elongated along one axis and is a common arrangement of the heads of bacteriophages.



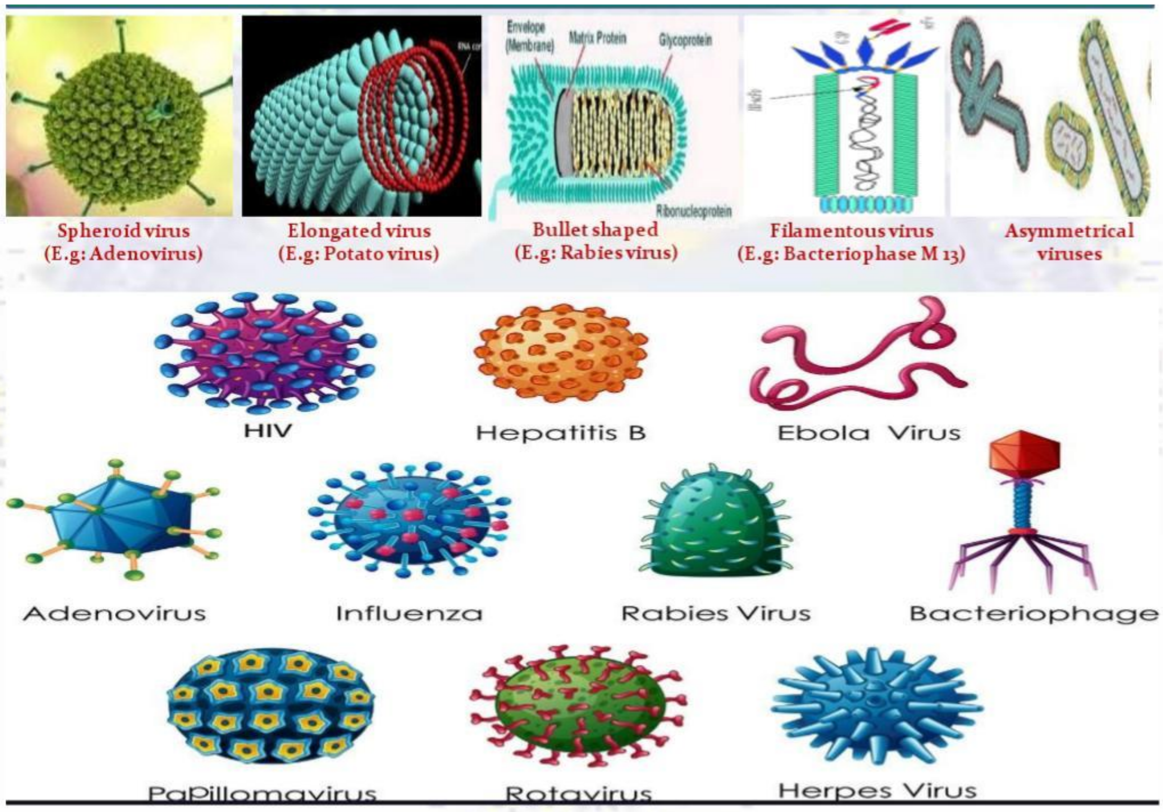
4. **Enveloped viruses:** Some virus envelop themselves in a modified outer lipid bilayer known as a viral envelope. E.g: HIV



5. Complex viruses: These viruses possess a capsid that is neither purely helical nor purely icosahedral, and that may possess extra structures such as protein tails or a complex outer wall. E.g: Bacteriophages



SHAPE OF VIRUSES



Size of Viruses

- Viruses display a wide diversity of sizes.
- In general, viruses are much smaller than bacteria.
- They are smaller than bacteria.
- Some are slightly larger than protein and nucleic acid molecules.
- Some are about of the same size (small pox virus) as the smallest bacterium and some virus are slightly larger than the smallest bacterium.

CHEMICAL COMPOSITION OF VIRUSES

Viral Protein: Proteins found in viruses may be grouped into the four categories:

➢ Envelope protein:

- Enveloped viruses contain glycoprotein which differ from virus to virus.

➢ Nucleocapside protein:

- Viral capsids are made up totally of protein of identical subunits (promoters). E.g: capsids contain single type of protein in TMV.

➢ Core protein:

- Protein found in the nucleic acid is known as core protein.

➢ Viral enzyme:

- In animal viruses especially in the enveloped viruses, many virion specific enzymes have been characterized. E.g: RNase, reverse transcriptase in retrovirus.

Viral envelope:

- It is 10-15 µm thick, made up of protein, lipids and carbohydrate.
- Lipid provide f lexibility to the shape.
- The spikes attached to the outer surface of the envelope are made up of glycoproteins.

Viral carbohydrates:

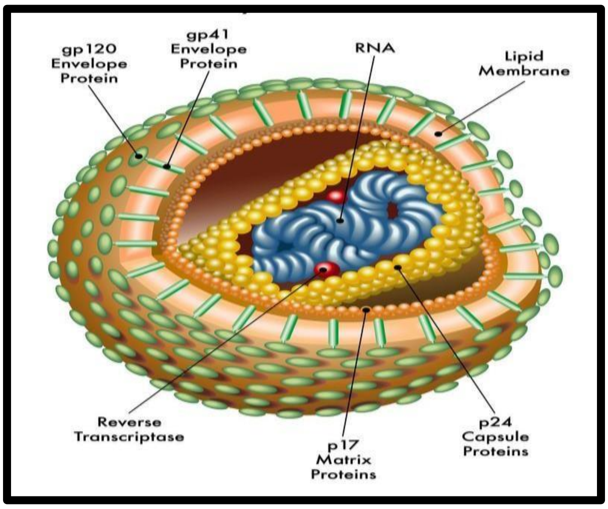
- A substantial amount of carbohydrate specified by rather host cell (arbovirus) or viral genome (vaccinia virus) is found in viral envelope. For example galactose, mannose, glucose, glucosamine, galactosamine are found in influenza virus, parainfluenza virus.

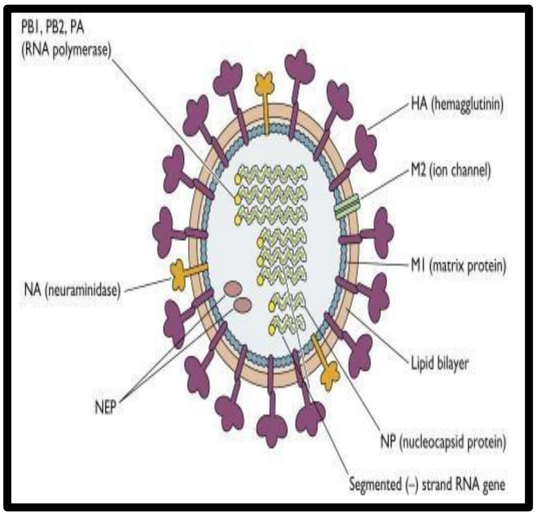
Nucleic Acid:

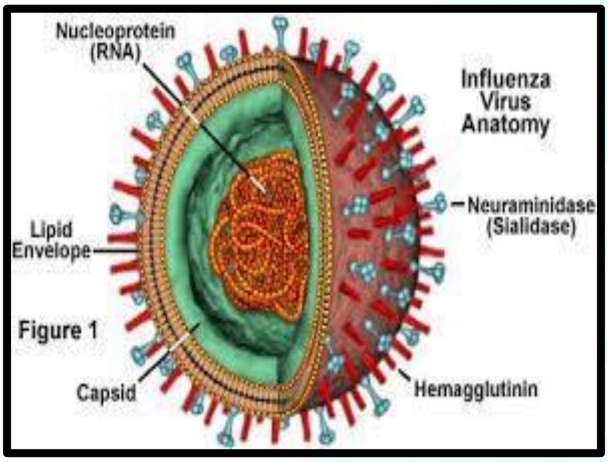
- Viruses contain either DNA or RNA for their genetic information.

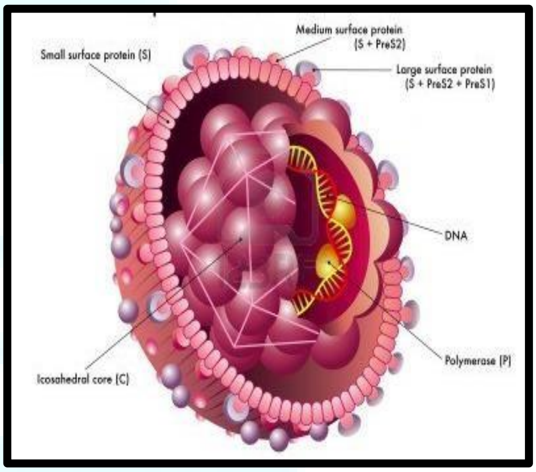
- Viruses containing DNA are called Deoxyviruses, whereas, having RNA called Riboviruses.

- In general, all plant viruses have ss-RNA.
- Animal viruses have either single or (rarely) ds-RNA or ds-DNA.
- Bacterial viruses contain mostly ds-DNA but can also have ss-DNA or RNA.
- Insect viruses contain RNA and only a few have DNA.
- DNA of some bacterial and animal viruses is circular but in others it is like RNA.
- DNA viruses cause human diseases, such as chickenpox, hepatitis B, and some venereal diseases, like herpes and genital warts.
- Mutations in RNA viruses occur more frequently than in DNA viruses.
- This causes them to change and adapt more rapidly to their host.
- Human diseases caused by RNA viruses include hepatitis C, measles, and rabies.









REPLICATION OF VIRUSES

- Viral populations do not grow through cell division, because they are acellular.

- Virus use the machinery and metabolism of a host cell to produce multiple copies of themselves.

- During the process of viral replication, a virus induces a living host cell to synthesize the essential components for the synthesis of new viral particles.

- The particles are then assembled into the correct structure, and the newly formed virions escape from the cell to infect other cells.

- The host cell is forced to rapidly produce thousands of identical copies of the original virus.

- Replication between viruses is varied and depends on the type of genes involved.

- Most DNA viruses assemble in the nucleus;

- Most RNA viruses develop solely in cytoplasm.

- Viral life cycle differs greatly between species, but there are basic stages in their life cycle:

- Attachment
- Penetration
- Uncoating
- Replication
- Assembly
- Release

Attachment	Penetration
Attachment is a specific binding between viral capsid proteins and specific receptors on the host cellular surface.	Virions enter the host cell through receptor- mediated endocytosis or membrane fusion. This is often called *viral entry*.
This specificity determines the host range and type of host cell of a virus.	The infection of plant and fungal cells is different from that of animal cells.
For example, HIV infects a limited range of human leucocytes.	Plants have a rigid cell wall made of cellulose, and fungi one of chitin, so

	most viruses can get inside these cells only after trauma to the cell wall.
This is because its surface protein, gp120, specifically interacts with the CD4 molecule—a chemokine receptor— which is most commonly found on the surface of CD4+ T-Cells.	However, nearly all plant viruses (such as tobacco mosaic virus) can also move directly from cell to cell, in the form of single- stranded nucleoprotein complexes, through pores called plasmodesmata.
This mechanism has evolved to favour those viruses that infect only cells in which they are capable of replication.	Bacteria, like plants, have strong cell walls that a virus must breach to infect the cell.
Attachment to the receptor can induce the viral envelope protein to undergo changes that result in the fusion of viral and cellular membranes, or changes of non-enveloped virus surface proteins that allow the virus to enter.	However, since bacterial cell walls are much less thick than plant cell walls due to their much smaller size, some viruses have evolved mechanisms that inject their genome into the bacterial cell across the cell wall, while the viral capsid remains outside

UNCOATING

- In this process viral capsid is removed: This may be by degradation by viral enzymes or host enzymes or by simple dissociation the end-result is the releasing of the viral genomic nucleic acid.

REPLICATION

- It involves synthesis of viral messenger RNA (mRNA) from "early" genes (with exceptions for positive sense RNA viruses), viral protein synthesis, possible assembly of viral proteins, then viral genome replication mediated by early or regulatory protein expression.

- This may be followed, for complex viruses with larger genomes, by one or more further rounds of mRNA synthesis: "late" gene expression is, in general, of structural or virion proteins.

ASSEMBLY

- Following the structure-mediated self-assembly of the virus particles, some modification of the proteins often occurs.
- Viruses such as HIV, modification occurs after the virus has been released from the host cell.

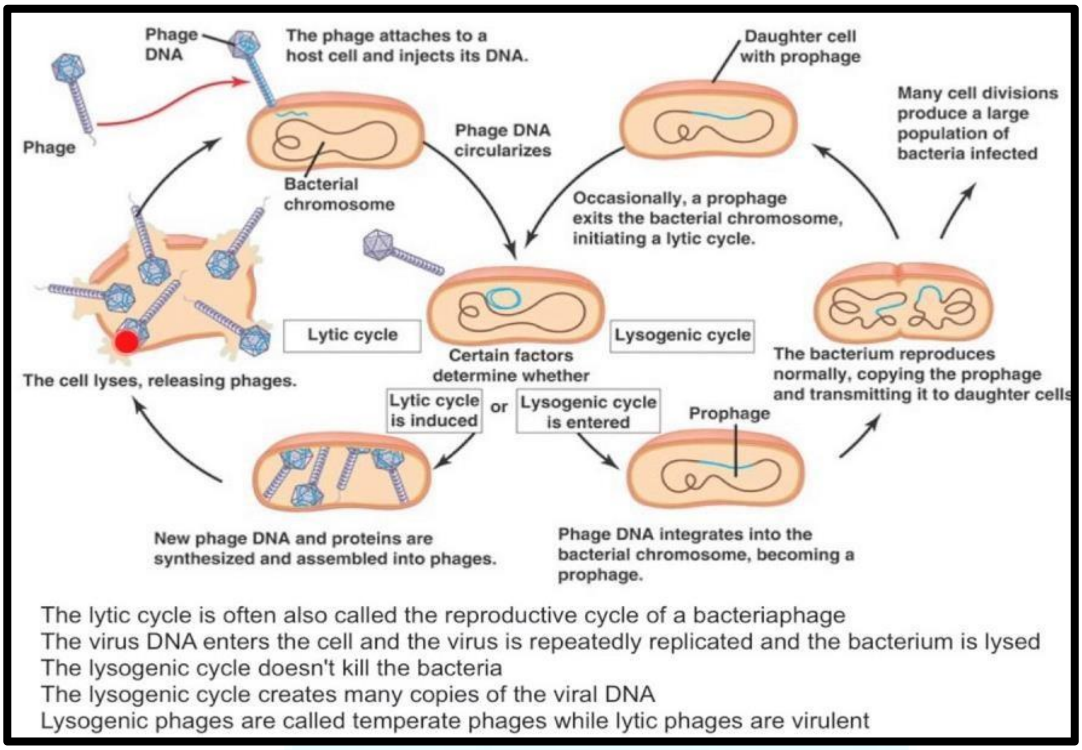
RELEASE

- Viruses can be released from the host cell by lysis, a process that kills the cell by bursting its membrane and cell wall.
- This is a feature of many bacterial and some animal viruses and called lytic cycle.
- Some viruses undergo a lysogenic cycle.
- In lysogenic cycle, viral genome is incorporated by genetic recombination into a specific place in the host's chromosome.
- The viral genome is then known as a "provirus" or, in the case of bacteriophages a "prophage".
- Whenever the host divides, the viral genome is also replicated.
- The viral genome is mostly silent within the host.
- At some point, the provirus or prophage may give rise to active virus, which may lyse the host cells.

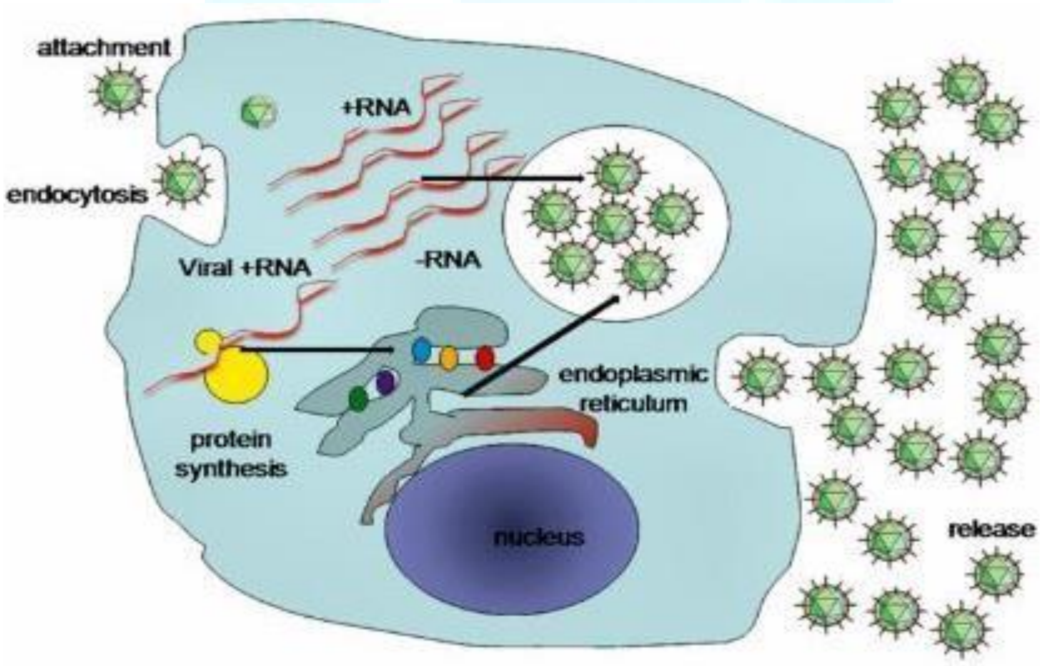
- Enveloped viruses (e.g., HIV) typically are released from the host cell by budding.

- During this process the virus acquires its envelope, which is a modified piece of the host's plasma or other, internal membrane.

LYTIC Vs LYSOGENIC MODE OF REPLICATION OF VIRUSES Mode of Replication of Virus

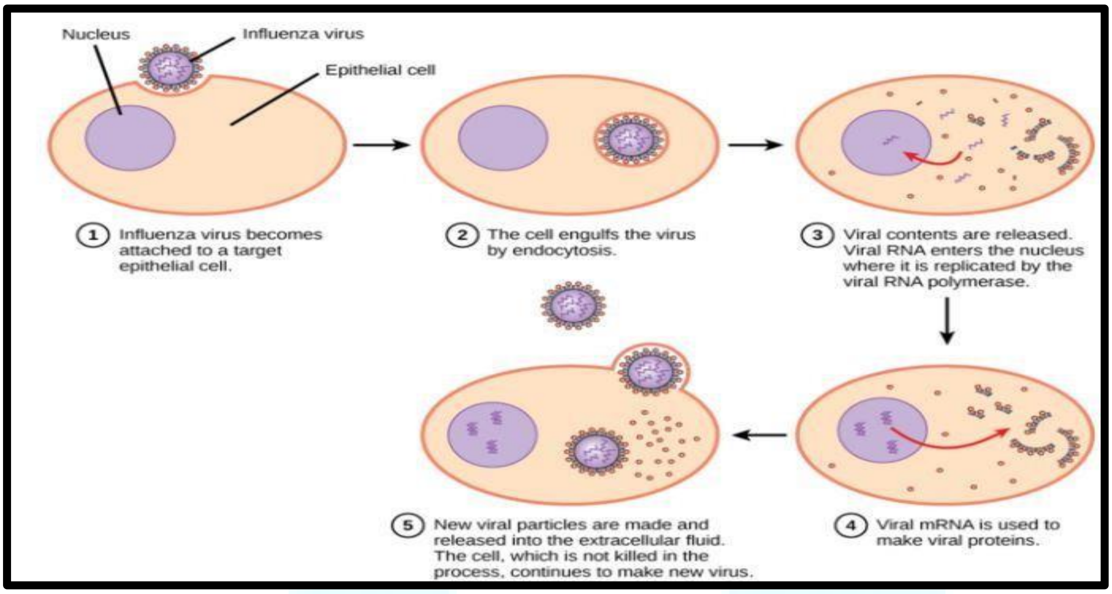


Hepatitis C virus: A simplified diagram of the Hepatitis C virus replication cycle.



Pathway to viral infection: In influenza virus infection, glycoproteins attach to a host epithelial cell. As a result,

the virus is engulfed. RNA and proteins are made and assembled into new virions



TRANSMISSION OF VIRUSES IN PLANTS

Problems associated with the viral transmission:

- Viruses are known to infect both plant cells, animal cells and bacteria.
- Viruses are obligate intracellular parasites they must develop directmethods of transmission, between hosts, in order to survive.
- The mobility of animals increases the mechanisms of viral transmission.
- The plants remain immobile and thus viruses must rely on environmental factors to be transmitted between hosts.

Transmission mode of plant viruses:

- Mechanical transmission by rubbing leaves together, injecting plant extract, by action of animals etc.
- Vegetative and graft transmission through rhizomes, bulbs, corns, tubers etc.

- Pollen transmission; when pollens consisting for viruses fall on stigma of female plants, they germinate and eventually facilitate the virus to infect the ovules of plants.
- Seed transmission; very rare
- Nematode transmission
- Fungal transmission
- Insect vector transmission

- Dodder transmission; dodder are the trailer or climber parasitic plant which grow forming bridge between two plants.

Natural transmission between plant hosts:

- the plants, the cell wall forms a tough barrier between the intracellular components and the extracellular environment, which has to be penetrated.

- The plant viruses relying on the wind and soil to transmit seeds as well as vectors. Vectors eithertransmit the virus propagative transmission, which results amplification of the virus by replication.

- Common vectors include Bacteria, Fungi, Nematodes, arthropods and arachnids.

- Furthermore, human intervention, including grafting and experimental mechanical damage, physically damages the cell wall, contributes to the array of transmission routes.

- The virus commonly uses these methods to be passed from one host to another.

- However, the virus is dependent upon physical damage, generated naturally by the wind and feeding of vectors or by human intervention.

Transmission between plant cells:

- Viral infections often develop into systemic infections as a means of transmission.
- The virus often infects many tissues, if not the whole plant.
- There are a variety of methods the virus can use to spread throughout the organism.
- The most common route use the vascular system, known as the xylem and phloem, and the plasmodesmata, which interconnect adjacent cells.
- The common mechanism involve by different virus is expressing proteins which coat the virus and interact with the structure of the plasmodesmata.
- The array of proteins expressed by the different viruses may act differently but all achieve a similar goal, passage between adjacent cells.

PLANT VIRUSE DISEASES

- Plant viruses are viruses that affect plants and obligate intracellular parasites.
- Plant viruses can be pathogenic to higher plants.
- Most plant viruses are rod-shaped, with protein discs forming a tube surrounding the viral genome; isometric particles are another common structure.
- They rarely have an envelope.

- The great majority have an RNA genome, which is usually small and single stranded (ss), but some viruses have double-stranded (ds) RNA, ssDNA or dsDNA genomes.
- Tobacco mosaic virus (TMV), the first virus to be discovered.
- Plant viruses are grouped into 73 genera and 49 families. However, these figures relate only to cultivated plants, which represent only a tiny fraction of the total number of plant species.
- Viruses in wild plants have been relatively little studied.
- To transmit from one plant to another and from one plant cell to another, plant viruses must use strategies that are usually different from animal viruses.
- Plants do not move, and so plant-to-plant transmission usually involves vectors (such as insects).
- Plant cells are surrounded by solid cell walls, therefore transport through plasmodesmata is the preferred path for virions to move between plant cells.
- Plants have specialized mechanisms for transporting mRNAs through plasmodesmata, and these mechanisms are thought to be used by RNA viruses to spread from one cell to another.
- Plant defenses against viral infection include, among other measures, the use of siRNA in response to dsRNA.
- Most plant viruses encode a protein to suppress this response.
- Plants also reduce transport through plasmodesmata in response to injury.

VIROIDES

- Viroids are infectious pathogens that affect only plants, therefore are also called as the plant pathogens.
- Structurally, viroids are smaller than viruses and possess circular strands of ribonucleic acids (RNA's) with no protein coating.
- These entities hijack the cellular machinery present in plant cells to replicate new copies of itself. It primarily affects all forms of higher plants.

Structure Of Viroids

- Viroids differ from the virus in structure and form. These consists of solely short strands of circular, and single-stranded RNA without the protein coats.
- The plants that are infected by viroids are responsible for the crop failures and also causes loss of millions of dollars in the agricultural revenue every year. Some of the plants that are affected by these pathogens are potatoes, tomatoes, cucumbers, chrysanthemums, coconut palms, avocados, etc.
- Viroids were first discovered by T.O. Diener in the year 1971. It was first examined in the potato spindle tuber viroid that caused a huge loss to the potato industry.
- Viroids are the plant parasites like transcriptional machinery of the cell organelles such as the nucleus or the chloroplast since they are known to be non-coding.
- These replicate by the process of RNA–RNA transcription. They mainly infect the epidermis of the hosts after causing mechanical damage to the cell wall of the plant.

Characteristic Features Of Viroids

- Some of the characteristic features of viroids are given below-
- Viroids contain only RNA.

- These are known to be smaller in size and infect only the plants.
- These are among the smallest known agents causing infectious disease.
- Viroids are the species of nucleic acid with relatively low molecular weight and a unique structure.
- They reproduce within the host cell which they affect in and cause variations in them causing death.
- Viroids are mainly classified into two families namely Pospiviroidae- nuclear viroids and Avsunviroidae- chloroplastic viroids.
- Viroids are said to move in an intracellular manner, cell to cell through the plasmodesmata, and a long-distance through the phloem.

Viroid Diseases

- Some of the diseases that are caused by the infection of viroids in plants are citrus exocortis, cucumber pale fruit, chrysanthemum stunt.
- These infectious disease are spread by the propagation of seeds in plants by cutting, tubers, etc and also by mishandling the contaminated implements.
- Hepatitis- D is caused in humans by viroid like particles.
- The symptoms that are caused by the infection of viroid in plants include stunting of growth, stem necrosis, deformation of the leaves and fruits, and at last causing the death of the plant.
- Most of the viroids are said to infect the plants, including coconut and the apple trees.
- The (PSTV) potato spindle tuber viroid causes significant crop damage to the potato yields causing the tubers to elongate and then crack.
- The other common type of viroid infection symptoms includes stunting and leaf epinasty.

VIRION

- A virion is a complete viral particle consisting of RNA or DNA surrounded by a protein shell, constituting the infective form of a virus.
- The virion shell or capsid protects the interior core that includes the genome and other proteins.
- After the virion binds to the surface of a specific host cell, its DNA or RNA is injected into the host cell and viral replication occurs, resulting in the spread of the infection to other host cells.
- A virion is the infectious particle that is designed for transmitting the nucleic acid genome among hosts or host cells.
- Virions are produced in the cytoplasm of complex viral 'factories,' the virus.
- A virion is an entire virus particle consisting of an outer protein shell called a capsid and an inner core of nucleic acid (either ribonucleic or deoxyribonucleic acid—RNA or DNA).
- The core confers infectivity, and the capsid provides specificity to the virus.
- In some virions the capsid is further enveloped by a fatty membrane, in which case the virion can be inactivated by exposure to fat solvents such as ether and chloroform.
- Many virions are spheroidal—actually icosahedral (the capsid having 20 triangular faces)—with regularly arranged units called capsomeres, two to five or more along each side.
- The nucleic acid is densely coiled within. Other virions have a capsid consisting of an irregular number of surface spikes, with the nucleic acid loosely coiled within.

- Virions of most plant viruses are rod-shaped; the capsid is a naked cylinder (lacking a fatty membrane) within which lies a straight or helical rod of nucleic acid.

- Virion capsids are formed from identical protein subunits called capsomeres.

- Viruses can have a lipid "envelope" derived from the host cell membrane.

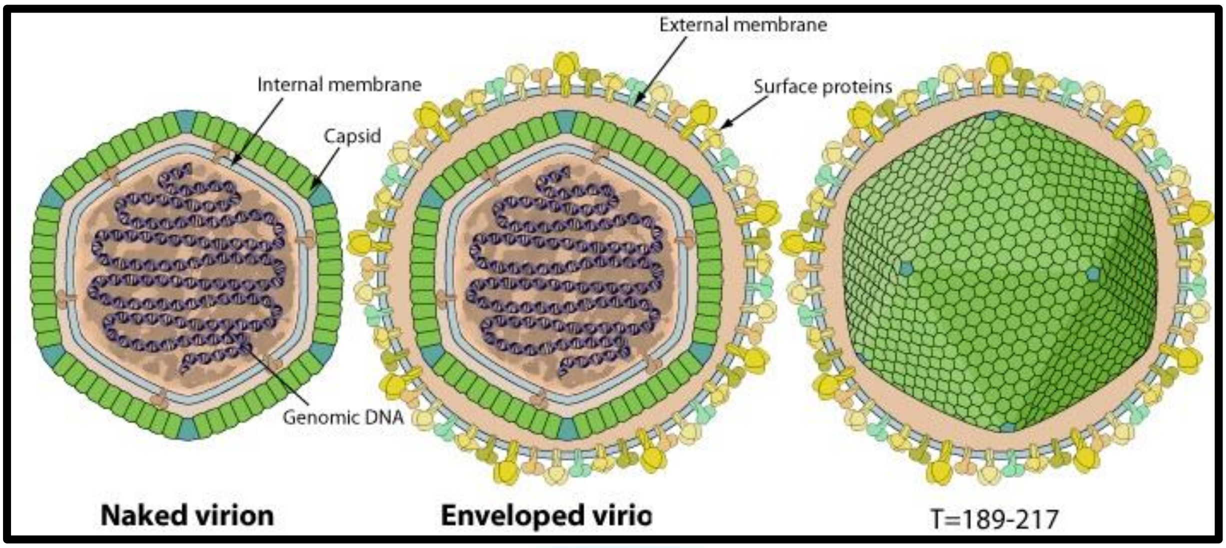
- The capsid is made from proteins encoded by the viral genome and its shape serves as the basis for morphological distinction.

- Virally coded protein subunits will self-assemble to form a capsid, in general requiring the presence of the virus genome.

- Complex viruses code for proteins that assist in the construction of their capsid.

- Proteins associated with nucleic acid are known as nucleoproteins, and the association of viral capsid proteins with viral nucleic acid is called a nucleocapsid.

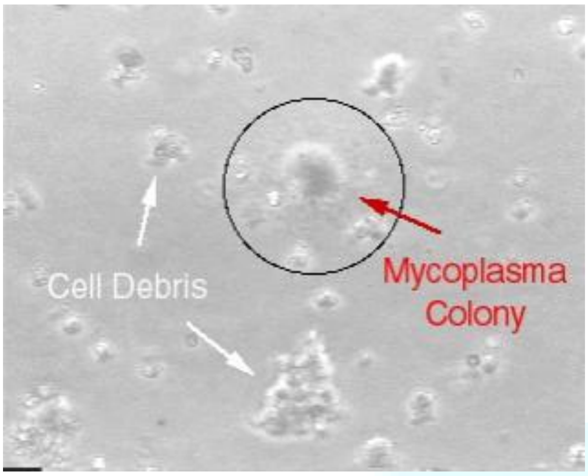
- The capsid and entire virus structure can be mechanically (physically) probed through atomic force microscopy.

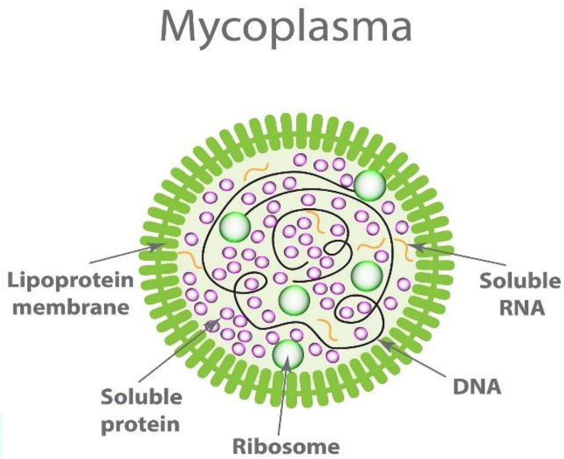


MYCOPLASMA

- Mycoplasma, any bacterium in the genus Mycoplasma.
- The name mycoplasma has also been used to denote any species in the class mollicutes or any genus in the order Mycoplasmatales.
- Mycoplasmas are among the smallest of bacterial organisms.
- The cell varies from a spherical or pear shape (0.3 to 0.8 micrometres [0.0000117 to 0.0000312 inch]) to that of a slender branched filament (up to 150 micrometres [0.00585 inch]).
- Mycoplasma species are mostly facultatively anaerobic, colonial microorganisms that lack cell walls.
- Mycoplasma species are parasites of joints and the mucous membranes lining the respiratory, genital, or digestive tracts of ruminants, carnivores, rodents, and humans.
- Toxic byproducts excreted by the bacterium accumulate in the host’s tissues, causing damage.
- M. pneumoniae causes a widespread but rarely fatal pneumonia in humans.

- Mycoplasma infection may also trigger a serious immune reaction in the host.





INTERFERON

- Interferon , any of several related proteins that are produced by the body's cells as a defensive response to viruses. They are important modulators of the immune response.
- Interferon was named for its ability to interfere with viral proliferation.
- The various forms of interferon are the body's most rapidly produced and important defense against viruses.
- Interferons can also combat bacterial and parasitic infections, inhibit cell division and promote or impede the differentiation of cells. They are produced by all vertebrate animals and possibly by some invertebrates as well.
- Interferons are categorized as cytokines, small proteins that are involved in intercellular signaling. Interferon is secreted by cells in response to stimulation by a virus or other foreign substance, but it does not directly inhibit the virus's multiplication.
- Rather, it stimulates the infected cells and those nearby to produce proteins that prevent the virus from replicating within them.

❖ Further production of the virus is thereby inhibited and the infection is stemmed.

❖ Interferons also have immunoregulatory functions—they inhibit B-lymphocyte (B-cell) activation, enhance T-lymphocyte (T-cell) activity, and increase the cellular-destruction capability of natural killer cells. Three forms of interferon alpha (α), beta (β), and gamma (γ)—have been recognized.

❖ These interferons have been classified into two types: type I includes the alpha and beta forms, and type II consists of the gamma form.

❖ This division is based on the type of cell that produces the interferon and the functional characteristics of the protein

❖ Type I interferons can be produced by almost any cell upon stimulation by a virus; their primary function is to induce viral resistance in cells.

❖ Type II interferon is secreted only by natural killer cells and T lymphocytes; its main purpose is to signal the immune system to respond to infectious agents or cancerous growth.

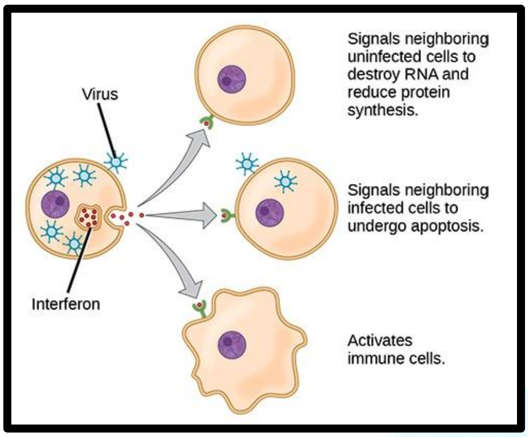
❖ Interferons were discovered in 1957 by British bacteriologist Alick Isaacs and Swiss microbiologist Jean Lindenmann.

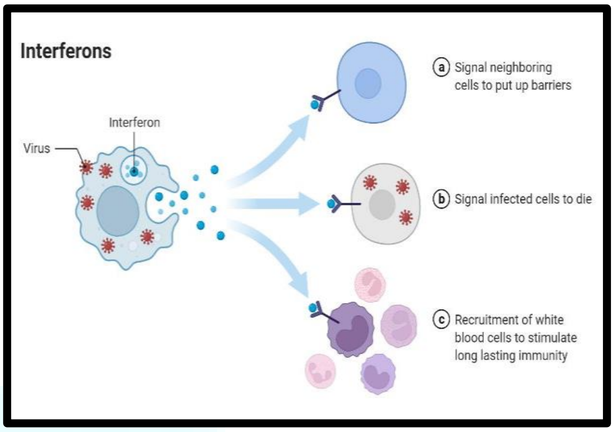
❖ Research conducted in the 1970s revealed that these substances could not only prevent viral infection but also suppress the growth of cancers in some laboratory animals.

❖ Hopes were raised that interferon might prove to be a wonder drug able to cure a wide variety of diseases, but its serious side effects, which include flulike symptoms of fever and fatigue as well as a decrease in the production of blood cells by the bone marrow, deflated expectations for its use against less serious diseases.

❖ Despite these setbacks, in the 1980s alpha interferon came into use, in low doses, to treat hairy-cell leukemia (a rare form of blood cancer) and, in higher doses, to combat Kaposi sarcoma, which frequently appears in AIDS patients.

❖ The alpha form also has been approved for treating the viral infections hepatitis B, hepatitis C (non-A, non-B hepatitis), and genital warts (condylomata acuminata).





❖ The beta form of interferon is mildly effective in treating the relapsing-remitting form of multiple sclerosis.

❖ Gamma interferon is used to treat chronic granulomatous disease, a hereditary condition in which white blood cells fail to kill bacteria.

ACTINOMYCETES

❖ The Actinomycetales is an order of Actinomycetota.

❖ A member of the order is often called an actinomycete.

❖ Actinomycetales are generally gram-positive and anaerobic and have mycelia in a filamentous and branching growth pattern.

❖ Some actinomycetes can form rod or coccoid shaped forms, while others can form spores on aerial hyphae.

❖ Actinomycetales bacteria can be infected by bacteriophages, which are called actinophages.

❖ Actinomycetales can range from harmless bacteria to pathogens with resistance to antibiotics.

Reproduction

❖ Actinomycetales have 2 main forms of reproduction: spore formation and hyphae fragmentation.

❖ During reproduction, Actinomycetales can form conidiophores, sporangiospores, and oidiospores.

❖ In reproducing through hyphae fragmentation, the hyphae formed by Actinomycetales can be a fifth to half the size of fungal hyphae, and bear long spore chains.

Presence and associations

❖ Actinomycetales can be found mostly in soil and decaying organic matter, as well as in living organisms such as humans and animals.

❖ They form symbiotic nitrogen fixing associations with over 200 species of plants, and can also serve as growth promoting or biocontrol agents, or cause disease in some species of plants.

❖ Actinomycetales can be found in the human urogenital tract as well as in the digestive system including the mouth, throat, and gastrointestinal tract in the form of *Helicobacter* without causing disease in the host.

❖ They also have wide medicinal and botanical applications, and are used as a source of many antibiotics and pesticides.

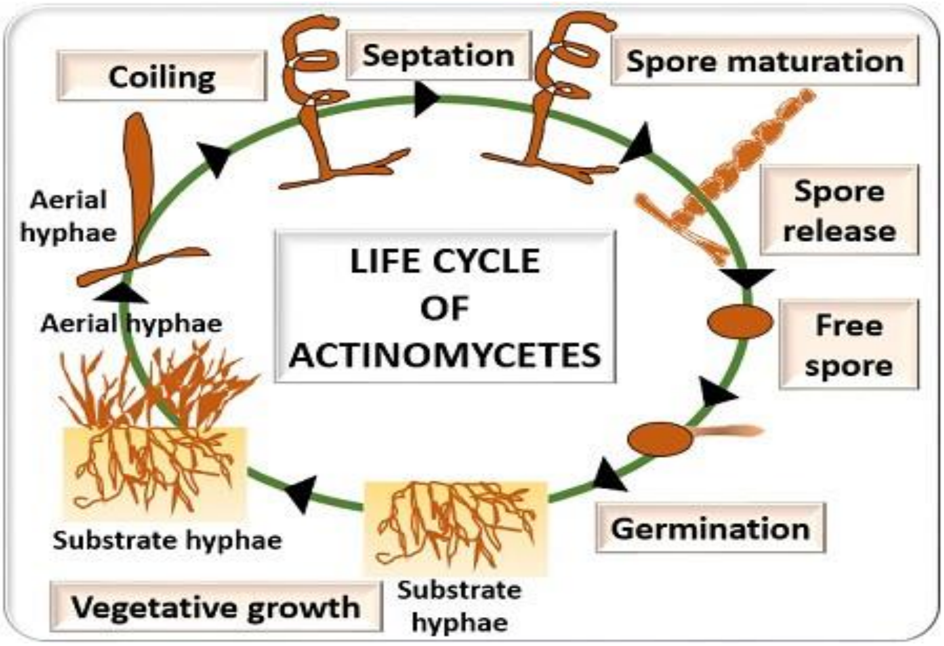
Antimicrobial properties

❖ Many species of Actinomycetes produce antimicrobial compounds under certain conditions and growth media.

❖ Streptomycin, actinomycin, and streptothricin are all medically important antibiotics isolated from Actinomycetes bacteria.

❖ Almost two-thirds of the natural antimicrobial drug compounds used currently are produced by different species of Actinomycetes.

Life cycle of Actinomycetes



BACTERIOPHAGES

❖ Bacteriophage also called phage or bacterial virus, any of a group of viruses that infect bacteria.

❖ Bacteriophages were discovered independently by Frederick W. Twort in Great Britain (1915) and Félix d'Hérelle in France (1917).

❖ D'Hérelle coined the term bacteriophage, meaning "bacteria eater," to describe the agent's bacteriocidal ability.

❖ Bacteriophages also infect the single-celled prokaryotic organisms known as archaea.

Characteristics of bacteriophages

- Thousands of varieties of phages exist, each of which may infect only one type or a few types of bacteria or archaea.
- Phages are classified in a number of virus families; some examples include Inoviridae, Microviridae, Rudiviridae, and Tectiviridae.
- Like all viruses, phages are simple organisms that consist of a core of genetic material (nucleic acid) surrounded by a protein capsid.
- The nucleic acid may be either DNA or RNA and may be double-stranded or single-stranded.
- There are three basic structural forms of phage: an icosahedral (20-sided) head with a tail, an icosahedral head without a tail, and a filamentous form.

Life cycles of bacteriophages

- During infection a phage attaches to a bacterium and inserts its genetic material into the cell.
- After that a phage usually follows one of two life cycles, lytic (virulent) or lysogenic (temperate).
- Lytic phages take over the machinery of the cell to make phage components.
- They then destroy, or lyse, the cell, releasing new phage particles. Lysogenic phages incorporate their nucleic acid into the chromosome of the host cell and replicate with it as a unit without destroying the cell. Under certain conditions lysogenic phages can be induced to follow a lytic cycle.
- Other life cycles, including pseudolysogeny and chronic infection, also exist.
- In pseudolysogeny a bacteriophage enters a cell but neither co-opts cell-replication machinery nor integrates stably into the host genome.
- Pseudolysogeny occurs when a host cell encounters unfavourable growth conditions and appears to play an important role in phage survival by enabling the preservation of the phage genome until host growth conditions have become advantageous again.

- In chronic infection new phage particles are produced continuously over long periods of time but without apparent cell killing.

ECONOMIC IMPORTANCE OF MICROBES

Microbes in Household Products:

- Microbes and their products are used in everyday life like production of curd, formation of dough, cheese, etc.
- Microorganisms like *Lactobacillus* and other Lactic Acid Bacteria (LAB) grow in milk, which convert it into curd. We have seen at home that a starter is added to milk which turn it into curd. This starter is known as inoculum, which contains millions of LAB.
- During growth, LAB produce acids that coagulate and partially digest the milk proteins. Thus, converting milk to curd. These also improve nutritional quality by increasing vitamin-B12 content of the curd. LAB also play very beneficial role in checking disease causing microbes in our stomach.

Fermentation by Microbes:

(i) Dough:

- It is fermented by bacteria in making foods such as dosa and idli.
- The puffed up appearance of dough is due to the production of CO_2 during fermentation. In bread making, dough is fermented using baker's yeast, i.e., *Saccharomyces cerevisiae.*

(ii) Toddy:

- It is a traditional drink of some parts of Southern India. It is made by yeast fermentation sap from palms trees, coconut, etc. Microbes are also used to ferment fish, soya bean, bamboo shoots, etc.

(iii) Cheese:

- It is known to be the oldest food item in which microbes are used. It is formed by partial degradation of milk by different microorganisms. Different varieties of cheese are known by their texture, flavour and taste.
- Swiss cheese with large holes is produced by *Propionibacterium*

sharmanii. Holes are created due to the production of large amount of CO_2 produced by this bacterium. Roquefort cheese is ripened by growing a specific fungi on them, which give them a particular flavour.

Microbes in Industrial Products:

- Microbes are used to synthesise a number of products valuable to human beings in industries also e.g., beverages and antibiotic. For industrial production, microbes are grown in very large vessels called fermenters.

1. Fermented Beverages:

- Yeasts have been used from ancient time for the production of beverages like wine, beer, whisky, brandy and rum. *Saccharomyces cerevisiae* commonly called brewer's yeast is used for bread making, fermenting malted cereals and fruit juices to ethanol.
- Depending upon the type of raw material and processes, different types of alcoholic drinks are prepared.
- Wine and beer are filtered, pasteurized and bottled without further distillation, whereas whisky, brandy and rum are produced by the distillation of fermented broth. Beer has an alcoholic content of 3-6%, while in wines; the alcoholic content is around 9-12%.

2. Antibiotics:

- The term 'antibiotics' was coined by Waksman (1942). The name antibiotic is derived from the Greek words against and bios life, together they mean 'against life' (with reference to disease causing organisms).
- These are the chemical substances, produced by some microbes and can kill or retard the growth of other disease causing microbes.
- The first antibiotic discovered was Penicillin. Alexander Fleming, while working on *Staphylococci* bacteria, found a chemical, which inhibits the bacterial growth.
- It was named as penicillin after the mould *Penicillium notatum*. The potential use of Penicillium as antibiotic was established by Ernest Chain and Howard Florey.

- Penicillium was extensively used in treating American soldiers wounded in World War II. Chain and Florey were awarded the Nobel Prize in 1945, for this discovery. Some other antibiotics were also purified after the successful discovery of Penicillium.

3. Chemicals, Enzymes and other Bioactive Molecules:

- Microbes are being used for the commercial and industrial production of certain chemicals like alcohols, organic acids and enzymes.
- The other molecules, which are functional in living systems or can interact with their components are called bioactive molecules.
- Enzymes are very well established in biotechnology and the microbes are also used in their production.

Microbes in Sewage Treatment:

- Sewage refers to the municipal wastewater generated every day in cities and towns.
- Human excreta is a major component of it. It contains large amount of organic matter, microbes and pathogens out of which many are pathogenic.

Microbes in Production of Biogas:

- Biogas is a mixture of gases, but the major content is methane gas. It is produced by the microbial activity in digestion of biomass with the help of certain bacteria. Biogas is used as fuel.
- The type of gas produced depends upon the microbes and the organic substrates they utilise. Certain bacteria, which grow anaerobically on cellulosic material, produce large amount of methane along with CO_2 and H_2.
- These bacteria are called methanogens. Methanogens produce large amount of methane (50-70%), CO_2 (30-40%) and H_2.
- Methanogens, are also present in anaerobic sludge during sewage treatment. They are also present in rumen (a part of stomach) of cattle,

where they help in break down of cellulosic material in the food and thus, play important role in nutrition of cattle.

Microbes as Bio-Control Agents:

❖ Bio-control is the use of biological methods for controlling plant diseases and pests. These chemicals are also harmful for human beings and animals. Thus, polluting the environment (soil, groundwater).

a) Chemical pesticides decrease the growth of weeds, reduce attack from pathogens and drive away or kill insects, worms and birds, which happen to feed on crop plants.

b) These undesirable species can range from agricultural pests to water contaminants to virulent pathogens. They are undesirable because these species are a detriment to human interests in an ecosystem.

c) Microbes used for bio-control reduce the target species population through many ecological mechanisms, including pathogenism, competition, production of allelochemicals and other interactions.

d) Bacteria, fungi and viruses can all act as bio-control agents due to the large diversity of target species and the variety of methods of action. The important examples of microbial bio-control agents include *Bacillus thuringiensis*, *Pseudomonas* and *Beauveria bassiana*.

Biological Control of Pests and Diseases:

❖ Bio-control is a holistic approach that seeks to develop an understanding of the interactions between various organisms and use this knowledge to control pests, weeds, etc.

❖ Bio-controlling requires familiarity with various life forms, their habitat, predators, life style, etc., to use them in bio-control measures and reducing the dependence on chemicals and pesticides.

❖ Bio-control microbes control their target species through a web of biological interactions.