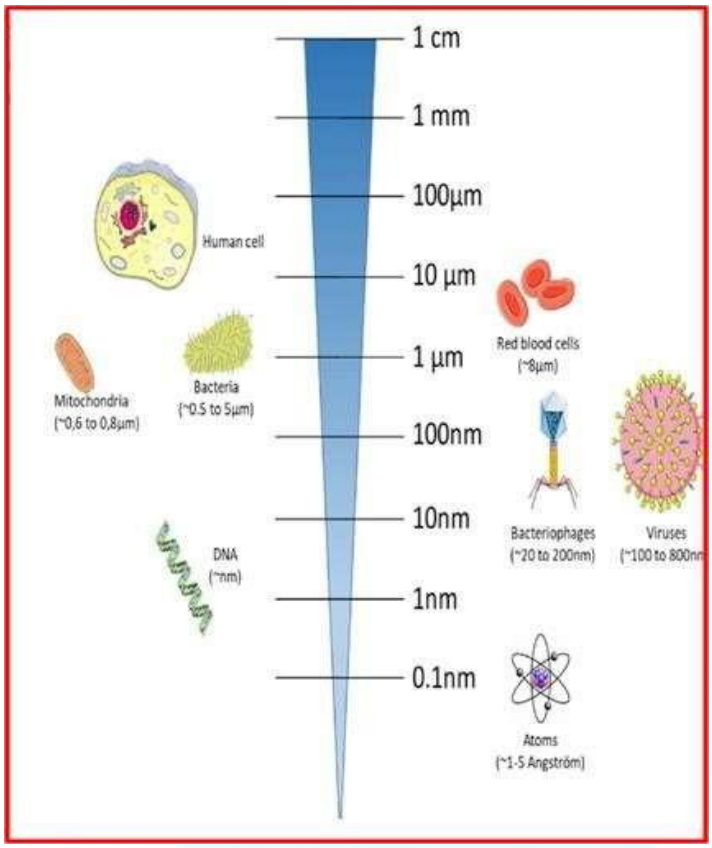
MICROBIOLOGY

BACTERIA

MORPHOLOGY OF BACTERIA

- 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 like organisms (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.



CLASSIFICATION OF BACTERIA

- The classification of bacteria has long presented unique challenges in biological systematics.
- In the 17th century, when bacteria were first observed under a microscope, only two categories of life were recognized in biological systematics: plants and animals.
- Lacking any obvious relation to animals, bacteria initially were classified in the plant kingdom.
- In the latter part of the 19th century, however, German zoologist Ernst Haeckel, recognizing the basic morphological characteristics of single-celled

life particularly the lack of a clearly defined nucleus among many of those organisms proposed a third kingdom of "lower" life, Protista, and within it the class Monera, which would contain the structureless (nuclei-lacking) microorganisms.

- About the same time, German naturalist and botanist Ferdinand Cohn began to systematically organize bacteria into genera and species.
- Although Cohn's arrangement of the bacteria was based on morphology, he recognized that bacteria could not be adequately classified by morphology alone. In 1938, seeking to further distinguish the bacteria from other forms of life, American biologist Herbert F. Copeland elevated Monera to the level of kingdom.
- Although kingdom Monera was readily adopted and later accepted as part of a Five Kingdom System (whereby American biologist Robert H. Whittaker separated the fungi into their own kingdom), in the purview of some researchers, Monera remained an unsatisfactory division.
- The differences between prokaryotic organisms, namely between bacteria and archaea, are great; those groups of organisms are as different from one another as they are from plants and animals.
- Hence, in 1990 Carl R. Woese and colleagues proposed the three-domain system, dividing life into the Bacteria, the Archaea, and the Eukarya.
- Still other researchers disagreed with the domain system, however, and in 1998 British zoologist Thomas Cavalier-Smith presented yet another classification scheme, the Six Kingdom system, which contained kingdom Bacteria with two subdivisions, Eubacteria and Archaebacteria.
- In 2015 Cavalier-Smith and others revised the system to include seven kingdoms, whereby kingdom Bacteria was split into two separate kingdoms Bacteria (containing the eubacteria) and Archaea (containing the archaebacteria).
- According to the rules of nomenclature under the International Code of Nomenclature of Bacteria the body that governs the naming of prokaryotes valid taxa for bacteria extend from subspecies to class; taxonomic categories above class (e.g., phylum) are not considered valid.

Classification Based on Shapes

- In the year 1872 scientist Cohn classified bacteria to 4 major types depending on their shapes are as follows:

1. Cocci:

- These types of bacteria are unicellular, spherical or elliptical shape. Either they may remain as a single cell or may aggregate together for various configurations. They are as follows:
  i. **Monococcus**: They are also called micrococcusand represented by single, discrete round Example: *Micrococcus flavus*.
  ii. **Diplococcus**: The cell of the *Diplococcus* divides ones in a particular plane and after division, the cells remain attached to each other. Example: *Diplococcus pneumonia*.
  iii. **Streptococcus**: Here the cells divide repeatedly in one plane to form chain of cells. Example: *Streptococcus pyogenes*.
  iv. **Tetracoccus**: This consists of four round cells, which defied in two planes at a right angles to one another. Example: *Gaffkya tetragena*.
  v. **Staphylococcus**: Here the cells divided into three planes forming a structured like bunches of grapes giving and irregular configuration. Example: *Staphylococcus aureus*.
  vi. **Sarcina**: In this case the cells divide in three planes but they form a cube like configuration consisting of eight or sixteen cells but they have a regular shape. Example: *Sarcina lutea*.

2. Bacilli:

- These are rod shaped or cylindrical bacteria which either remain singly or in pairs. Example: *Bacillus cereus*.

3. Vibro:

- The vibro are the curved, comma shaped bacteria and represented by a single genus. Example: *Vibro cholerae*.

4. Spirilla:

- These type of bacteria are spiral or spring like with multiple curvature and terminal flagella. Example: *Spirillum volutans*.

Classification Based on Mode of Nutrition

1. Phototrophs:

- Those bacteria which gain energy from light. Phototrops are further divided into two groups on the basis of source of electron.
  i. **Photolithotrophs**: these bacteria gain energy from light and uses

reduced inorganic compounds such as H2S as electron source. Eg. *Chromatium okenii*.

ii. **Photoorganotrophs**: these bacteria gain energy from light and uses organic compounds such as succinate as electron source.

2. Chemotrophs:

- Those bacteria gain energy from chemical compounds. They cannot carry out photosynthesis.
- Chemotrops are further divided into two groups on the basis of source of electron.

i. **Chemolithotrophs:** they gain energy from oxidation of chemical compound and reduces inorganic compounds such as NH3 as electron source. Eg. *Nitrosomonas*.

ii. **Chemoorganotrophs**: they gain energy from chemical compounds and uses organic compound such as glucose and amino acids as source of electron. eg. *Pseudomonas pseudoflava*.

3. Autotrophs:

- Those bacteria which uses carbondioxide as sole source of carbon to prepare its own food. Autotrophs are divided into two types on the basis of energy utilized to assimilate carbondioxide. ie. Photoautotrophs and chemoautotrophs. They utilized light to assimilate CO2.
- They are further divided into two group on the basis of electron sources. Ie. **Photolithotropic autotrophs** and **Photoorganotropic autotrophs**.
- **Chemoautotrophs:** They utilize chemical energy for assimilation of CO2.

4. Heterotrophs:

- Those bacteria which uses organic compound as carbon source.
- They lack the ability to fix CO2. Most of the human pathogenic bacteria are heterotropic in nature.
- Some heterotrops are simple, because they have simple nutritional requirement. However there are some bacteria that require special nutrients for their growth; known as fastidious heterotrophs.

Classification Based on Temperature Requirement

- Bacteria can be classified into the following major types on the basis of their temperatures response as indicated below:

1. **Psychrophiles:** Bacteria that can grow at 0°C or below but the optimum temperature of growth is 15 °C or below and maximum temperature is 20°C are called psychrophiles. Psychrophiles have polyunsaturated fatty acids in their cell membrane which gives fluid nature to the cell membrane even at lower temperature. Examples: *Vibrio psychroerythrus*, *Vibrio marinus, Polaromonas vaculata, Psychroflexus*.
2. **Psychrotrops (facultative psychrophiles):** Those bacteria that can grow even at 0°C but optimum temperature for growth is (20-30) °C.
3. **Mesophiles:** Those bacteria that can grow best between (25-40)o C but optimum temperature for growth is 37C. Most of the human pathogens are mesophilic in nature. Examples: *E. coli, Salmonella, Klebsiella, Staphylococci*.
4. **Thermophiles:** Those bacteria that can best grow above 45C. Thermophiles capable of growing in mesophilic range are called facultative thermophiles. True thermophiles are called as Stenothermophiles, they are obligate thermophiles, Thermophils contains saturated fatty acids in their cell membrane so their cell membrane does not become too fluid even at higher temperature. Examples: *Streptococcus thermophiles, Bacillus stearothermophilus, Thermus aquaticus*.
5. **Hypethermophiles:** Those bacteria that have optimum temperature of growth above 80C. Mostly Archeobacteria are hyperthermophiles. Monolayer cell membrane of Archeobacteria is more resistant to heat and they adopt to grow in higher remperature. Examples: *Thermodesulfobacterium, Aquifex, Pyrolobus fumari, Thermotoga*.

Classification Based on Oxygen Requirement

Obligate Aerobes:

- Require oxygen to live.
- Example: *Pseudomonas*, common nosocomial pathogen.

Facultative Anaerobes:

- Can use oxygen, but can grow in its absence.
- They have complex set of enzymes.

- Examples: *E. coli*, *Staphylococcus*, yeasts, and many intestinal bacteria.

Obligate Anaerobes:

- Cannot use oxygen and are harmed by the presence of toxic forms of oxygen.
- Examples: *Clostridium* bacteria that cause tetanus and botulism.

Aerotolerant Anaerobes:

- Cannot use oxygen, but tolerate its presence.
- Can break down toxic forms of oxygen.
- Example: *Lactobacillus* carries out fermentation regardless of oxygen presence.

Microaerophiles:

- Require oxygen, but at low concentrations.
- Sensitive to toxic forms of oxygen.
- Example: *Campylobacter*.

Classification Based on pH of Growth

Acidophiles:

- These bacteria grow best at an acidic pH.
- The cytoplasm of these bacteria are acidic in nature.
- Some acidopiles are thermophilic in nature, such bacteria are called Thermoacidophiles.
- Examples: *Thiobacillus thioxidans, Thiobacillus, ferroxidans, Thermoplasma, Sulfolobus.*

Alkaliphiles:

- These bacteria grow best at an alkaline pH.
- Example: *Vibrio cholerae* optimum ph of growth is 8.2.

Neutrophiles:

- These bacteria grow best at neutral pH (6.5-7.5).
- Most of the bacteria grow at neutral pH.
    - Example: *E. coli*

Classification Based on Number of Flagella

On the basis of flagella the bacteria can be classified as:

1. **Atrichos:** These bacteria has no flagella. Example: *Corynebacterium diptherae*.
2. **Monotrichous:** One flagellum is attached to one end of the bacteria cell. Example: *Vibro cholerae*.
3. **Lophotrichous:** Bunch of flagella is attached to one end of the bacteria cell. Example: *Pseudomonas*.
4. **Amphitrichous:** Bunch of flagella arising from both end of the bacteria cell. Example: *Rhodospirillum rubrum*.
5. **Peritrichous:** The flagella are evenly distributed surrounding the entire bacterial cell. Example: *Bacillus*.

- Bacterial classification may be defined as the arrangement of organisms into taxonomic groups (taxa) on the basis of their phenotypic (observable) and genotypic (genetic) similarities and differences.
- It allows proper and systematic grouping of microorganisms.
- Organisms are classified into three main kingdoms:
    1. Animals
    2. Plants
    3. Protista.
- The Protista contains unicellular microorganisms including eukaryotes and prokaryotes.
- Although no universally accepted bacterial classification system is available, three main approaches are usually followed. These include:
  (a) Phylogenetic
  (b) Adansonian
  (c) Genetic classifications.

Phylogenetic classification

- The phylogenetic classification is a type of hierarchical classification that represents a branching tree-like arrangement, one characteristic being employed for divisions at each branch or level. It is called phylogenetic

classification, because it denotes an evolutionary arrangement of species.

- This classification groups together the types that are related on evolutionary basis where several groups are used, such as Divisions, Classes, Orders, Families, Tribes, Genera, and Species.

- Some characters of special importance, such as Gram staining properties, lactose fermentation, spore formation, etc., are used to differentiate major groups, whereas less important properties, such as nutritional requirements for growth of bacteria, production of certain enzymes by bacteria, etc., are employed to distinguish minor groups, such as the genera and species.

- As per the classification, the full taxonomical position of a bacterium (*E. coli*) can be described as follows:

Division: Protophyta

Class: Schizomycetes

Order: Eubacteriales

Family: Enterobacteriaceae

Tribe: Escherichiae

Genus: *Escherichia*

Species: *coli*

- *Bergey's Manual of Systematic Bacteriology* is an authoritative published compilation that describes a phylogenetic classification of bacteria.

- The manual is a useful compilation of names and descriptions of bacteria and is the most standard reference book accepted worldwide.

- The book is extremely useful for identification of newly isolated bacterial types.

- A minimum number of important characters, such as morphology of the bacteria, staining properties, cultural characteristics, biochemical reactions, antigenic structure, and guanine to cytosine ratio of DNA, etc., are used for identification and classification of bacteria.

Adansonian classification

- The Adansonian classification makes no phylogenetic assumption, but considers all the characteristics expressed at the time of the study. Hence it is called a phonetic system.
- The Adansonian classification was first proposed by Michael Adanson in the eighteenth century. It avoids the use of weighted characteristics.
- This classification gives equal weight to all measurable features and groups of bacteria on the basis of similarities of several characteristics.
- Recently, availability of computer facilities has expanded the scope of phonetic classification by permitting comparison of very large number of properties of several organisms at the same time.
- The computer analysis of large number of characteristics of a bacterium facilitates the identification of several broad subgroups of bacterial strains that are further subdivided into species.
- This type of classification, based on the properties of large number of properties, is known as numerical taxonomy.

Genetic classification;

- The genetic or molecular classification is based on homology of the DNA base sequences of the microorganisms.
- DNA relatedness of the microorganisms is tested first by extracting DNA from the organism to be studied, and then studying the nucleotide sequence of DNA by DNA hybridization or recombination methods.
- The degree of hybridization can be assessed by many methods, such as by using labeled DNA preparations.
- The study of messenger RNA (mRNA) also provides useful information on genetic relatedness among bacteria.
- The analysis of ribosomal RNA (rRNA) has proved to be of immense value.
- Study of the nucleotide sequence of 16S ribosomal RNA from different

biologic sources has shown evolutionary relationships among widely divergent organisms and has contributed to the understanding of new groups of bacteria, such as the *Archaebacteria*.

Intraspecies classification;

- Intraspecies classification makes an attempt to sub classify species of a bacteria based on biochemical properties (bio-types), antigenic properties (serotypes), susceptibility to bacteriophage (phage types), and production of bacteriocins (colicin types).
- Recently, molecular methods have increasingly been used for intraspecies classification of microorganisms, especially viruses.

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 Ca2+, Mg2+ 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 150-200A0 thick	Triple layered and 75-120A0 thick
Outer membrane	• Absent	• Present
Periplasmic space	• Present in some	• Present in all
Chemical composition	• 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 A0 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.

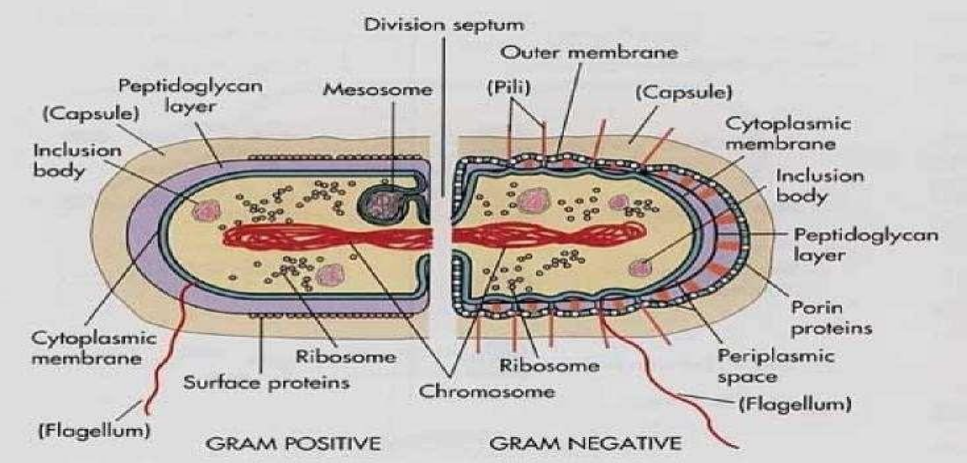
❖ Bacterial ribosmoes are 70s type (50s and 30s subunits) consists of two subunits. Mesosomes are complex localized infoldings of the cytoplasmic membrane and higher in bacteria which show high respiratory activity, such as nitrifying bacteria.

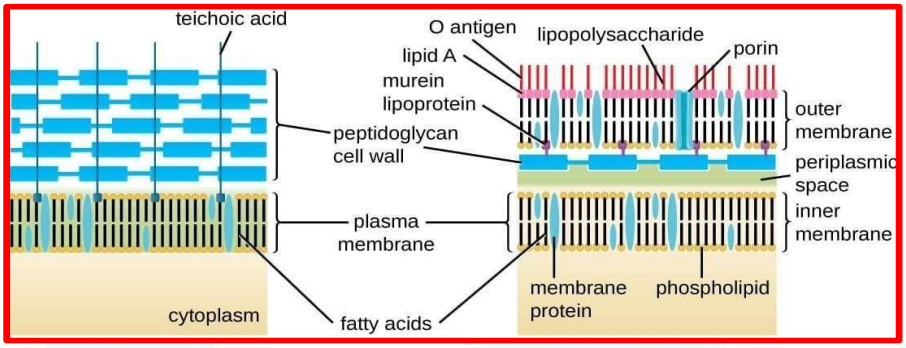
❖ It has been suggested that mesosomes serves to accommodate more centres of respiration. But the absence of enzymes like ATPase, dehydrogenase and cytochrome in mesosome indicates that they are not the sites of respiration.

❖ 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 integrated 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).





LOCOMOTION IN BACTERIA - FLAGELLA

- Some bacteria are selfmotile. 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 flagella at one end.	Vibrio chlolerae, Pseudomonas
Amphitrichous	One flagella at each end.	Nitosomonas, Spirillum
Cephalotrichous	Two or more flagella at one end only.	Pseudomonas fluorescens
Lophotrichous	Tufts of flagella at both the ends.	Spirillum volutans

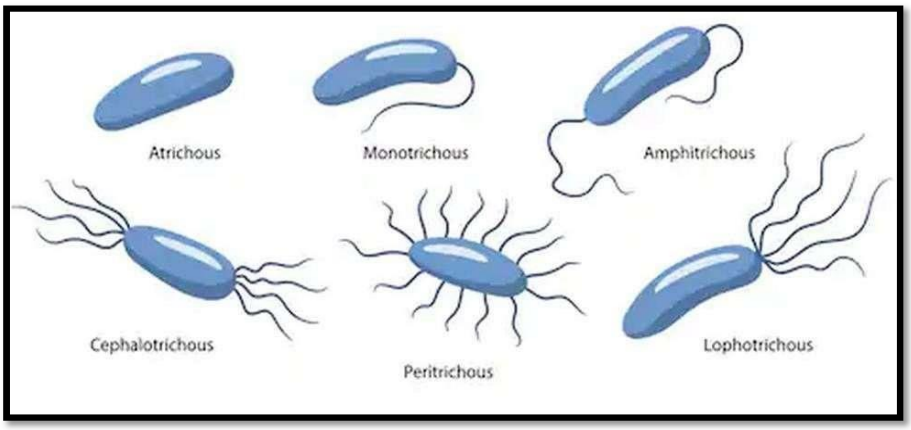
(c) Non-polar flagellation:

- 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 flagella. Eg. *Lactobacillus*

ARRANGMENT AND STRUCTURE OF FLAGELLA

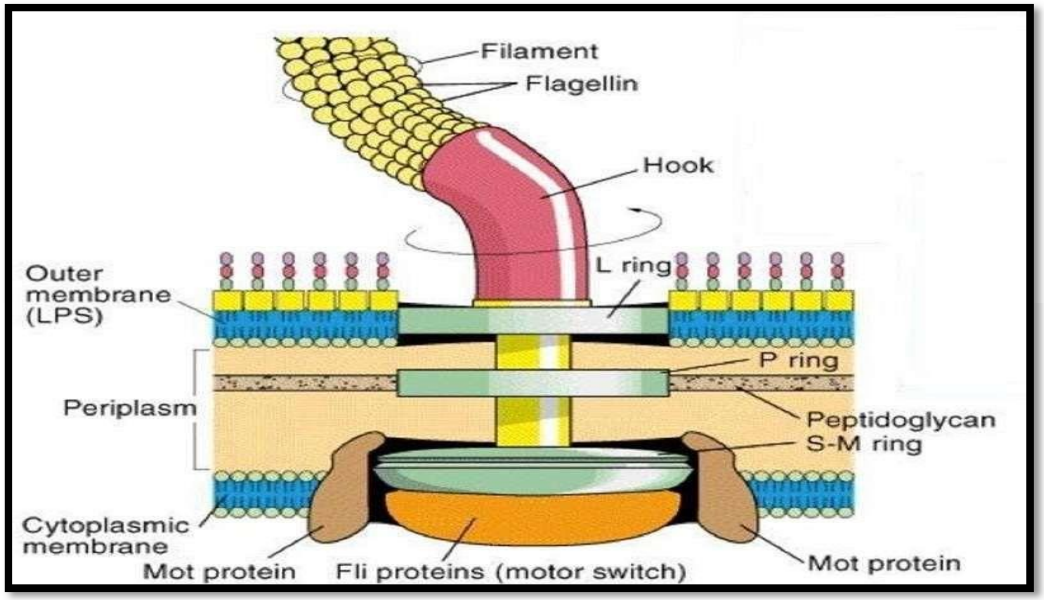
STRUCTURE OF FLAGELLUM



- 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 flagellin 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 flagella 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.

FIMBRIAE AND PILI

- Not only are bacteria able to swim or glide toward more favourable environments, but they also have appendages that allow them to adhere to surfaces and keep from being washed away by flowing fluids.
- Some bacteria, such as *E. coli* and *Neisseria gonorrhoeae*, produce straight, rigid, spike like projections called fimbriae (Latin for "threads" or "fibres") or pili (Latin for "hairs"), which extend from the surface of the bacterium and attach to specific sugars on other cells for these strains, intestinal or urinary tract epithelial cells, respectively.
- Fimbriae are present only in gram negative bacteria.
- Certain pili (called sex pili) are used to allow one bacterium to recognize and adhere to another in a process of sexual mating called conjugation.
- Many aquatic bacteria produce an acidic mucopolysaccharide holdfast, which allows them to adhere tightly to rocks or other surfaces.

BACTERIAL METABOLISM

Heterotrophic metabolism

- Heterotrophic (or organotrophic) bacteria require organic molecules to provide their carbon and energy.
- The energy yielding catabolic reactions can be of many different types, although they all involve electron-transfer reactions in which the movement of an electron from one molecule to another is coupled with an energy-trapping reaction that yields ATP.
- Some heterotrophic bacteria can metabolize sugars or complex carbohydrates to produce energy.
- These bacteria must produce a number of specific proteins, including enzymes that degrade the polysaccharides into their constituent sugar units, a transport system to accumulate the sugar inside the cell, and enzymes to convert the sugar into one of the central intermediates of metabolism, such as glucose-6-phosphate.
- There are several central pathways for carbohydrate utilization, including the Embden-Meyerhof pathway of glycolysis and the pentose phosphate pathway, both of which are also present in eukaryotic cells.
- Some bacteria possess the Entner-Doudoroff pathway, which converts glucose primarily to pyruvate, as well as other pathways that

accomplish the conversion of glucose into smaller compounds with fewer enzyme catalyzed steps.

Autotrophic metabolism

- Autotrophic bacteria synthesize all their cell constituents using carbon dioxide as the carbon source.
- The most common pathways for synthesizing organic compounds from carbon dioxide are the reductive pentose phosphate (Calvin) cycle, the reductive tricarboxylic acid cycle, and the acetyl-CoA pathway.
- The Calvin cycle, elucidated by American biochemist Melvin Calvin, is the most widely distributed of these pathways, operating in plants, algae, photosynthetic bacteria, and most aerobic lithoautotrophic bacteria.
- The key step in the Calvin cycle is the reaction of ribulose 1,5-bisphosphate with carbon dioxide, yielding two molecules of 3-phosphoglycerate, a precursor to glucose.
- This cycle is extremely expensive for the cell in terms of energy, such that the synthesis of one molecule of glyceraldehyde-3-phosphate requires the consumption of nine molecules of ATP and the oxidation of six molecules of the electron donor, the reduced form of nicotinamide adenine dinucleotide phosphate (NADPH).
- Autotrophic behaviour depends on the ability of the cell to carry out photosynthetic or aerobic respiratory metabolism, which are the only processes able to deliver sufficient energy to maintain carbon fixation.
- The aerobic non-photosynthetic lithoautotrophs are those bacteria that not only use carbon dioxide as their sole carbon source but also generate energy from inorganic compounds (electron donors) with oxygen as an electron acceptor.
- These bacteria are taxonomically diverse and are usually defined by the electron donor that they use.
- Example: *Nitrosomonas europaea* oxidizes ammonia (NH_4^+) to nitrite, and *Nitrobacter winogradskyi* oxidizes nitrite to nitrate.
- *Thiobacillus* oxidizes thiosulfate and elemental sulfur to sulfate, and *A. ferrooxidans* oxidizes ferrous ions to the ferric form. This diverse oxidizing ability allows *A. ferrooxidans* to tolerate high concentrations of many different ions, including iron, copper, cobalt, nickel, and zinc.
- All of these types of bacteria appear to be obligate lithotrophs and are unable to use organic compounds to a significant degree.

- Carbon monoxide (CO) is oxidized to carbon dioxide by *Oligotropha carboxidovorans*, and hydrogen gas (H2) is oxidized by *Alcaligenes eutrophus* and, to a lesser degree, by many other bacteria.

Phototrophic metabolism

- Life on Earth is dependent on the conversion of solar energy to cellular energy by the process of photosynthesis.
- The general process of photosynthesis makes use of pigments called chlorophylls that absorb light energy from the Sun and release an electron with a higher energy level.
- This electron is passed through an electron transport chain, with the generation of energy by formation of a proton gradient and concomitant ATP synthesis.
- The electron ultimately returns to the chlorophyll. This cyclic reaction path can fulfill the energy needs of the cell.
- For the cell to grow, however, the Calvin cycle of carbon dioxide fixation must be activated, and electrons must be transferred to the cofactor NADP to form NADPH, which is needed in large amounts for the operation of the cycle.
- Thus, phototrophic cell growth requires that a source of electrons be available to replace the electrons that are consumed during biosynthetic reactions.

BACTERIAL GROWTH

- Bacterial growth refers to an increase in bacterial numbers, not an increase in the size of the individual cells.
- In most bacteria, growth first involves increase in cell mass and number of ribosomes, then duplication of the bacterial chromosome, synthesis of new cell wall and plasma membrane, partitioning of the two chromosomes, septum formation, and cell division.
- This asexual process of reproduction is called binary fission and results in two daughter cells that are genetically identical.
- This is accomplished by the process of binary fission, where a single bacterial cell divides into two.
- The dynamics of bacterial growth follow a predictable pattern visualized as a bacterial growth curve.

- This growth curve is generated by plotting the increase of cell number versus time. The curve can then be used to determine the generation time, the time required for a microbial population to double in cell number.
- There are typically four growth phases in a closed bacterial culture vessel, like a flask or tube. The phases are lag, log/exponential, stationary, and death phases.

Lag Phase:

- Immediately after inoculation of the cells into fresh medium, the population remains temporarily unchanged (notice the line here is flat, no change in cell number).
- Although there is no apparent cell division occurring, the cells may be growing in volume or mass, synthesizing enzymes, proteins, RNA, etc., and increasing in metabolic activity.
- The cells are also adapting and adjusting to this media and growth condition, different genes may be turned on to start metabolizing different substrates.
- There is some repair processes going in, cell is re-synthesizing damaged cell constituents in preparation for binary fission.
- The length of the lag phase is dependent on a wide variety of factors, including the size of the inoculum; time necessary to recover from physical damage or shock in the transfer; time required for synthesis of essential coenzymes or division factors; and time required for synthesis of new (inducible) enzymes that are necessary to metabolize the substrates present in the medium, the age of the inoculum (microbe introduced into a culture medium to initiate growth), an “old” culture will probably a lot of dead/aged cells and may take longer to adjust to this medium.

Log (Exponential) Phase:

- The exponential phase of growth is a pattern of balanced growth wherein all the cells are dividing regularly by binary fission, and are growing by geometric progression.
- The cells divide at a constant rate depending upon the composition of the growth medium and the conditions of incubation. The rate of exponential growth of a bacterial culture is expressed as generation time, also the doubling time of the bacterial population.

- This phase is usually relatively short in the scheme of the entire growth curve. Cells in this phase are most active metabolically, and is preferred for industrial purposes where, for example a product needs to be produced efficiently.
- Exponentially growing cells are typically at their healthiest and are thus most desirable for studies of their enzymes or other cell components. Because the generation time is constant, a logarithmic plot of growth during the log phase is a straight line.
- Exponential growth cannot be continued forever in a batch culture. Population growth is limited by one of three factors:

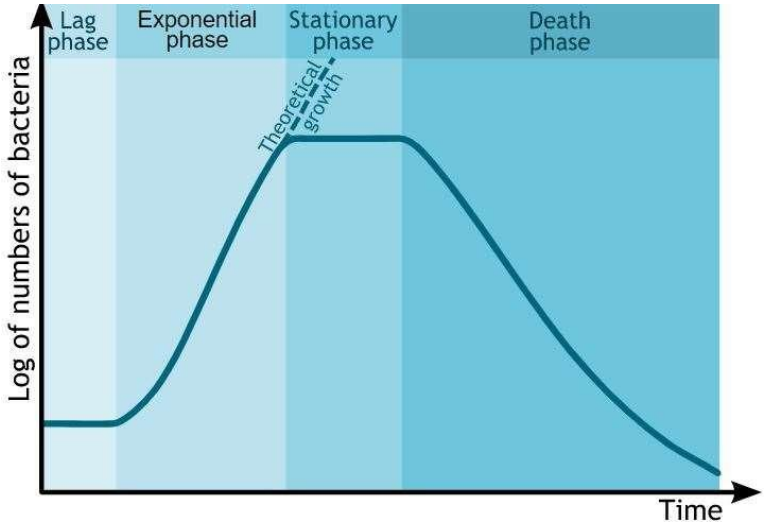
1. Exhaustion of available nutrients.
2. Accumulation of inhibitory metabolites or end products.
3. Exhaustion of space, in this case called a lack of "biological space".

Stationary phase:

- Eventually the growth rate slows, the number of microbial deaths balances the number of new cells, and the population stabilizes.
- This period of equilibrium is called the Stationary phase.
- Bacteria that produce secondary metabolites, such as antibiotics, often do so during the stationary phase of the growth cycle (Secondary metabolites are defined as metabolites produced after the active stage of growth).
- It is during the stationary phase that spore-forming bacteria have to induce or unmask the activity of dozens of genes that may be involved in sporulation process to prepare for a dormant period.

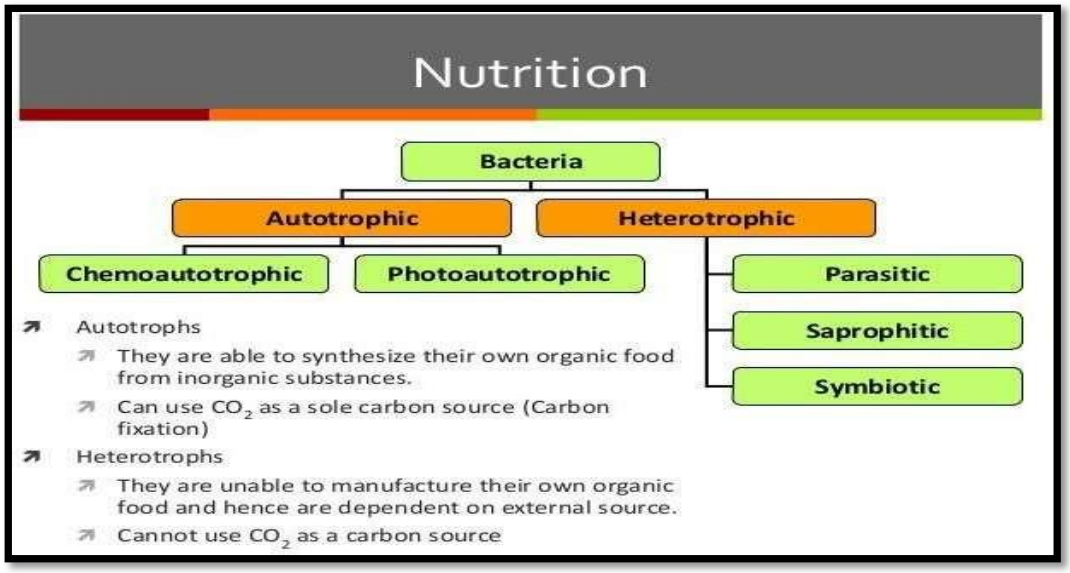
Death phase:

- If incubation continues after the population reaches stationary phase, a death phase follows, in which the viable cell population declines.
- During the death phase, the number of viable cells decreases geometrically (exponentially), essentially the reverse of growth during the log phase.
- This phase continues until the population is diminished to a tiny fraction of the number of cells in the previous phase or until the population dies out entirely.
- Bacterial growth curve showing 4 phases.



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*

2H2S or S2+ O2=====□ 2S + 2H2O + energy

ii. **Iron bacteria:** They use chemical energy while there is oxidation compound (Fe2+ to Fe3+). E.g: *Leptothrix, Ferobacillus, Cladothrix*

4FeCO3+ O2+ 6H2O=====□ 4Fe(OH)3+ 4CO2+ Energy

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

H2+ ½ O2===□ H2O + Energy

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

2NO2+ O2=======□ 2NO3+ 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$(CH_2O) + S + H_2O$ (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.

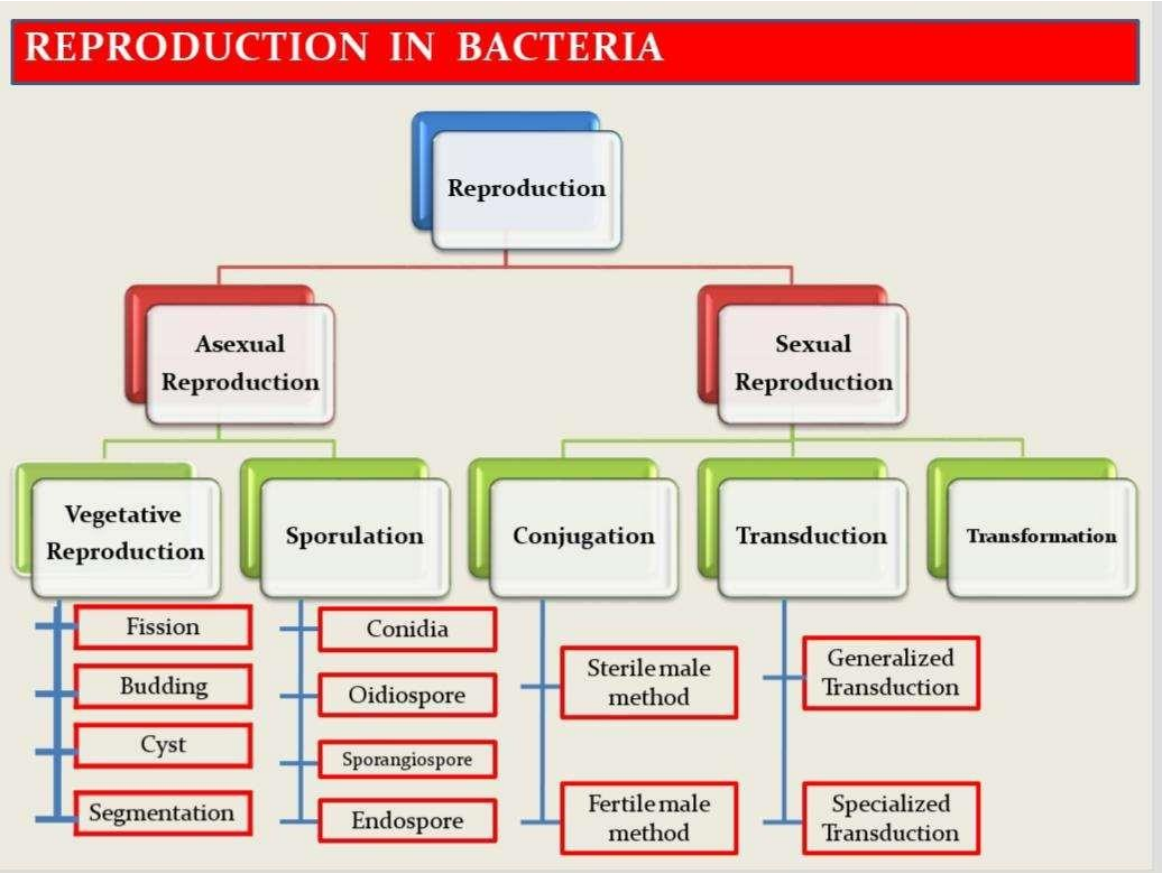
C. Symbiotic bacteria:

- 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.

REPRODUCTION IN BACTERIA



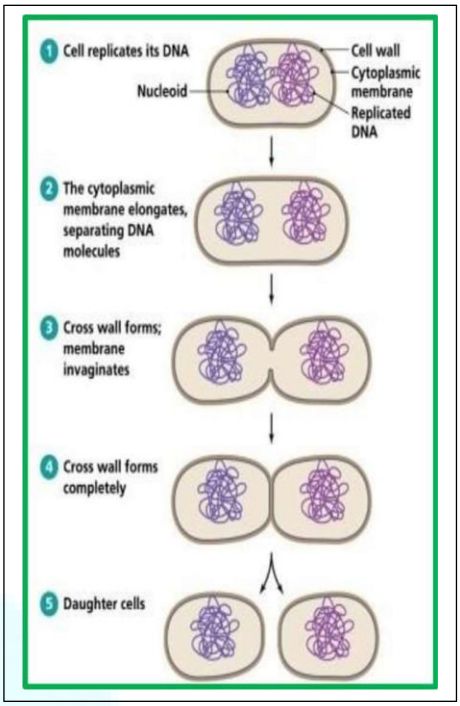
- Asexual reproduction is characteristic of all bacteria.
- Sexual reproduction was long through to be absent but investigation with the help of electron microscope have clearly demonstrated the exchange of genetic material in some species of bacteria.

1. ASEXUAL REPRODUCTION

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

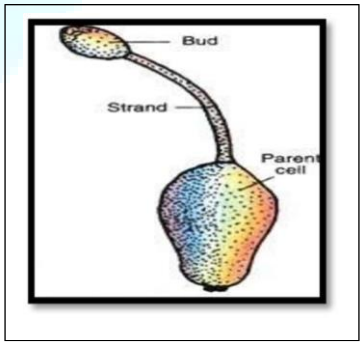
Vegetative reproduction: It take place by the following methods.

Binary Fission:



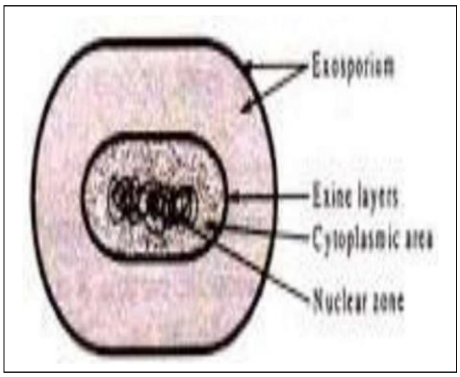
- The most common way by which the bacteria reproduce itself is the Binary Process. It is a process by which a single bacterial cell simply divides into two in half an hour time.
- The various events of binary fission are as follows: The nucleoid gradually become elongated in size and form dumbel shaped 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.

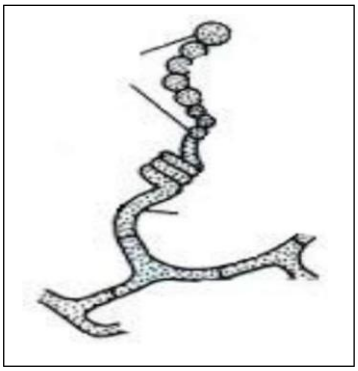
Segmentation:

- 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:

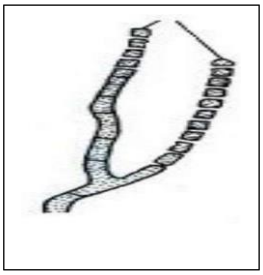
Conidia:



- 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.

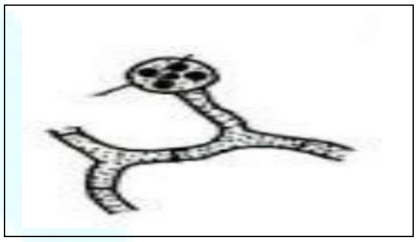
- After liberation each conidium gives rise to a new filamentous bacterium, provided conditions for germination are favourable.

Oidiospores:



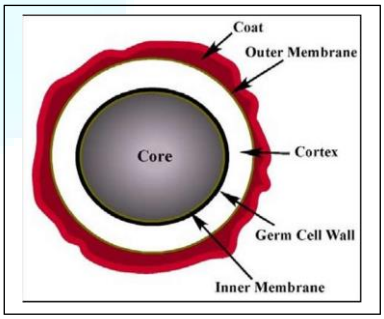
- In an another member Actinomyces hypha instead of obstructing spore in succession at the free end, undergoes additional separation through its length to form numerous small reproductive units known as oidiospores.
- Each oidiospores on germination produces, a filamentous bacterium.

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



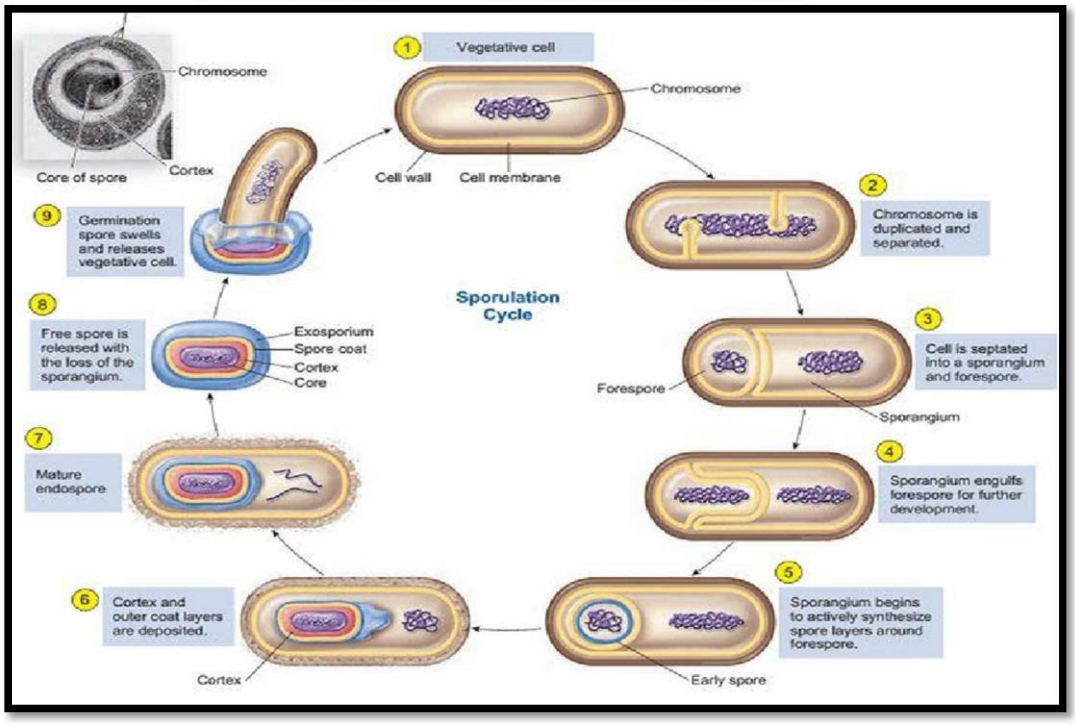
- During the unfavorable condition, eubacteria have the ability to become endospores. In this state, the bacteria can tolerate exceedingly high and low temperatures, acidic and basic conditions, and large amounts of radiation.
- Endospores are extremely hard to kill. Surprisingly, they can be boiled 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 80oC 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. H2SO4).
- 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 Ca2+ 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.

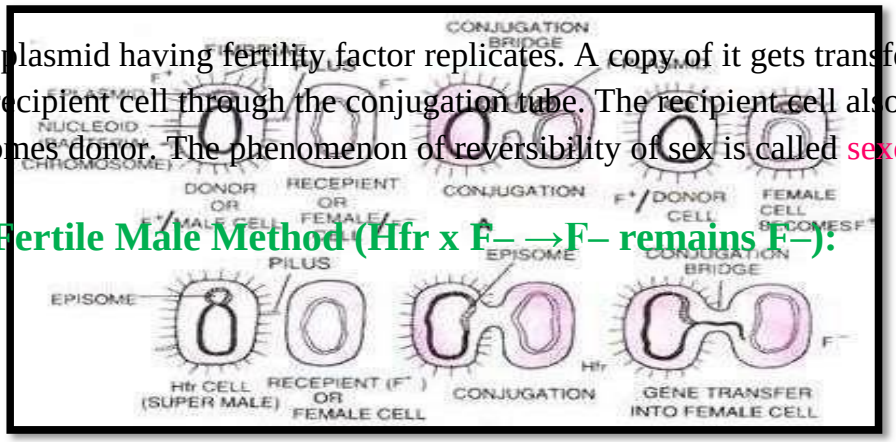
- Sex pili are 1- 4 narrow protoplasmic outgrowths. Both sex pili and fertility factor are absent in female or recipient cells.

- 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– → F– becomes F+):

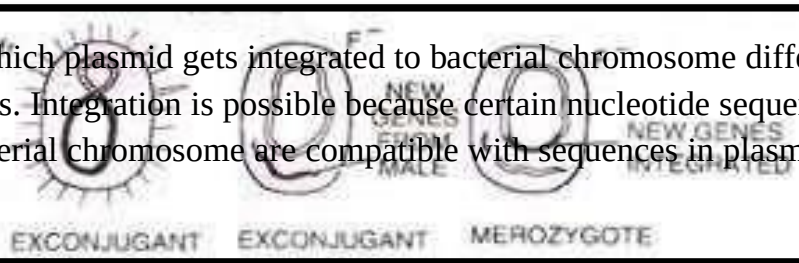
- The plasmid having fertility factor replicates. A copy of it gets transferred to the recipient cell through the conjugation tube. The recipient cell also becomes donor. The phenomenon of reversibility of sex is called sexduction.

Fertile Male Method (Hfr x F– →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.

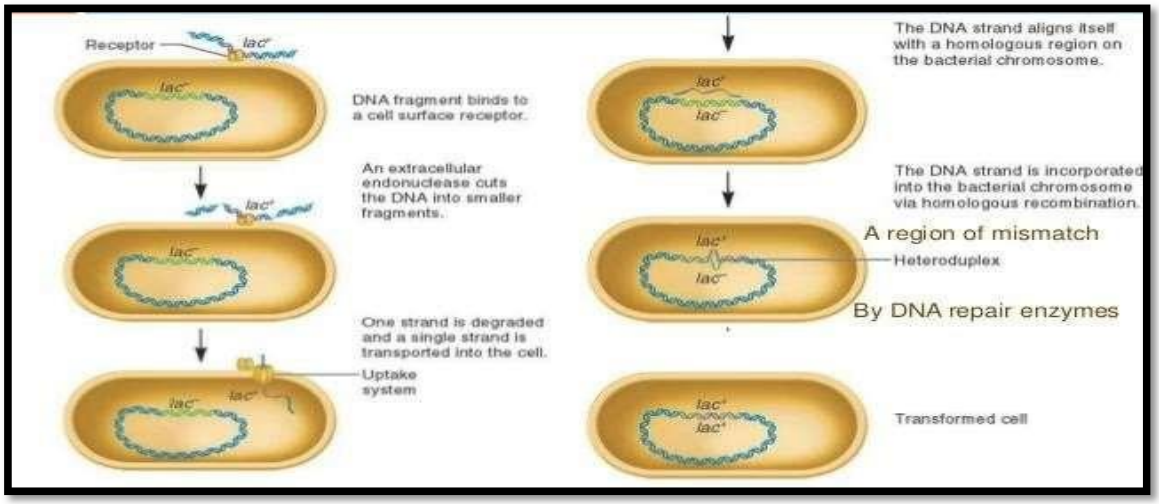
- Conjugation produces an incompletely diploid “zygote” known as mesozygote or partial zygote. The new genes may replace the genes present in the recipient cells (those of the recipient cells disintegrate) or get added to them.

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.

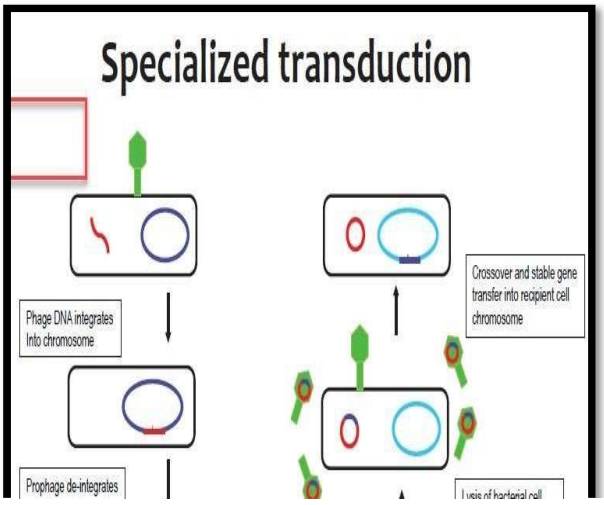
- The DNA of bacteria is broken. Some pieces of DNA also enter into capsid of virus. Bacteria burst and release new phage viruses. Now this phage enters into recipient bacteria and transfer DNA of donor bacteria into the DNA of recipient bacteria.

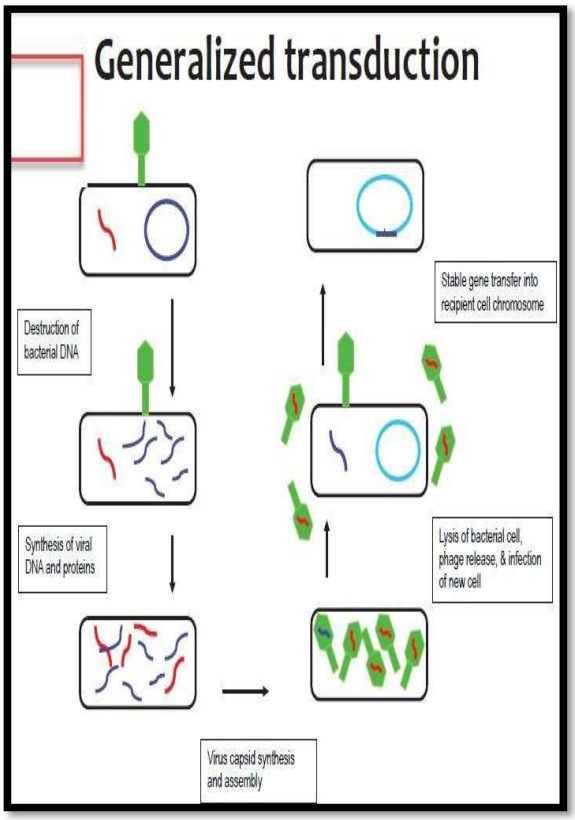
- Bacterial endonucleases enzymes destroy the phage virus. Now these bacteria incorporate genes of donor bacteria and replicates.

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.





VIRUSES

- 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.

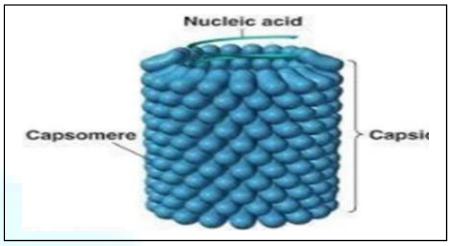
- Viruses are host specific that they infect only a single species and definite cells of the host.

- They are highly resistant to germicides and extremes of physical conditions.
- Viruses are called connective link between living and non living.

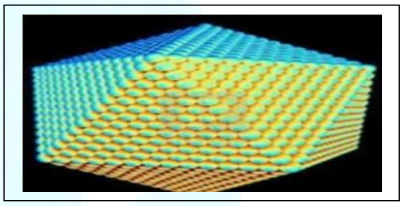
ULTRASTRUCTURE OF VIRUSES

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

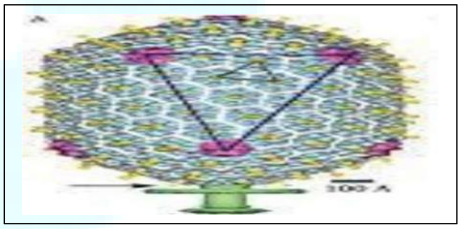
1. **Helical viruses**: Composed of a single type of capsomer stacked around a central axis to form a helical structure, which may have a central cavity, or hollow tube. E.g: TMV



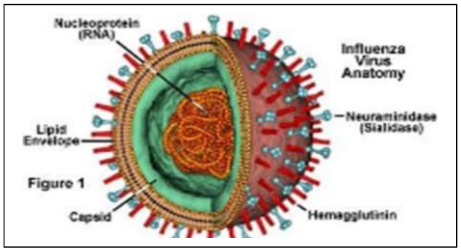
2. **Icosahedral:** Most animal viruses are icosahedral or near-spherical with icosahedral symmetry. E.g: *Adenovirus*



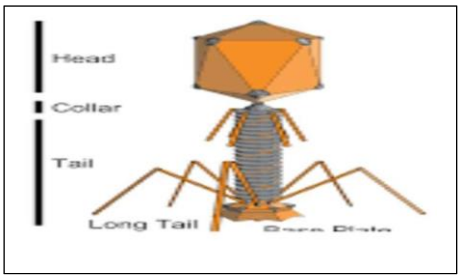
3. **Prolate:** This is an isosahedron elongated along one axis and is a common arrangement of the heads of bacteriophages.



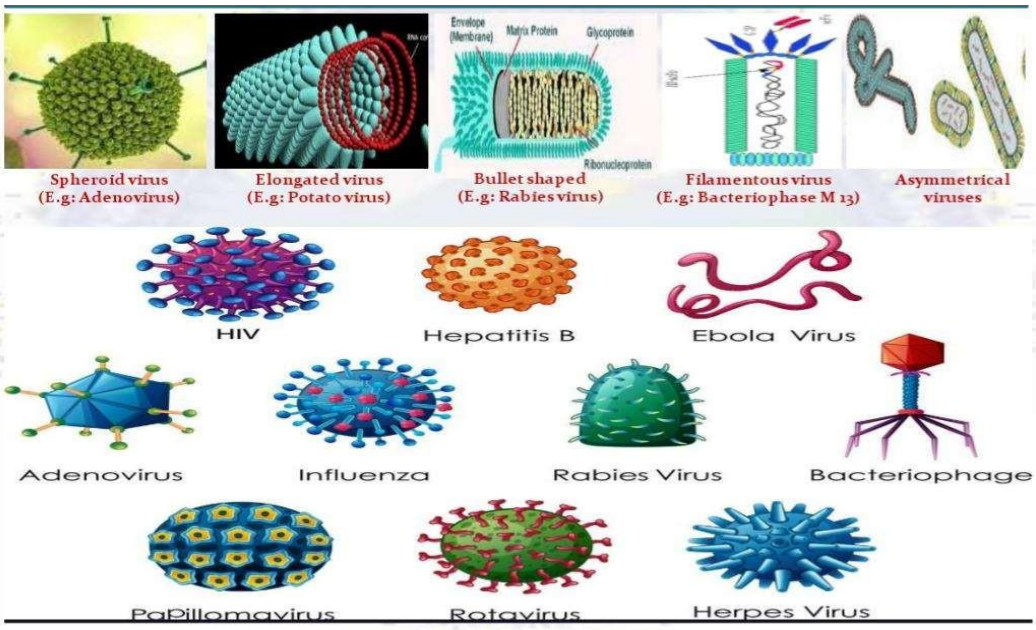
4. **Enveloped viruses**: Some virus envelop themselves in a modified outer lipid bilayer known as a viral envelope. E.g: HIV



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 flexibility to the shape.
- The spikes attached to the outer surface of the envelope are made up of glycoproteins.

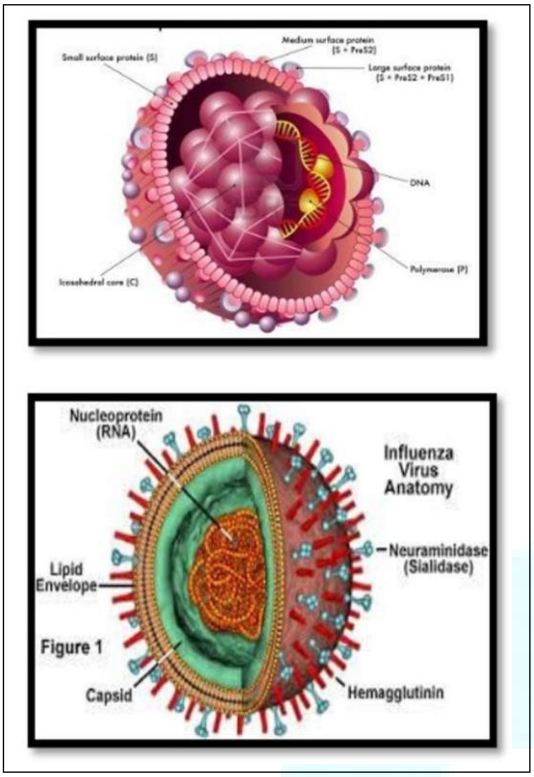
Viral carbohydrates:

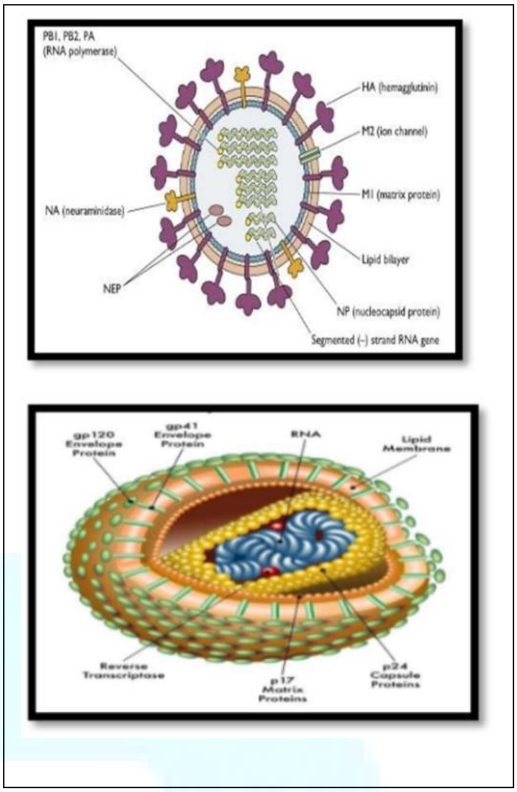
- A substantial amount of carbohydrate specified by rather host cell (arbovirus) or viral genome (vaccinia virus) is found in viral envelope. For example galactose, mannose, glucose, glucosamine, galactosamine are found in influenza virus, parainfluenza virus.

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 positivesense 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.

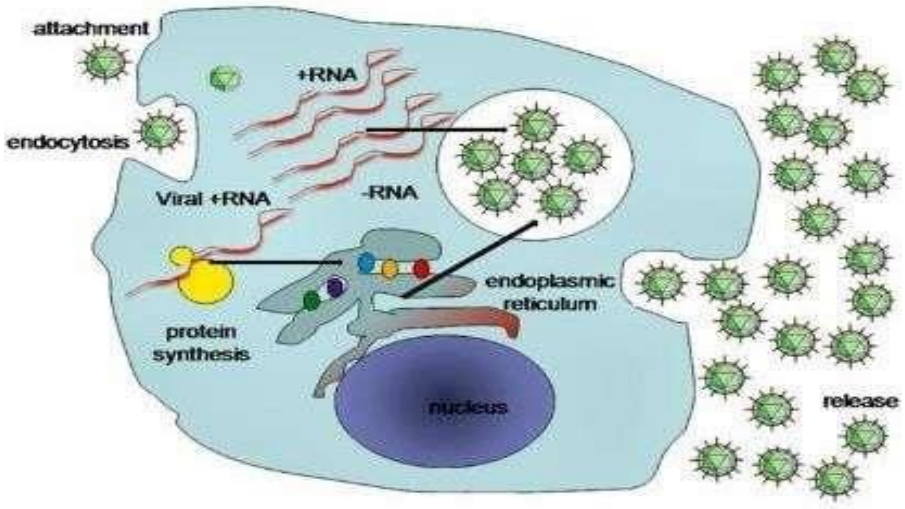
- The viral genome is then known as a "provirus" or, in the case of bacteriophages a "prophage". Whenever the host divides, the viral genome is also replicated.

- 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.

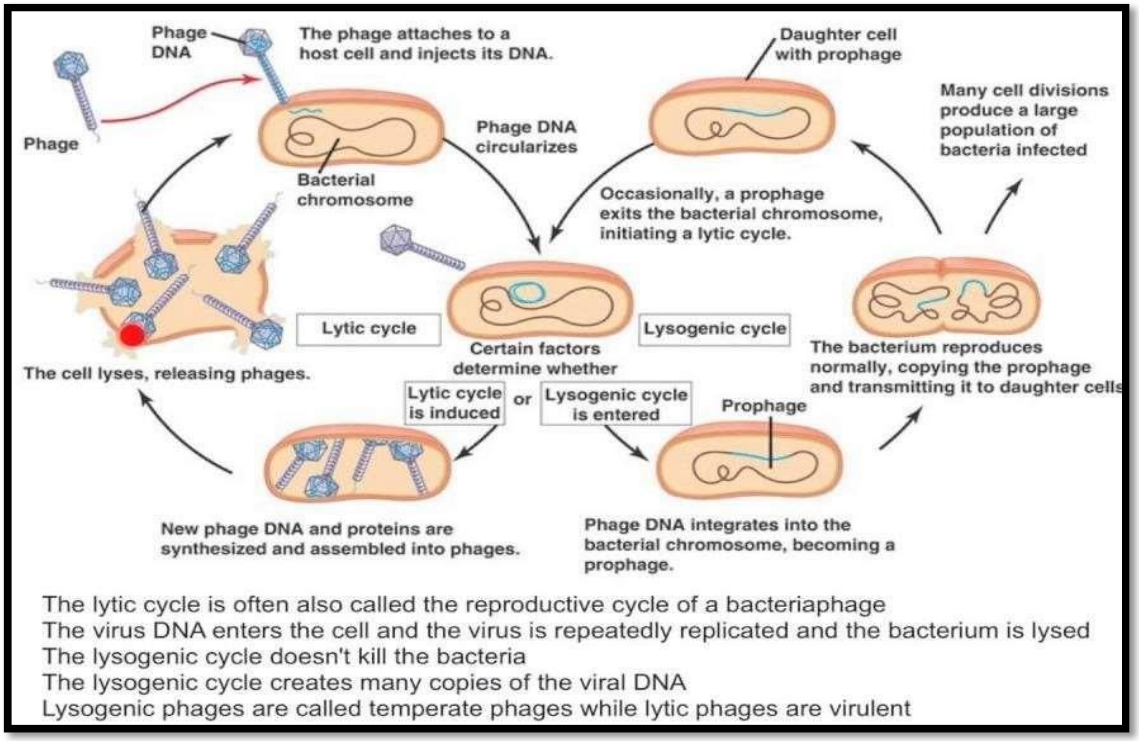
- Enveloped viruses (e.g., HIV) typically are released from the host cell by budding.

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

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

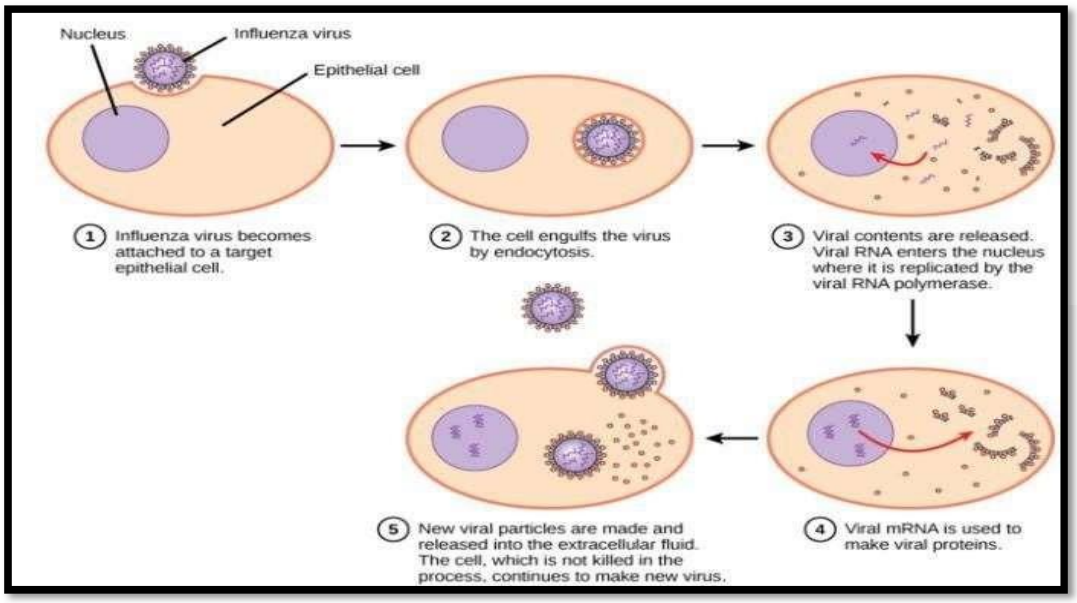


LYTIC Vs LYSOGENIC MODE OF REPLICATION OF VIRUSES



The lytic cycle is often also called the reproductive cycle of a bacteriaphage
The virus DNA enters the cell and the virus is repeatedly replicated and the bacterium is lysed
The lysogenic cycle doesn't kill the bacteria
The lysogenic cycle creates many copies of the viral DNA
Lysogenic phages are called temperate phages while lytic phages are virulent

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



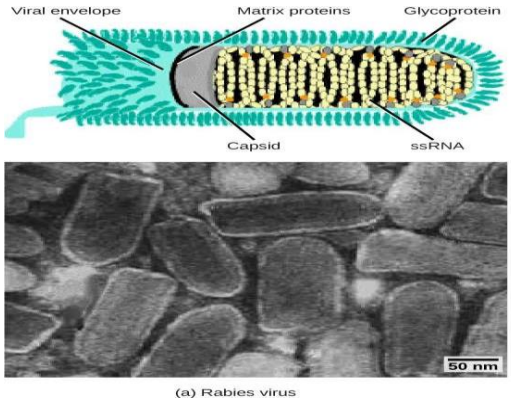
VIRUS CLASSIFICATION

Past Systems of Classification;

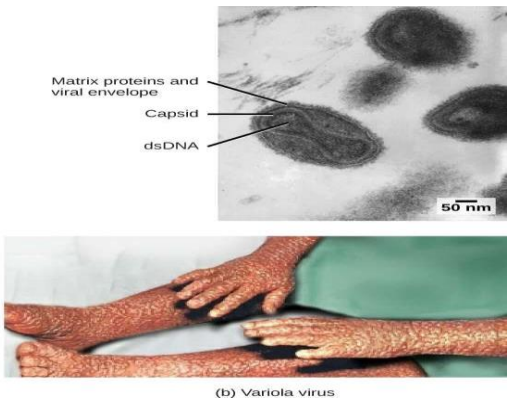
- Viruses contain only a few elements by which they can be classified: the viral genome, the type of capsid, and the envelope structure for the enveloped viruses.
- Viral genomes may vary in the type of genetic material (DNA or RNA) and its organization (single- or double-stranded, linear or circular, and segmented or non-segmented). In some viruses, additional proteins needed for replication are associated directly with the genome or contained within the viral capsid.

Virus Classification by Genome Structure and Core

Core Classifications	Examples
RNA	Rabies virus, retroviruses
DNA	Herpesviruses, smallpox virus
Single-stranded	Rabies virus, retroviruses
Double-stranded	Herpesviruses, smallpox virus
Linear	Rabies virus, retroviruses, herpesviruses, smallpox virus
Circular	Papillomaviruses, many bacteriophages
Non-segmented: genome consists of a single segment of genetic material	Parainfluenza viruses
Segmented: genome is divided into multiple segments	Influenza viruses



(a) Rabies virus

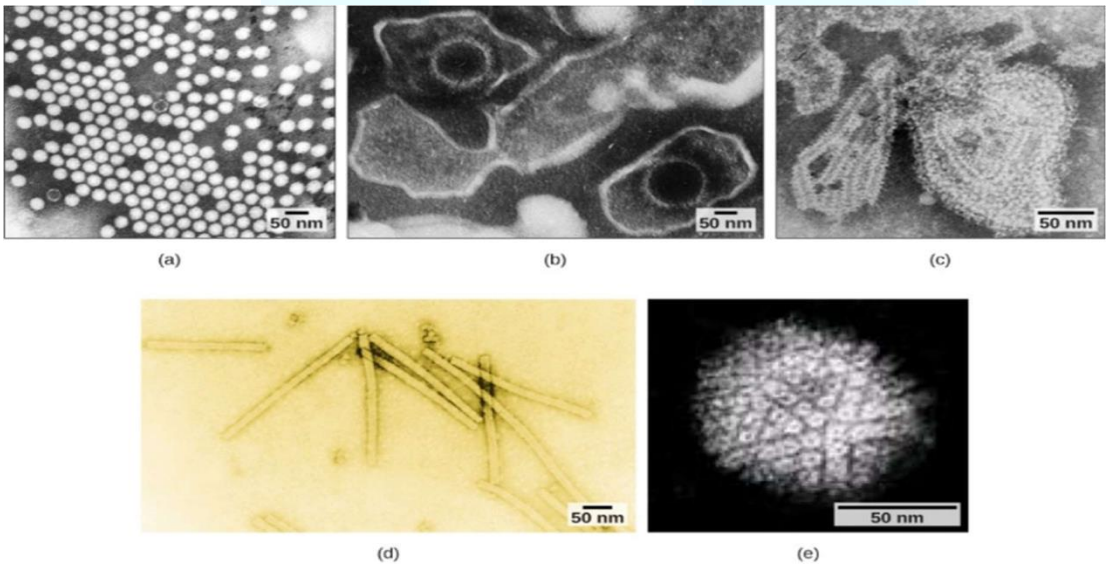


(b) Variola virus

Virus Classification by Capsid Structure

- Viruses can also be classified by the design of their capsids.
- Capsids are classified as naked icosahedral, enveloped icosahedral, enveloped helical, naked helical, and complex.
- The type of genetic material (DNA or RNA) and its structure (single- or double-stranded, linear or circular, and segmented or non-segmented) are used to classify the virus core structures.

Capsid Classification	Examples
Naked icosahedral	Hepatitis A virus, polioviruses
Enveloped icosahedral	Epstein-Barr virus, herpes simplex virus, rubella virus, yellow fever virus, HIV-1
Enveloped helical	Influenza viruses, mumps virus, measles virus, rabies virus
Naked helical	Tobacco mosaic virus
Complex with many proteins; some have combinations of icosahedral and helical capsid structures	Herpesviruses, smallpox virus, hepatitis B virus, T4 bacteriophage



a).Polio virus is naked icosahedral. b). Epstein-Barr virus capsid is enveloped icosahedral. c). The mumps virus capsid is an enveloped helix. d). The tobacco mosaic virus capsid is naked helical and e). The herpesvirus capsid is complex.

Baltimore Classification;

- The most commonly used system of virus classification was developed by Nobel Prize-winning biologist David Baltimore in the early 1970s.
- In addition to the differences in morphology and genetics mentioned above, the Baltimore classification scheme groups viruses according to how the mRNA is produced during the replicative cycle of the virus.

Group I

- Viruses contain double-stranded DNA (dsDNA) as their genome.
- Their mRNA is produced by transcription in much the same way as with cellular DNA.

Group II

- Viruses have single-stranded DNA (ssDNA) as their genome.
- They convert their single-stranded genomes into a dsDNA intermediate before transcription to mRNA can occur.

Group III

- Viruses use dsRNA as their genome.
- The strands separate, and one of them is used as a template for the generation of mRNA using the RNA-dependent RNA polymerase encoded by the virus.

Group IV

- Viruses have ssRNA as their genome with a positive polarity.
- Positive polarity means that the genomic RNA can serve directly as mRNA. Intermediates of dsRNA, called replicative intermediates, are made in the process of copying the genomic RNA.

- Multiple, full-length RNA strands of negative polarity (complimentary to the positive-stranded genomic RNA) are formed from these intermediates, which may then serve as templates for the production of RNA with positive polarity, including both full-length genomic RNA and shorter viral mRNAs.

Group V

- Viruses contain ssRNA genomes with a negative polarity, meaning that their sequence is complementary to the mRNA.
- As with Group IV viruses, dsRNA intermediates are used to make copies of the genome and produce mRNA.
- In this case, the negative-stranded genome can be converted directly to mRNA.
- Additionally, full-length positive RNA strands are made to serve as templates for the production of the negative-stranded genome.

Group VI

- Viruses have diploid (two copies) ssRNA genomes that must be converted, using the enzyme reverse transcriptase, to dsDNA; the dsDNA is then transported to the nucleus of the host cell and inserted into the host genome.
- Then, mRNA can be produced by transcription of the viral DNA that was integrated into the host genome.

Group VII

- Viruses have partial dsDNA genomes and make ssRNA intermediates that act as mRNA, but are also converted back into dsDNA genomes by reverse transcriptase, necessary for genome replication.
- The characteristics of each group in the Baltimore classification are summarized in Table 3 with examples of each group.

Baltimore Classification

Group	Characteristics	Mode of mRNA Production	Example
I	Double-stranded DNA	mRNA is transcribed directly from the DNA template	Herpes simplex (herpesvirus)

II	Single-stranded DNA	DNA is converted to double-stranded form before RNA is transcribed	Canine parvovirus (parvovirus)
III	Double-stranded RNA	mRNA is transcribed from the RNA genome	Childhood gastroenteritis (rotavirus)
IV	Single stranded RNA (+)	Genome functions as mRNA	Common cold (pircornavirus)
V	Single stranded RNA (−)	mRNA is transcribed from the RNA genome	Rabies (rhabdovirus)
VI	Single stranded RNA viruses with reverse transcriptase	Reverse transcriptase makes DNA from the RNA genome; DNA is then incorporated in the host genome; mRNA is transcribed from the incorporated DNA	Human immunodeficiency virus (HIV)
VII	Double stranded DNA viruses with reverse transcriptase	The viral genome is double-stranded DNA, but viral DNA is replicated through an RNA intermediate; the RNA may serve directly as mRNA or as a template to make mRNA	Hepatitis B virus (hepadnavirus)

VIROIDS

- 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

BACTERIOPHAGE

- 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

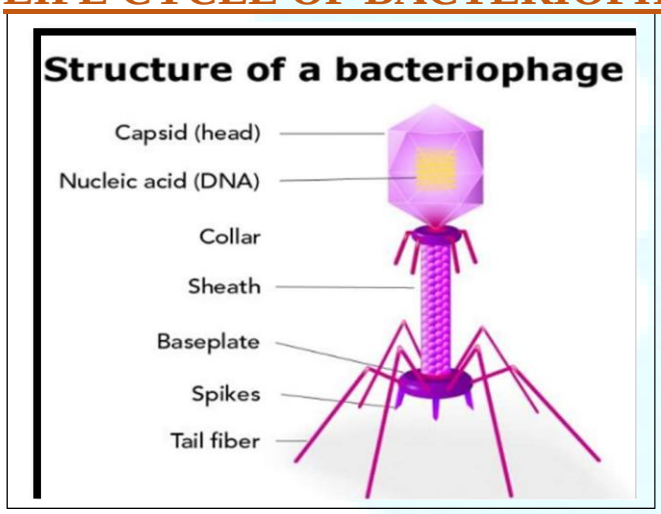
- Thousands of varieties of phages exist, each of which may infect only one type or a few types of bacteria or archaea.
- Phages are classified in a number of virus families; some examples include Inoviridae, Microviridae, Rudiviridae, and Tectiviridae.
- Like all viruses, phages are simple organisms 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.

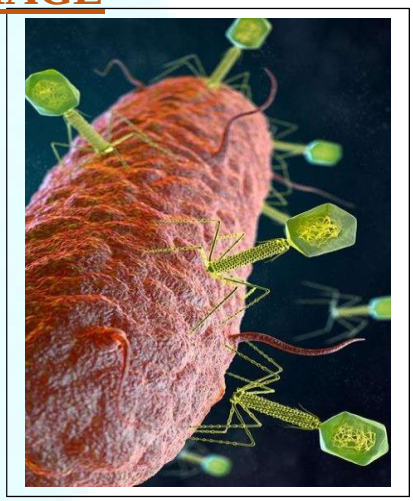
Life cycles of bacteriophages

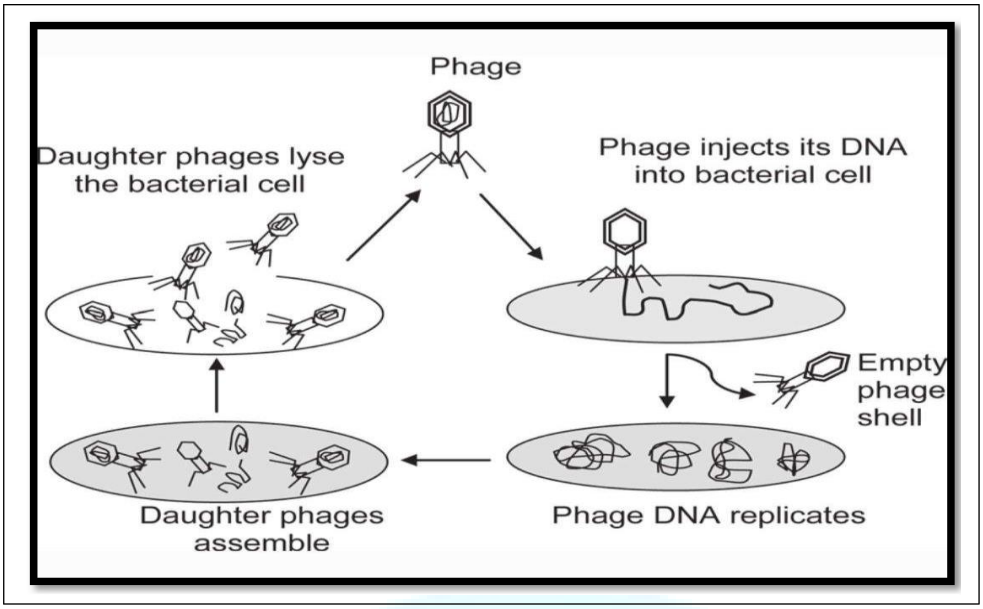
- During infection a phage attaches to a bacterium and inserts its genetic material into the cell.
- After that a phage usually follows one of two life cycles, lytic (virulent) or lysogenic (temperate).
- Lytic phages take over the machinery of the cell to make phage components.

- 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.

LIFE CYCLE OF BACTERIOPHAGE







LYTIC AND LYSOGENIC CYCLE

- Lytic and Lysogenic cycles are the method of viral multiplication.
- Lytic cycle, comparitively more common, is a method of viral multiplication wherein the virus attacks a host cell.
- It destroys the host cell totally by feeding on the metabolism of the host in order to multiply.
- Lysogenic cycle, not a common method of viral reproduction, majorly is dependant on the lytic cycle. In this method, the virus unites its genetic details with that of the host, turning dormant and lets the host to reproduce while continuing its regular activities.
- Although similar at times, understanding the difference between lytic cycle and lysogenic cycle is important.

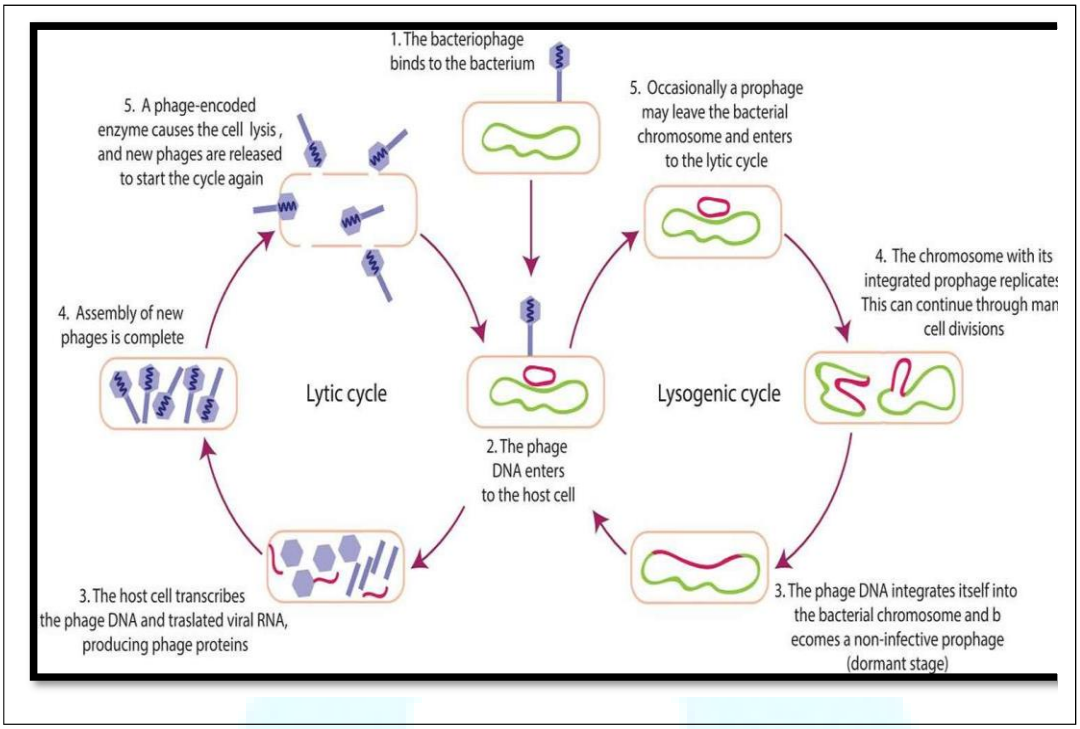
Lytic vs Lysogenic Cycle

LyticCycle	LysogenicCycle

The DNA of the virus doesn't integrate into the host DNA	The DNA of the virus integrates into the host DNA
Host DNA hydrolysed	Host DNA not hydrolysed
Absence of prophage stage	Presence of prophage stage
DNA replication of virus takes place independently from the host DNA replication	DNA replication of the virus takes place along with the host DNA replication
Occurs within a short period of time	Takes time
Symptoms of viral replication are evident	Symptoms of viral replication not evident
Genetic recombination in the host bacterium not allowed	Genetic recombination in the host bacterium allowed
The cellular mechanism of the host cell is totally undertaken by the viral genome	The cellular mechanism of the host cell is somewhat disturbed by the viral genome

- The main difference between the lysogenic cycle and lytic cycle is their influence on the host cell.

Lytic and Lysogenic Cycle

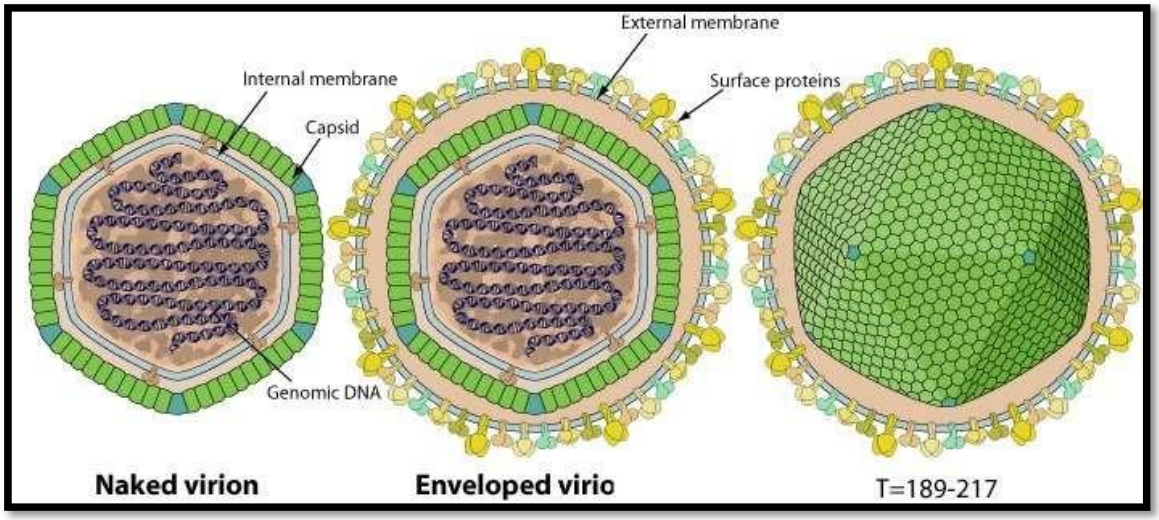


VIRIONS

- 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.



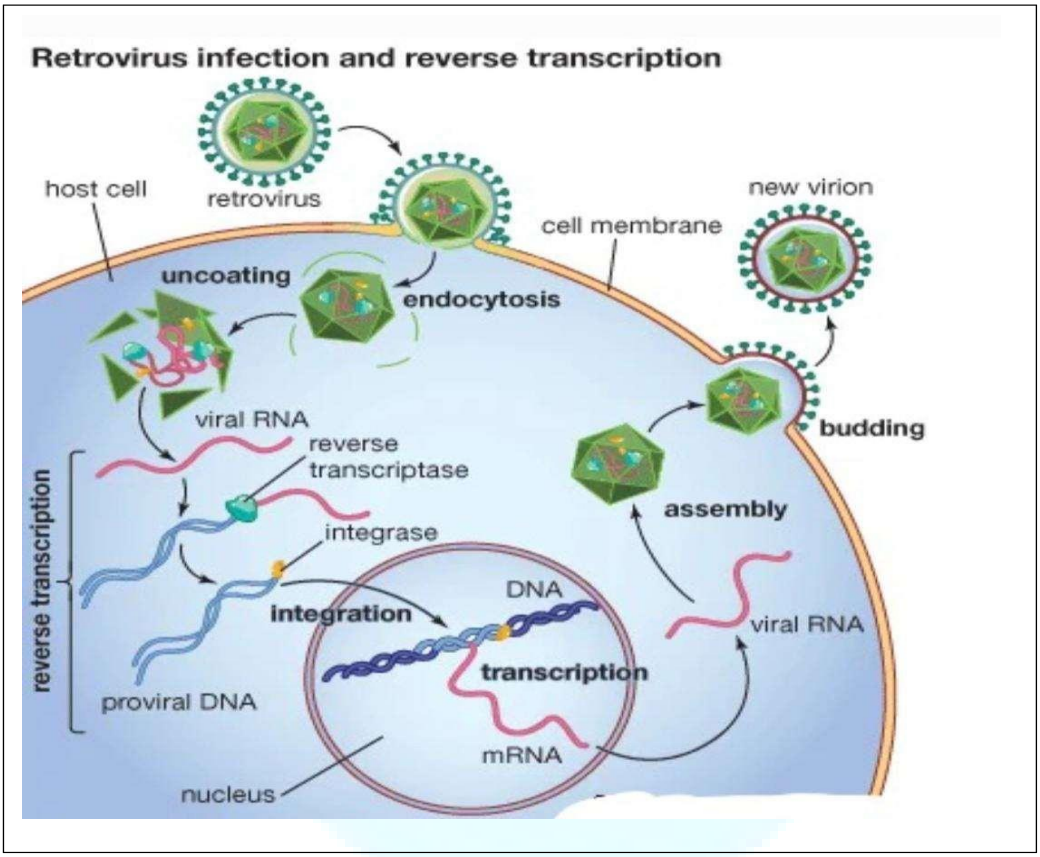
RETROVIRUS

- Retrovirus any of a group of viruses that belong to the family Retroviridae and that characteristically carry their genetic blueprint in the form of

ribonucleic acid (RNA).

- Retroviruses are named for an enzyme known as reverse transcriptase, which was discovered independently in 1971 by American virologists Howard Temin and David Baltimore.
- Reverse transcriptase transcribes RNA into deoxyribonucleic acid (DNA), a process that constitutes a reversal of the usual direction of cellular transcription (DNA into RNA).
- The action of reverse transcriptase makes it possible for genetic material from a retrovirus to become permanently incorporated into the DNA genome of an infected cell; the enzyme is widely used in the biological sciences to synthesize genes.
- Retroviruses cause tumour growth and certain cancers in animals and are associated with slow infections of animals, such as equine infectious anemia.
- In humans, a retrovirus known as human T-cell lymphotropic virus type 1 (HTLV-1) causes a form of cancer called adult T-cell leukaemia (ATL).
- It can also cause a neurodegenerative condition known as HTLV-1-associated myelopathy/tropical spastic paraparesis (HAM/TSP).
- A closely related virus named HTLV-2 is associated with relatively mild neurological disorders but has not been identified as a causative agent of human disease.
- As many as 20 million people worldwide are thought to be infected with HTLVs, but only a small percentage of infected individuals actually develop ATL or HAM/TSP.
- The retrovirus known as human immunodeficiency virus (HIV) causes acquired immunodeficiency syndrome (AIDS) in humans.
- HIV is closely related to simian immunodeficiency virus (SIV), a retrovirus found in chimpanzees and gorillas.
- Endogenous retroviruses (ERVs) are persistent features of the genomes of many animals.
- ERVs consist of the genetic material of extinct, or “fossil,” viruses, the genomic constitution of which is similar to that of extant retroviruses.
- Human ERVs (HERVs) have become distributed within human DNA over the course of evolution.
- They are passed from one generation to the next and make up an estimated 1 to nearly 5 percent of the human genome.
- HERVs are suspected of having influenced the evolution of certain elements of the human genome.

- They also have been implicated in certain human diseases, including multiple sclerosis.
- HTLV-1 was the first human retrovirus to be discovered, having been detected and isolated in 1979 by American virologist Robert C. Gallo and colleagues.
- HIV was first isolated in 1983.



PRIONS

- Prion, an abnormal form of a normally harmless protein found in the brain that is responsible for a variety of fatal neurodegenerative diseases of animals, including humans, called transmissible spongiform encephalopathies.
  - In the early 1980s American neurologist Stanley B. Prusiner and colleagues identified the "proteinaceous infectious particle," a name that was shortened to "prion" (pronounced "pree-on").
  - Prions can enter the brain through infection, or they can arise from mutations in the gene that encodes the protein.
  - Once present in the brain prions multiply by inducing benign proteins to refold into the abnormal shape.
  - This mechanism is not fully understood, but another protein normally found in the body may also be involved.
  - The normal protein structure is thought to consist of a number of flexible coils called alpha helices.
  - In the prion protein some of these helices are stretched into flat structures called beta strands.
  - The normal protein conformation can be degraded rather easily by cellular enzymes called proteases, but the prion protein shape is more resistant to this enzymatic activity.
  - Thus, as prion proteins multiply, they are not broken down by proteases and instead accumulate within neurons, destroying them.
  - Progressive neuron destruction eventually causes brain tissue to become filled with holes in a sponge like, or spongiform, pattern.

  - Diseases caused by prions that affect humans include:
    a. Creutzfeldt-Jakob disease
    b. Gerstmann-Sträussler-Scheinker disease
    c. Fatal familial insomnia
    d. kuru
  - Prion diseases affecting animals include:
    (i) Scrapie
    (ii) Bovine spongiform encephalopathy (commonly called mad cow disease).
    (iii) Chronic wasting disease of mule deer and elk.

- For decades physicians thought that these diseases resulted from infection with slow-acting viruses, so called because of the lengthy incubation times required for the illnesses to develop.
- These diseases were, and sometimes still are, referred to as slow infections.
- The pathogenic agent of these diseases does have certain viral attributes, such as extremely small size and strain variation, but other properties are atypical of viruses.
- In particular, the agent is resistant to ultraviolet radiation, which normally inactivates viruses by destroying their nucleic acid.
- Prions are unlike all other known disease-causing agents in that they appear to lack nucleic acid i.e., DNA or RNA which is the genetic material that all other organisms contain.
- Another unusual characteristic of prions is that they can cause hereditary, infectious, and sporadic forms of disease for example, Creutzfeldt-Jakob disease manifests in all three ways, with sporadic cases being the most common.
- Prion proteins can act as infectious agents, spreading disease when transmitted to another organism, or they can arise from an inherited mutation.
- Prion diseases also show a sporadic pattern of incidence, meaning that they seem to appear in the population at random.
- The underlying molecular process that causes the prion protein to form in these cases is unknown.