

Unit 2: Bacteria and Viruses

Long Questions

DESCRIPTIVE QUESTIONS

Q1. Comment about latest taxonomic status of bacteria.

Ans. Over the years many schemes have been proposed for classifying organisms into kingdoms. The five-kingdom **classification system**, proposed by **Robert H. Whittaker in 1969**, is recommended in biology. This system classified the organisms in a comprehensive way that reflects evolutionary history of organisms. According to this classification system, all prokaryotes are included in a separate kingdom i.e., the kingdom Monera.

Reason for Creating Separate Classification for Prokaryote

In the last decade, molecular studies have highlighted **serious flaws** in the five- kingdom classification system. In **1990**, American microbiologist **Carl Woese** suggested that there are **two separate groups** of prokaryotes i.e., **Archaea and Bacteria**. He classified living organisms into three domains i.e., domain Archaea, domain Bacteria and domain Eukarya. According to three-domain system, domain **Archaea** and domain Bacteria contain prokaryotes but they differ in a number of features. e.g. cell membrane lipids, cell wall composition, metabolic differences. **Molecular evidence** suggests that archaea are more closely related to eukaryotes than to bacteria.

★ Robert H. Whittaker proposed the five kingdoms system of classification i.e. Monera, Protista, Fungi, Plantae and Animalia. The first one includes prokaryotes and other four include eukaryotes.

Most biologists favour replacing it with a new system, called three-domain system. It is more aligned with the data gained from molecular studies.

Bacteria are the prokaryotes classified in the domain of their own, i.e., the domain Bacteria.

STRUCTURE OF BACTERIA

Q2. Write composition of bacterial cell wall. Compare and contrast the cell wall of gram positive and gram-negative bacteria.

Ans. Cell wall composition: It is a **rigid wall** around the plasma membrane of bacterial cell. The major component of bacterial cell wall is a unique **macromolecule**, called **peptidoglycan or murein**. It is composed of **long glycan** (polysaccharide) chain, cross-linked with **short peptide** fragments. Its amount differs in different bacteria. Cell wall also contains lipids, which are linked to peptidoglycan.

Gram's Staining

★ **Sir Hans Christian Gram** devised the technique of Gram's staining. Gram-positive bacteria **stain purple** because they retain **violet dye (CV-I complex)** in their cell walls.

★ **Note:** All questions and paragraphs marked with a star ★ are explanations of the Box Information provided in the textbook.

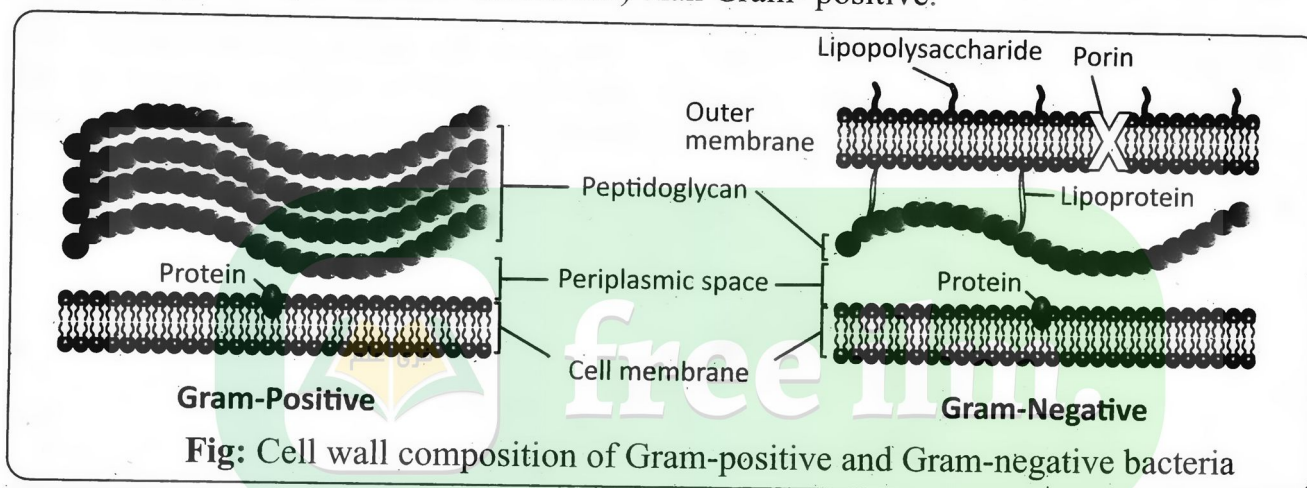
Gram- negative bacteria do not retain violet dye (they retain safranin) and so they appear in original (pink) colour.

Composition of cell wall: The composition of cell wall is quite different in Gram-positive and Gram- negative bacteria.

Gram-Positive Bacteria: The cell wall of Gram-positive bacteria contains **thick layer** of peptidoglycan and has **less lipid content**.

Gram-Negative Bacteria: The cell wall of Gram-negative bacteria has a **thin layer** of peptidoglycan and **more lipid content**.

- They have an outer membrane made of **lipopolysaccharides** and **lipoproteins**. The outer membrane makes Gram-negative bacteria resistant to many antibiotics.
- It contains a protein called **porin**, which acts like a **pore for specific molecules**. The cell wall of Gram-negative bacteria has more **periplasmic space** (space between peptidoglycan layer and cell membrane) than Gram- positive.



Characteristics	Gram-Positive	Gram-Negative
Number of major layers	One	Two
Chemical make up	Peptidoglycan (50% of dry weight in some bacterial cells), Teichoic acid and lipoteichoic acid Lipids (1-4%)	Peptidoglycan (10% dry weight of some bacterial cells), Lipopolysaccharides and Lipoproteins Lipids (11-12%)
Overall thickness	20-80nm	8-11 nm
Outer membrane	No	Yes
Periplasmic space	Present in some	Present in all
Permeability	More permeable	Less permeable

Q3. Briefly describe the following bacterial cell structure.

(i) Cell membrane

(ii) Cytoplasm and Genetic material

Ans. (i) Cell Membrane

- **Location:** Cell membrane or plasma membrane is present just beneath cell wall. It lies at the outermost in bacteria that lack cell wall (e.g., *Mycoplasmas* and *Spiroplasmas*).
- **Lack Sterols:** The cell membrane of bacteria does not have sterols (e.g., **cholesterol**) in its chemical makeup.

- **Mesosomes:** At some points, cell membrane invaginates and forms **vesicles, tubules** or **lamellae** in cytoplasm. These structures are known as mesosomes. These are involved in **DNA replication, cell division** and also serve as **respiratory centres**.

ii) Cytoplasm and Genetic Material

- **Composition:** Cytoplasm contains dissolved substances and large structures such as **nucleoid, ribosomes**, and **mesosomes**.
- **Organelles:** It lacks **cytoskeleton** and membrane-bounded organelles. Many ribosomes are freely dispersed in cytoplasmic matrix and some are loosely attached to plasma membrane. Bacterial ribosomes are **smaller than eukaryotic (80s)** ribosomes. Each ribosome sediments at **70S** (larger subunit at 50S and smaller subunit at 30S).
- **Nucleoid and Genetic Material:** Near the centre of cytoplasm, there is an irregular-shaped dense area i.e., **nucleoid**. It contains DNA. A **bacterium** possesses a single, **circular**, double stranded DNA. Bacterial DNA does **not have attached histones**. It is sometimes called the chromosome of bacterium.
- **Plasmids:** Some bacteria have circular, double-stranded **extra chromosomal DNA** molecules, called plasmids. They are self-replicating and can replicate before or after cell division. They contain **genes** that enable bacteria for resistance against unfavourable conditions (e.g., **antibiotics**).

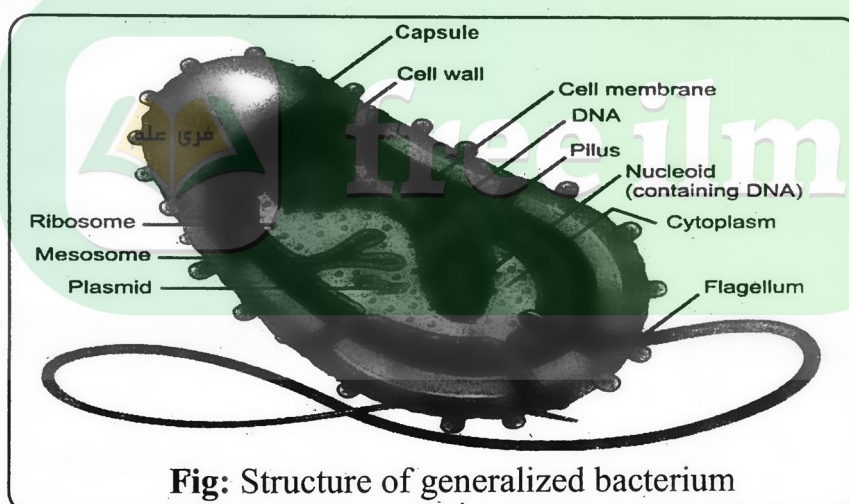


Fig: Structure of generalized bacterium

★ Plasmids as Vectors

Plasmids also serve as important vectors, in genetic engineering. They are used to carry selected genes to bacteria for cloning or for the synthesis of specific proteins.

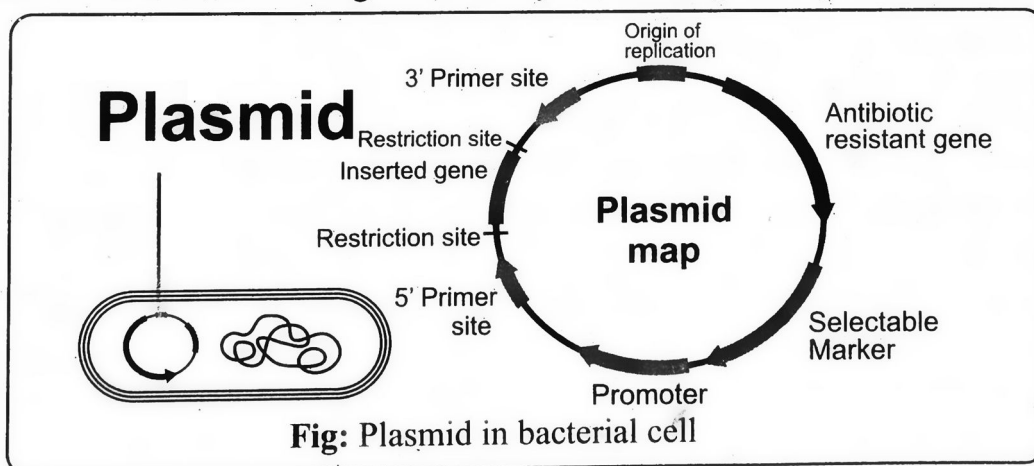


Fig: Plasmid in bacterial cell

ENDOSPORE FORMATION IN BACTERIA

Q4. State the formation of endospore in bacteria. / Explain the mechanism of sporulation in bacteria.

Ans. Definition: Endospores are thick-walled, metabolically inactive (dormant) specialized “resting” cells, which enable bacteria to survive, extended periods of harsh conditions.

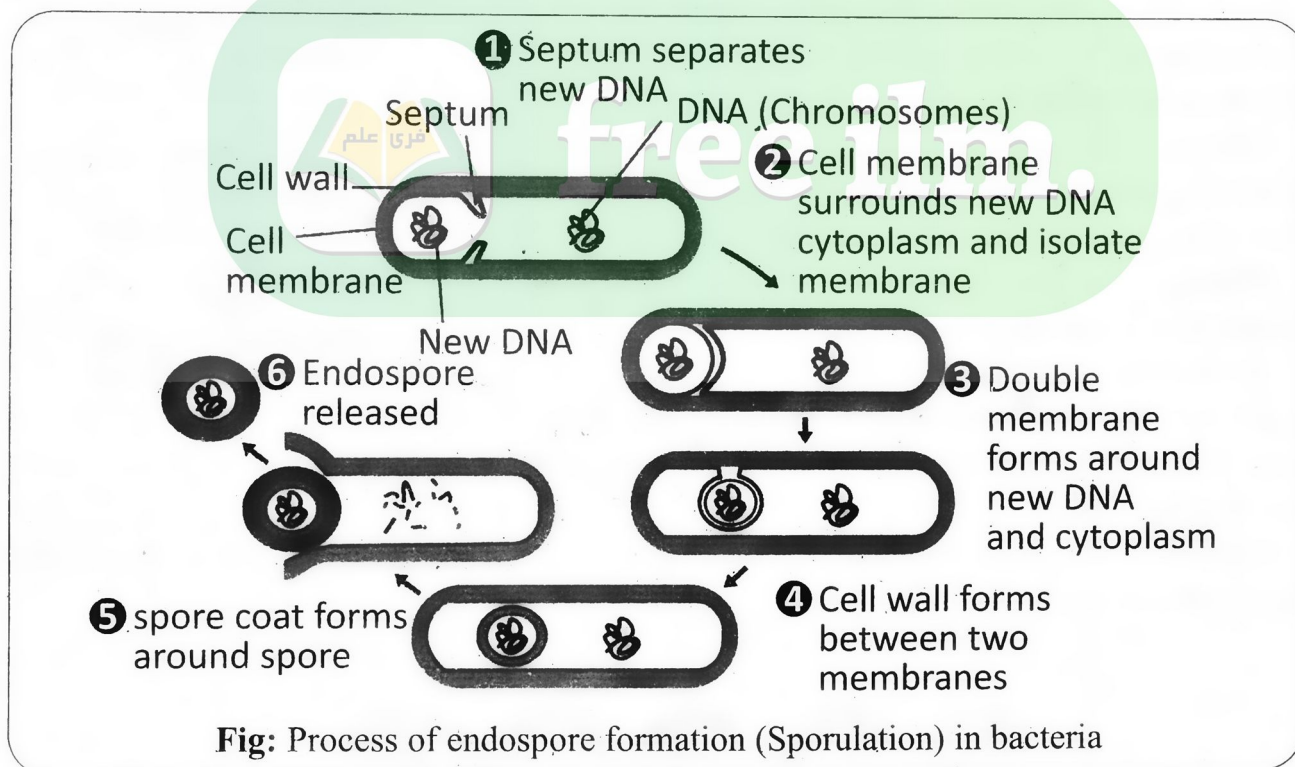
Sporulation: The process by which bacteria make endospores, is called sporulation.

Mechanism of Spore formation/Sporulation

i. DNA Replication and Septum Formation: When a bacterium faces unfavourable conditions, it **replicates its DNA**. Cell membrane makes a **septum** to isolate the new DNA and a small portion of cytoplasm, then the cell membrane surrounds DNA, cytoplasm and isolated membrane.

ii. Double Membrane Formation: Cell membrane again grows around the new DNA, cytoplasm, and septum. In this way, the new DNA is surrounded by two membranes.

iii. Formation of New Peptidoglycan: The DNA of vegetative cell disintegrates and whole cell begins to dehydrate. A new peptidoglycan layer forms between the membranes around separated DNA and cytoplasm.



iv. Spore Coat Formation and Endospore Release: A spore coat also forms around it. The structure matures into endospore. The vegetative cell breaks and endospore is released. Endospore remains dormant unless favourable conditions return.

v. Endospore Germination: Under favourable conditions, endospore germinates to give rise to a new vegetative cell.

Examples: Endospore formation is common in Gram-positive bacteria like *Bacillus* and *Clostridium*.

MOTILITY IN BACTERIA

Q5. Explain different methods of movement/locomotion in bacteria.

Ans. Bacteria use different motility patterns to navigate and explore natural habitats. Following are some important methods of locomotion in bacteria.

a. Flagellar movements: The process of locomotion **powered by flagella** is called flagellar movement, it may be swimming or swarming. Counter clockwise rotation of flagellum pushes the cell forward with flagellum trailing behind.

Swimming: Swimming refers to the movement of individual bacteria in liquid environment. They swim by using their flagella, most bacilli and spirilla move by means of flagella.

Swarming: The coordinated movement of a **group / population** of bacteria is called swarming. Flagellar movement allows bacteria to travel in **liquid media**.

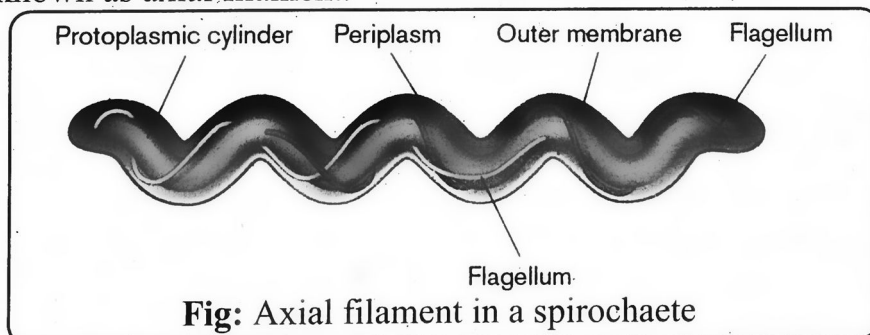
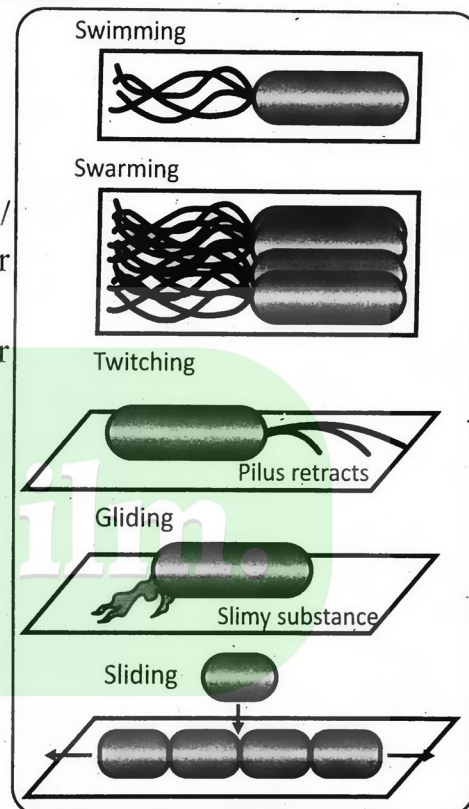
b. Twitching or crawling: It is used to move over surfaces. It is **mediated by pili**, which bind to surrounding solid surface and **retract**. Thus, bacterial cell is **pulled forward**.

c. Gliding: In gliding, bacteria **secrete slimy substance**, which help them for smooth gliding over solid surfaces. It is similar to twitching.

d. Sliding: The movement due to the **expansion** created by the **pushing force** of dividing cells.

e. Brownian movement: Some bacteria (e.g., Streptococcus) that **do not have flagella or pili**, move due to the **random and uncontrolled movements** of the **particles** present in fluid is called Brownian movement.

f. Movement by axial filament: Some bacteria (e.g., spirochaetes), have a **modified flagellum**. It is known as axial filament.



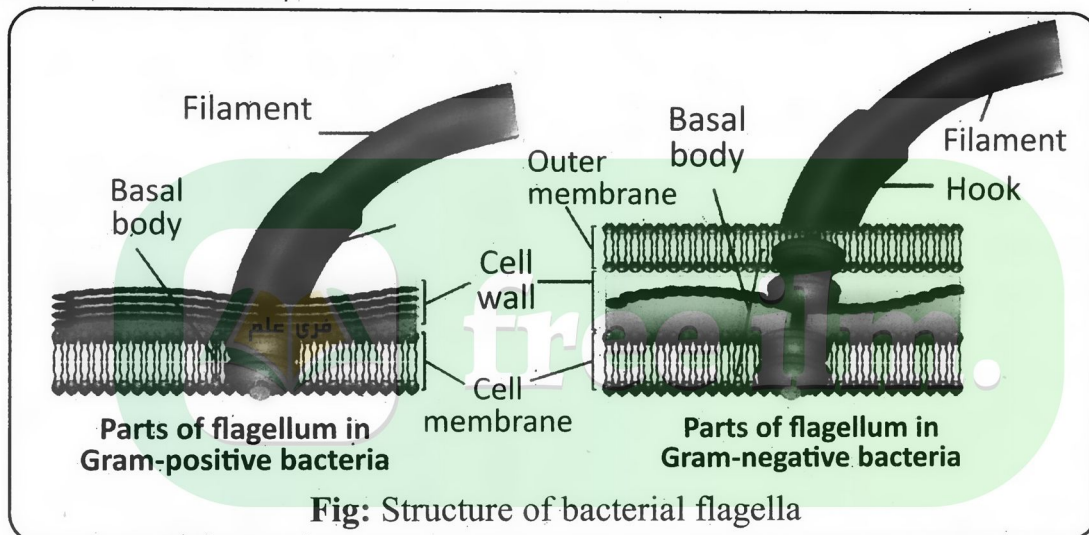
It is anchored at one end and runs **length-wise** in periplasmic space (between cell membrane and outer membrane). It consists of two sets of flagella-like fibrils anchored at the two poles of cell. It helps spirochaetes for **flexing, swimming, creeping** and **spinning movements**.

FLAGELLA

Q6. Explain the structure of bacterial flagellum. Classify bacteria on basis of flagella.

Ans. Structure of Flagellum

- The flagellum of bacteria is entirely different in structure from the flagellum of eukaryotes. They are **not built on 9+2 pattern of microtubules**, but are composed of **flagellin protein**.
- The bacterial flagellum consists of a **basal body**, a **hook** and a **filament**.
- i. Basal Body:** The basal body is present just beneath cell membrane. It consists of **rotating rings** (one pair in Gram-positive bacteria and two pairs in Gram-negative bacteria). The rings anchor the flagellum in cell membrane and cell wall.
- ii. Hook:** The hook is a **curved structure** that connects basal body with the filament.
- iii. Filament:** Filament is elongated **thread like structure** composed of flagellin protein sub-units in helical fashion.



★ **Pili in Bacteria:** Some bacteria have pili (singular; pilus). These are **non-helical, filamentous** appendages and are **smaller** and **thinner** than **flagella**. Pili are used for **attachment of bacteria** to various surfaces. They are also involved in the **mating process** (conjugation) between cells.

Classification of Bacteria on Basis of Flagella

The primary function of flagella is to provide **locomotion** to bacteria. Many kinds of bacteria have flagella, which enable them to move.

- The **secondary function** of flagella is to detect and respond to chemical signals (chemotaxis).
- 1. Atrichous:** The bacteria which do not possess flagella are called atrichous.
- 2. Monotrichous:** The bacteria with single polar flagellum are called monotrichous.
- 3. Lophotrichous:** The bacteria with a tuft of flagella at one pole are called lophotrichous.
- 4. Amphitrichous:** The bacteria with tuft of

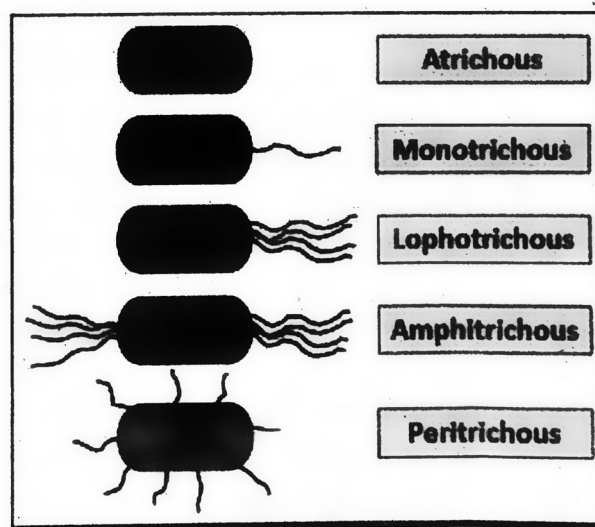


Fig: The different arrangements of bacterial flagella

flagella at each of two poles are called amphitrichous.

5. **Peritrichous:** The bacteria with flagella surrounding the whole cell are called peritrichous.

BACTERIA; ECOLOGY AND DIVERSITY

Q7. Elaborate major groups of domain bacteria.

Ans. Important groups of the domain bacteria

Margulis and Schwartz proposed a useful classification system for all prokaryotes. They classified bacteria into **16 phyla**. The following discussion deals with the important groups of the domain bacteria.

1. Omnibacteria

- These are **rigid, rod-shaped, heterotrophic, Gram-negative bacteria**.
- Many important **pathogens** are included in this group. Most of these bacteria have flagella.
- They do **not produce spores**. They are usually aerobic.
- **Examples:** *Escherichia coli* and *Vibrios*.

2. Cyanobacteria

- These are **photosynthetic bacteria**.
- They played most important role in the history of the Earth for increasing **free oxygen in atmosphere**.
- They contain **chlorophyll-a** and accessory pigments like **carotenoids**, and **blue and red phycobilins**.
- Many cyanobacteria fix atmospheric nitrogen in their special cells called **heterocysts**. They are common in soil in the form of **mats**. The mats on the sediments in the sea are dominated by cyanobacteria.
- Cyanobacteria containing **lichens** are found on rock surfaces.
- ★ In the recent discovery that the bulk of our modern **petroleum deposits** were formed by masses of decayed cyanobacteria.
- ★ **Colourful blooms** may occur in polluted water as a result of the rampant growth of cyanobacteria. The colours of such blooms result from the photosynthetic pigments of cyanobacteria.

3. Mycoplasmas and Spiroplasmas

- These groups **differ** from all other bacteria in that they **lack cell walls**.
- As they lack cell walls, they are **resistant to penicillin** and other antibiotics that work by **inhibiting cell wall growth**.

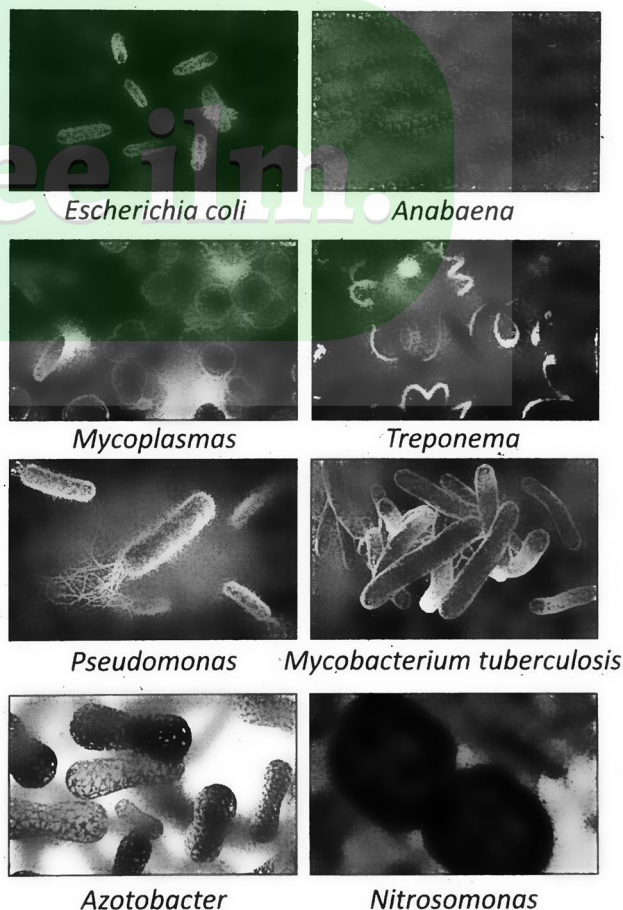


Fig: Major groups of bacteria

- Some mycoplasmas cause **diseases** in mammals e.g., certain types of **pneumonia** in humans.
- Spiroplasmas cause significant plant diseases e.g., the lethal **yellowing disease of coconuts**.

4. Spirochaetes

- These are **long spirilla** with Gram-negative cell walls.
- They may have **2** to more than **100** flagella.
- **Treponema** are important spirochaetes. They cause **syphilis** (a fatal sexually transmitted disease).

5. Pseudomonas

- These are **straight or curved** Gram-negative rods with one or many flagella at one end.
- They are found in soil and water. They can **easily break down organic compounds**.
- Some of them are autotrophic but many are plant pathogens.
- Some of them play role in **denitrification**. *Pseudomonas aeruginosa* occurs in soil, water and raw vegetables.
- Although it is usually harmless, it can form **serious infections in weak people**.

6. Actinomycetes

- These have **filamentous growth forms**. They **produce spores** that are resistant to unfavourable conditions.
- Some actinomycetes are **nitrogen fixers** and are found in the **root nodules** of many flowering plants.
- Some actinomycetes are responsible for **dental plaque**, in which the enamel of teeth is destroyed.
- A member of this group i.e., *Mycobacterium leprae* causes **leprosy**.
- Another member i.e., *Mycobacterium tuberculosis* is the cause of **tuberculosis**.
- Many **antibiotics** e.g., tetracycline, chloramphenicol, erythromycin, and neomycin were derived originally from actinomycetes.

7. Nitrogen -fixing aerobic bacteria

- This group includes economically important bacteria.
- They are Gram- negative and most are flagellated.
- *Azotobacter* is a member of this group. It is found in soil and water and converts atmospheric nitrogen into nitrates.

8. Chemosynthetic bacteria (chemoautotrophs)

- These bacteria **derive energy from the oxidation of inorganic compounds** of nitrogen, sulphur and iron. They use this energy for the synthesis of their food.
- *Nitrosomonas* and *Nitrobacter* are included in this group. They oxidize nitrogen compounds (NH_3) to gain energy.
- The NH_3 is in turn converted to nitrite and nitrate. Thus, they play vital role in nitrogen cycle.

IMPORTANCE OF BACTERIA

Q8. Briefly describe the economical and ecological importance of bacteria.

Ans. Among the great diversity of bacteria, many bacteria are beneficial ecologically as well as economically.

a. Ecologically Important Bacteria

1. Recyclers of Nature

Bacteria are involved in almost all **biogeochemical cycles** in which different essential elements move to and fro between organisms and environment.

- **Nitrifying bacteria** (*Nitrosomonas*, *Nitrobacter* and *Azotobacter*) and **denitrifying bacteria** (*Pseudomonas*) play significant role in the completion of nitrogen cycle.
- **Decomposer bacteria** decompose dead organic matter and play key role in carbon-hydrogen-oxygen cycle. The activities of **photosynthetic bacteria** e.g., cyanobacteria play role in the increase of free oxygen in Earth's atmosphere.

2. Environmental Cleaners

Many bacteria can degrade organic compounds very easily. Such bacteria have been used for the removal or degradation of pollutants (**bioremediation**) from environment.

For example, bacteria are used to **decompose city sewage** into harmless products. Some bacteria can **digest the hydrocarbons** present in petroleum. These bacteria are used to **clean up oil spills**. Bacteria are also used for the **bioremediation** of industrial toxic wastes.

b. Economically important bacteria

1. Makers of useful products

Fermented Food: Many bacteria e.g., *Lactobacillus* in combination with yeasts and molds, have been used for thousands of years in the preparation of fermented foods such as **cheese, pickles, soy sauce, vinegar, wine and yogurt**.

Pharmaceutical and Agrochemical industry: In pharmaceutical and agrochemical industry, bacteria are most important in the production of important chemicals. Some bacteria are used for the **production of antibiotics**.

Commercial preparation of animals' skin for making leather goods, involves the use of bacteria.

2. As biopesticides

Biological Pest Control: Bacteria are used in the place of pesticides in biological pest control.

Example: This commonly involves *Bacillus thuringiensis*, a Gram-positive, soil dwelling bacterium. These biopesticides are **environmental friendly** and have little or no effect on humans, wildlife, pollinators and most other beneficial insects.

Q9. Explain the use of bacteria in research and technology.

Ans. Determine the Function of Genes and Enzymes

Bacteria can grow quickly and scientists can manipulate with them very easily. Due to these reasons, bacteria are used in the fields of **molecular biology, genetics and biochemistry**. Scientists make **mutations in bacterial DNA** and examine the changes in characteristics. In

this way, they determine the function of genes and enzymes in bacteria. This knowledge is then applied to study the same genes and enzymes in more complex organisms.

Human Genes in Bacteria: Scientists also insert human genes in bacterial plasmids to produce **therapeutic proteins** e.g., insulin, growth hormones, or antibodies.

NORMAL FLORA

Q10. Define normal flora. State the benefits which we get from normal bacterial flora.

Ans. Definition: The mixture of organisms regularly found at any anatomical site is referred to as the normal flora.

Description: In a healthy animal, the **internal tissues**, e.g., blood, brain, muscle, etc., are normally free of microorganisms.

- On the other hand, the **surface tissues**, e.g., **skin** and **mucous membranes**, are constantly in contact with environment and are colonized by certain microbial species. The normal flora of humans consists of **bacteria**, a few **fungi** and **protists**, and some **methanogenic archaea**. Bacteria are the most numerous and obvious microbial components of normal flora.

Benefits to normal flora

- The associations between humans and their normal flora are **mutualistic**.
- In human body, normal flora gets **nutrients**, a stable environment and constant temperature, protection, and transport.

Benefits to Humans

- Similarly, body also gets many benefits from normal bacteria. For example;
 - Synthesis of vitamins:** Bacteria in **alimentary canal** produce vitamins. They excrete vitamins which are in excess of their needs. From alimentary canal, these vitamins are absorbed and distributed in body. For example, **enteric bacteria** secrete **Vitamin K** and **Vitamin B₁₂**, and **lactic acid bacteria** produce certain **B-vitamins**.
 - Prevent colonization by pathogens:** The bacteria of normal flora **compete** with pathogens for **attachment** sites and nutrients. So, pathogens have less chance of entering body tissues.
 - Inhibit or kill pathogens:** The intestinal bacteria produce a variety of substances, which inhibit or kill pathogen bacteria.
 - Stimulates the production of cross-reactive antibodies:** Since the normal flora **behaves** as **antigens**, they induce immunological response. Low levels of antibodies produced against the normal flora are known to **cross-react** with certain pathogens, and thereby prevent infection or invasion.

VIRUS

Q11. Explain the structure and shapes of viruses.

Ans. Structure of Virus: Viruses are extremely small infectious agents and can only be seen under electron microscope.

Size: They range in size from **20 nm (parvovirus)** to **250 nm (pox viruses)**. They are **10 to 1000 times** smaller than most **bacteria**. That is why, they can pass through the pores of filter paper.

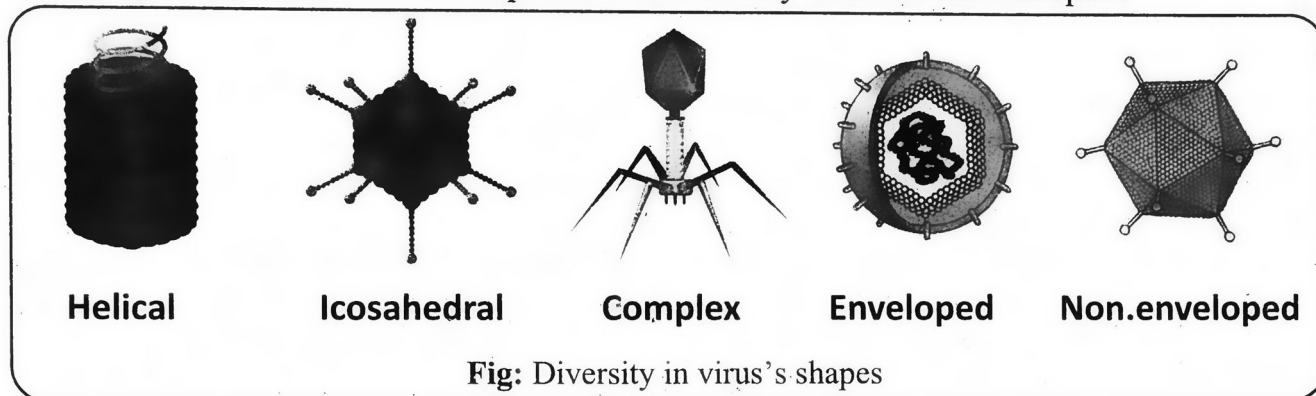
Genome: The **central core** of a virus is its genome. It is made up of nucleic acid (either DNA or RNA).

Capsid and Capsomers: The core is surrounded by a **protein coat**, called capsid. It gives definite shape to virus. Capsid is made up of **protein subunits** called as capsomeres. The number and kind of capsomeres is characteristic of a particular virus.

★ **Herpes virus** contains **162 capsomeres** in its capsid (causes cold sores, chickenpox etc.)

★ **Adenovirus** contains **252 capsomeres** in its capsid (causes common cold).

Nucleocapsid: Central core and capsid are collectively called as nucleocapsid.



Envelope: It is a lipid-rich membrane and is derived from host cell.

Enveloped viruses: In some animal viruses, nucleocapsid is covered by another membrane called envelope.

Naked viruses: Non enveloped viruses are known as **naked-viruses**.

General appearance: There is a great diversity in the general appearance of viruses.

Animal and Plant Viruses: The animal and plant viruses may be **polyhedron** (having many sides) or **helical**.

Bacterial Viruses: The bacterial viruses (**bacteriophages**) may be **cubical**, **icosahedral** (having 20 faces), **helical**, or complex (polyhedral head and rod-shaped tail).

Q12. Explain the structure of a model bacteriophage.

Ans. Bacteriophages

Bacteriophages are a diverse group of viruses that attack bacteria. They are among the **most complex** viruses. The best known phages of *Escherichia coli* are T-phages. There are many varieties of T-phages.

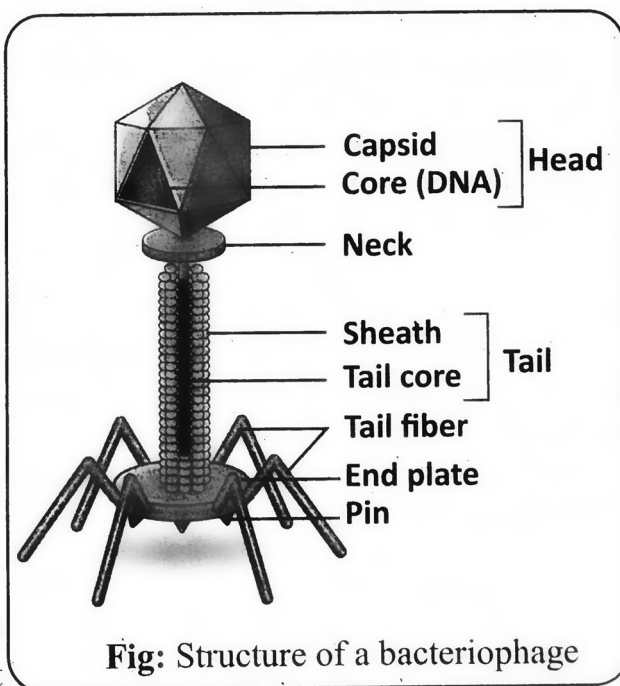
Structure of T4 phage

A T4 phage consists of a **head** and a **tail**.

i.) **Head:** The **head** is an elongated pyramidal (with two triangles having a common base), **hexagonal** (six sided), prism-shaped structure.

Capsid and Core: Its capsid is made of proteins while core contains a long double stranded DNA. A straight tail is attached with head.

ii.) **Tail:** The tail is also made of **inner core** and outer **sheath**, both of which are made of different



proteins. A **neck** attaches sheath with head and an **end plate** is present on the other side of sheath. **Six tail fibres** are attached with end plate. They help the phage to attach with bacterial wall. These structures are also made of proteins.

Q13. Explain the structure of HIV.

Ans. Structure of HIV: Human Immunodeficiency Virus (HIV) belongs to the group called **retroviruses**. It is a special group of animal viruses. Retroviruses contain RNA and their capsids.

Envelope: These structures are surrounded by lipid rich envelopes. The envelope also comprising **glycoproteins spikes**, which help the virus identify and bind to its target. They are **spherical** in form and are about **100 nm** in diameter.

Reverse transcriptase:

The most distinguishing character of retroviruses is the presence of a specific enzyme, reverse transcriptase.

This enzyme catalyses the process of reverse transcription in which a single stranded **RNA** is reversely transcribed into a strand of **DNA**. The enzyme then uses DNA strand to complete a double helix of DNA.

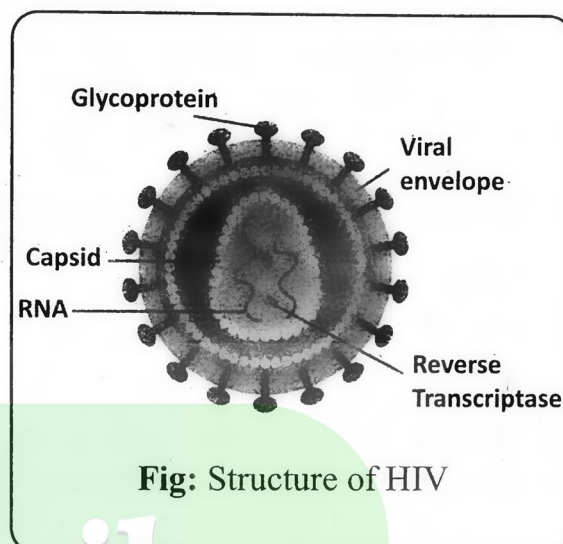


Fig: Structure of HIV

Q14. How possibly HIV got entry to humans? Relate its discovery with AIDS.

Ans. ★ Possible Origin of HIV: Experts have concluded that HIV originated in the jungles of Africa among **wild chimps**. Evidence suggests that a form of this virus entered human species and became HIV by way of **monkey bites** or ingesting monkey meat and brains.

AIDS: HIV is responsible for the disease AIDS (Acquired Immunodeficiency Syndrome). AIDS weakens the immune system of patient. The disease is fatal because no one can survive without immune system to defend against other viral and bacterial infections (opportunistic infections).

Discovery: The disease was first reported in **1981** and the patients were found **homosexual**. Later on, AIDS was discovered in non-homosexual patients too who had received **blood or blood products** from other AIDS patients.

In **1984**, it was discovered that the **agent causing** AIDS was a virus. In **1986**, the AIDS causing virus was given the name Human Immunodeficiency Virus (HIV). It is a host specific virus. It can multiply in monkeys but do not cause AIDS in them.

Because HIV attaches to human cells using specific binding factor known as CD₄ receptor which are not present in monkeys.