Chapter 2

BACTERIA AND VIRUSES

STUDENTS' LEARNING OUTCOMES

After studying this chapter, the students will be able to:

- Draw an annotated diagram of a generalized bacterial cell.
- Describe detailed structure and chemical composition of bacterial cell wall and other coverings.
- Justify the endospore formation in bacteria to withstand unfavourable conditions.
- Explain motility in bacteria.
- Describe with diagram structure of bacterial flagellum.
- Describe bacteria as recyclers of nature.
- Outline the ecological and economic importance of bacteria.
- Explain the use of bacteria in research and technology.
- Define the term normal flora.
- Describe the benefits of the bacterial flora of humans.
- Describe the structure of a model bacteriophage, and HIV.

Recalling:
Robert H. Whittaker proposed the five-kingdoms of life i.e., Monera, Protista, Fungi, Plantae, and Animalia. The first one includes prokaryotes and the other four include eukaryotes.

You know that over the years many schemes have been proposed for classifying organisms into kingdoms. You have studied in chapter 1, the five-kingdom classification system, proposed by **Robert H. Whittaker**, 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.

In the last decade, molecular studies have highlighted serious flaws in the five-kingdom classification system. You have also studied in chapter 1, most biologists favour replacing it with a new system, called **three-domain system**. It is more aligned with the data gained from molecular studies.

You know that bacteria are the prokaryotes classified in the domain of their own, i.e., the domain Bacteria. In this chapter we will study detailed structure of bacterial cell. We will also study the importance of bacteria.

2.1- STRUCTURE OF BACTERIA

Bacteria are a diverse group and all of them have unicellular prokaryotic organization, which lack membrane bounded organelles, including a well-defined nucleus. They have the simplest cellular organization.

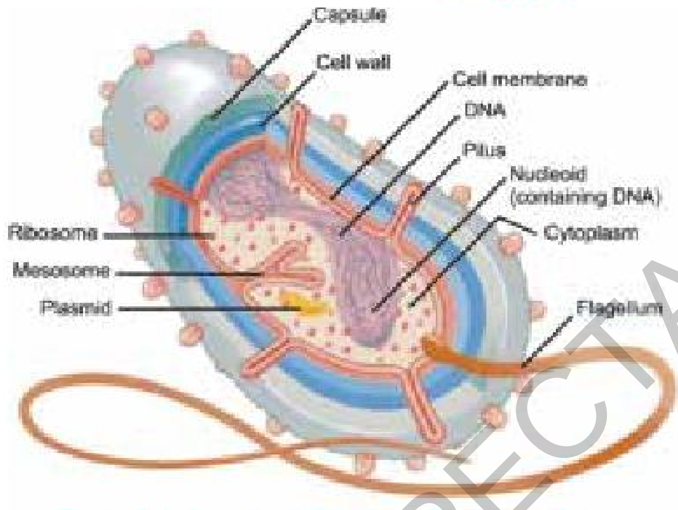

Figure 2.1: Structure of a generalized bacterium

Cell Wall

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 (Figure 2.2). Its amount differs in different bacteria. Cell wall also contains lipids, which are linked to peptidoglycan.

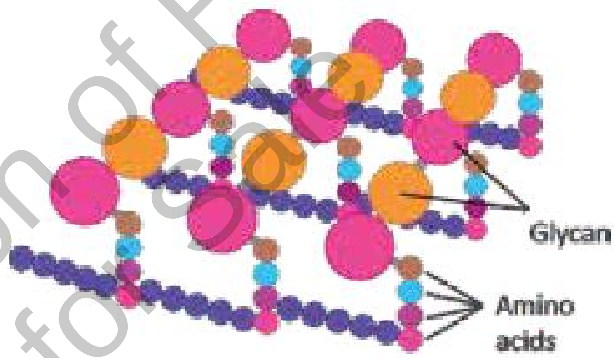

Figure 2.2: The molecular model of peptidoglycan

Sir Hans Christian Gram devised the technique of Gram's staining. Gram-positive bacteria stain purple because they retain violet dye. Gram-negative bacteria do not retain violet dye and so they appear in original colour.

The composition of cell wall is quite different in Gram-positive and Gram-negative bacteria. The cell wall of Gram-positive bacteria contains thick layer of peptidoglycan and has less lipid content. While the cell wall of Gram-negative bacteria has a thin layer of peptidoglycan.

The cell wall of Gram-negative bacteria has 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.

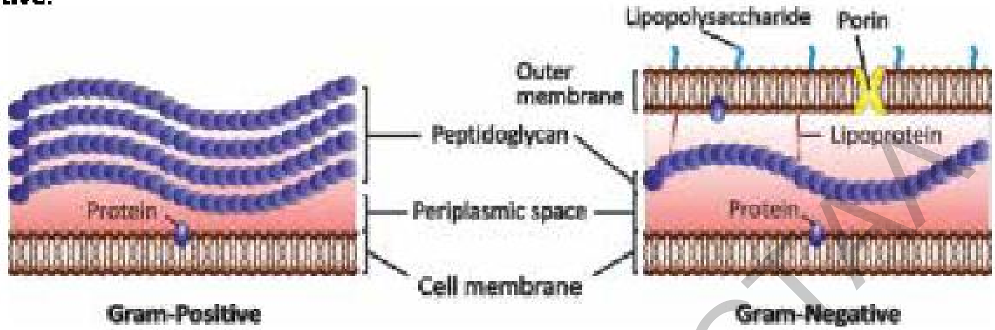

Figure 2.3: Cell wall composition of Gram-positive and Gram-negative bacteria

Some bacteria produce **capsule** outside their cell walls. It is a gelatinous layer and gives sticky characters to bacterial colonies.

Cell Membrane

Cell membrane or plasma membrane is present just beneath cell wall. It lies at the outer most in bacteria that lack cell wall (e.g., *Mycoplasmas* and *Sarcoplasmas*). The cell membrane of bacteria does not have sterols (e.g., cholesterol) in its chemical makeup. 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 and cell division and also serve as respiratory centres.

Cytoplasm and Genetic Material

Cytoplasm contains dissolved substances and large structures such as nucleoid, ribosomes, and mesosomes. 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 ribosomes. Each ribosome sediments at 70S (larger subunit at 50S and smaller subunit at 30S). 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 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.

Some bacteria have circular, double-stranded extra chromosomal DNA molecules, called **plasmids**. They are self-replicating and can replicate before or after division. They contain genes that enable bacteria for resistance against unfavourable conditions (e.g., antibiotics).

2.2- ENDOSPORE FORMATION IN BACTERIA

Many bacteria can survive extended periods of harsh conditions by forming specialized "resting" cells, called **endospores**(Figure 2.4). Endospores are thick-walled and metabolically inactive (dormant). The process by which bacteria make endospores, is called **sporulation**. It happens in the following way:

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. Cell membrane again grows around the new DNA, cytoplasm, and septum. In this way, the new DNA is surrounded by two membranes. 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. 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. Under favourable conditions, endospore germinates to give rise to a new vegetative cell.

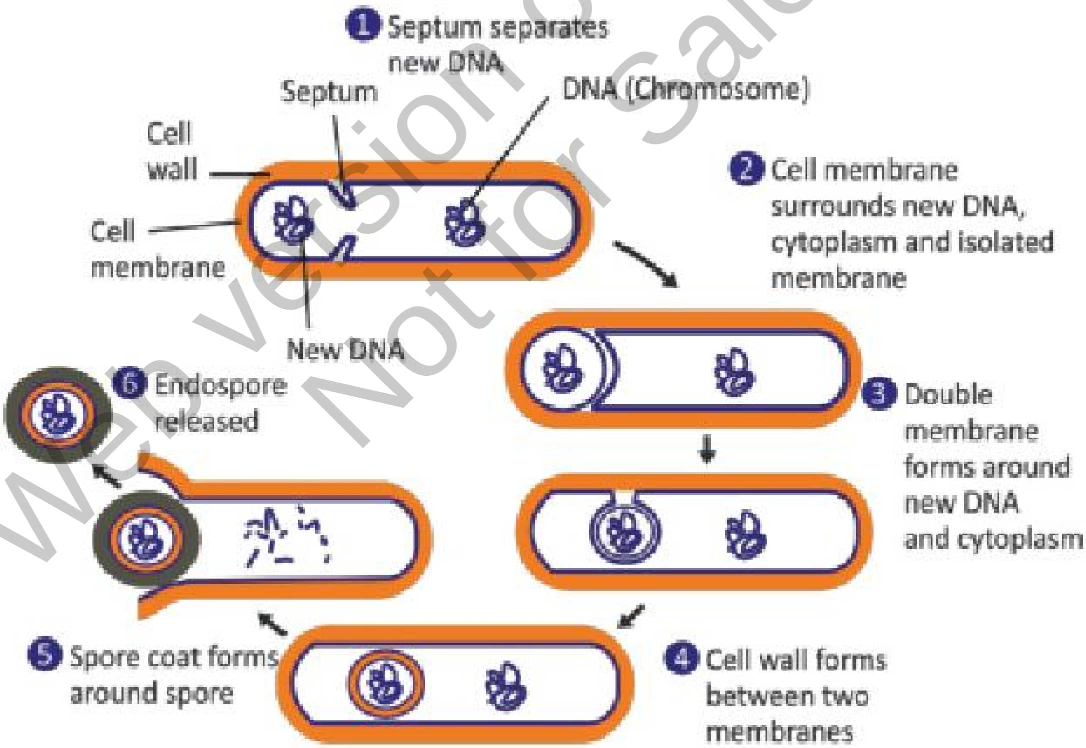

Figure 2.4: Process of endospore formation (sporulation) in bacteria

2.3- MOTILITY IN BACTERIA

Bacteria use different motility patterns to navigate and explore natural habitats.

Flagellar movements: Most bacilli and spirilla bacteria move by means of flagella. They swim by using their flagella. When a bacterial population moves together by means of flagella, the movement is called **swarming**. Flagellar movement allows bacteria to travel in liquid media. Counter clockwise rotation of flagellum pushes the cell forward with the flagellum trailing behind.

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.

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

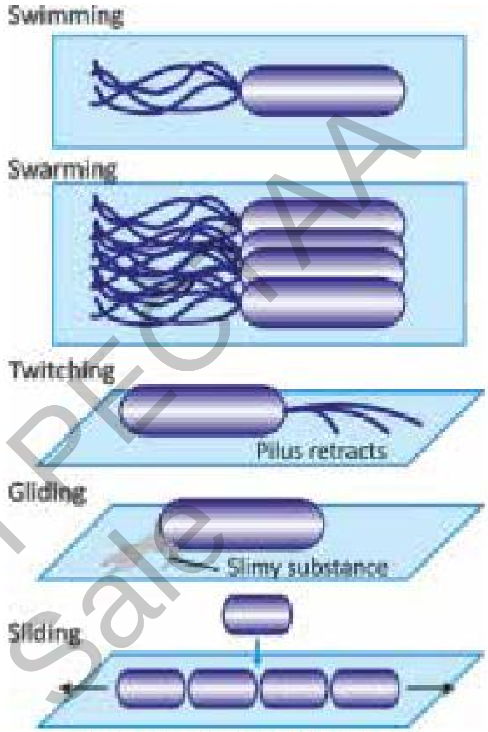

Figure 2.5: Motility in bacteria

Sliding: It is due to the expansion created by the pushing force of dividing cells.

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.

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.

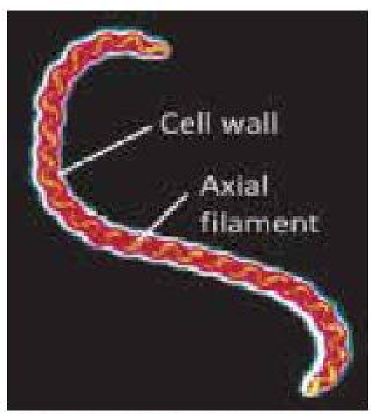

Figure 2.6: Axial filament in a spirochaete

2.4- FLAGELLA

Many kinds of bacteria have flagella, which enable them to move. The secondary function of flagella is to detect and respond to chemical signals. The bacteria which do not possess flagella are called atrichous. The bacteria with single polar flagellum are called monotrichous. The bacteria with a tuft of flagella at one pole are called lophotrichous. The bacteria with flagella at each of two poles are called amphitrichous. The bacteria with flagella surrounding the whole cell are called peritrichous (Figure 2.7).

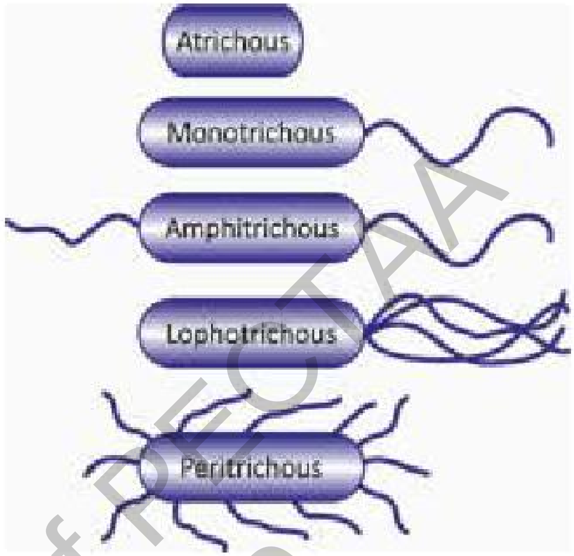

Figure 2.7: The different arrangements of bacterial flagella

Structure

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. 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. The hook is a curved structure that connects basal body with the filament.

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.

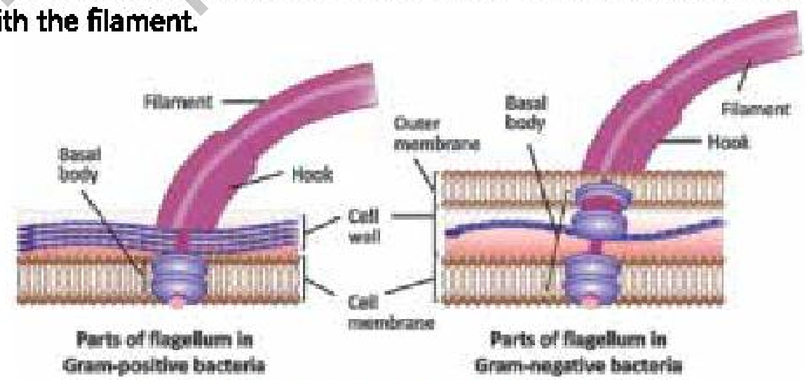

Figure 2.8: The structure of bacterial flagella

2.5- BACTERIA; ECOLOGY AND DIVERSITY

The fossil record shows that prokaryotes i.e., archaea and bacteria were abundant 3.5 billion years ago. They evolved and remained all alone on Earth for the next 2 billion years. Today, prokaryotes (archaea and bacteria) are found wherever there is life. Bacteria are found in water, air, soil, food and in the bodies of animals and plants. They outnumber all eukaryotes. They can survive in extreme habitats.

Diversity in Bacteria and their Ecology

Perhaps most interesting of all is the recent discovery that the bulk of our modern petroleum deposits were formed by masses of decayed cyanobacteria.

Margulis and **Schwartz** proposed a useful classification system for all prokaryotes. They classified them into 16 phyla. The following discussion deals with the important groups of the domain bacteria (Figure 2.9).

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. *Escherichia coli* is an example of such bacteria. This group also includes vibrios.

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.

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. Cyanobacteria-containing lichens are found on rock surfaces. The mats on the sediments in the sea are dominated by 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. 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. Pseudomonads: 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.

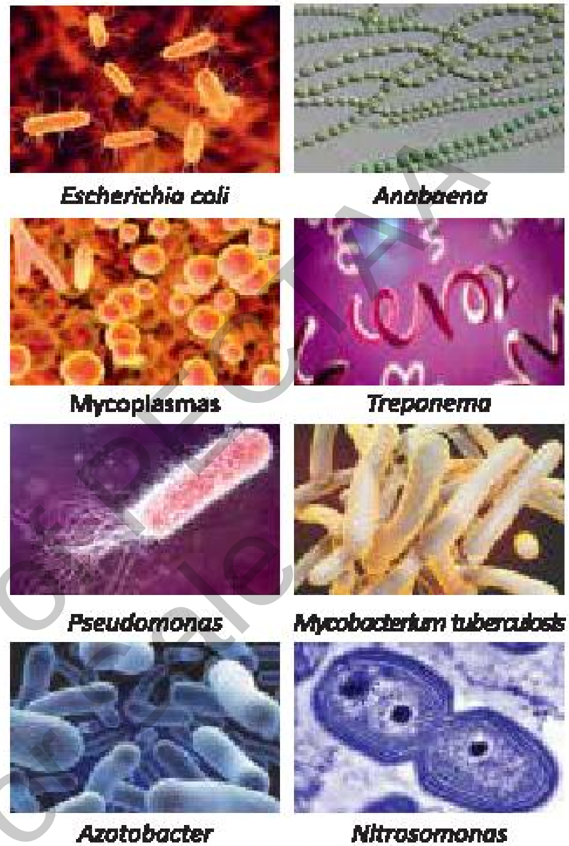

Figure 2.9: Major groups of bacteria

About 150 new antibiotics from actinomycetes are being discovered each year.

8. Chemosynthetic bacteria: 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.

Table: Characteristics of some Groups of Bacteria

Name of Group	Form	Motility	Nutrition	Ecological role
Omnibacteria	R	N, F	H	Pathogens and decomposers
Cyanobacteria	R, C, M	G, N	P	Carbon and nitrogen fixers
Mycoplasmas and Spiroplasmas	No wall	N	H	Pathogens
Spirochaetes	S	F	H	Decomposers and pathogens

Pseudomonads	R	F	H, C	Decomposers and plant pathogens
Actinomycetes	M, R	N	H	Pathogens and nitrogen fixers
N-fixing aerobes	R	N, F	H	Free-living and mutualistic nitrogen fixers
Chemosynthetic	R, C	N, F	C	Oxidize nitrogen and sulphur compounds, play role in nitrogen cycle

Form: R, rods (bacilli); C, cocci; S, spirilla; M, regular chains or aggregations
Motility: F, flagellated; N, nonmotile; G, gliding
Nutrition: H, heterotrophic; C, chemosynthetic; P, photosynthetic

2.6- IMPORTANCE OF BACTERIA

Bacteria are very important organisms not only for environment but also for all other organisms. They have beneficial as well as harmful effects on life on Earth.

Beneficial Bacteria

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

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.

Makers of useful products

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. 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.

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.

Biopesticides

Bacteria are used in the place of pesticides in biological pest control. This commonly involves *Bacillus thuringiensis*, a Gram-positive, soil dwelling bacterium.

These biopesticides are environmentally friendly and have little or no effect on humans, wildlife, pollinators and most other beneficial insects.

Research and technology tools

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. Scientists also insert human genes in bacteria and produce therapeutic proteins e.g., insulin, growth hormones, or antibodies.

2.7- Normal Flora

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

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 of Bacterial Flora of Humans

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. Similarly, body also gets many benefits from normal bacteria; for example;

1. 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.

2. 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.

3. Inhibit or kill pathogens: The intestinal bacteria produce a variety of substances, which inhibit or kill pathogen bacteria.

4. 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.

2.8- VIRUS

You are familiar with the five kingdoms of living organisms. You also know that there are some creatures that do not possess cellular organization yet show some characteristics of livings. Viruses are the representatives of such organisms.

Structure of Virus

Viruses are extremely small infectious agents and can only be seen under electron microscope. 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.

The central core of a virus is its genome. It is made up of nucleic acid (either DNA or RNA). 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. Central core and capsid are collectively called as **nucleocapsid**.

Herpes virus (causes cold sores, chickenpox etc.) contains 162 capsomeres in its capsid.
Adenovirus (causes common cold) contains 252 capsomeres in its capsid.

In some animal viruses only, nucleocapsid is covered by another membrane called **envelope**. It is a lipid-rich membrane and is derived from host cell. Non enveloped viruses are known as naked-viruses. There is a great diversity in the general appearance of viruses (Figure 2.10). The animal and plant viruses may be polyhedron (having many sides) or helical. The bacterial viruses (bacteriophages) may be cubical, icosahedral (having 20 faces), helical, or complex (polyhedral head and rod-shaped tail).

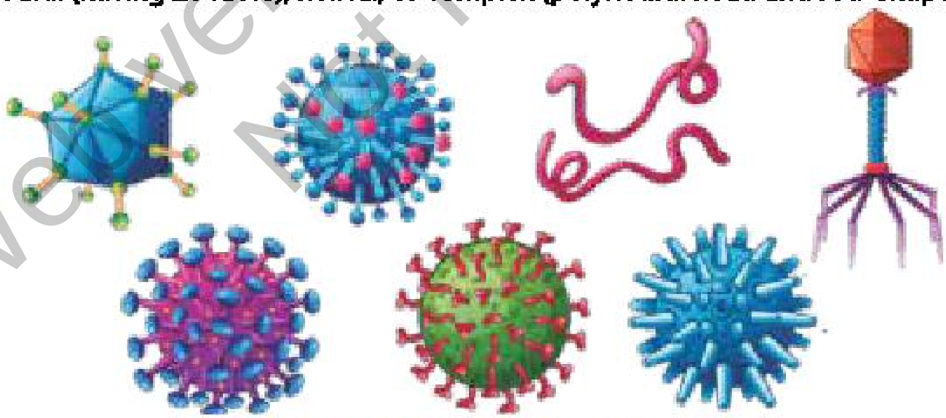

Figure 2.10: Diversity in viruses' shapes

Structure of Bacteriophage

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. A T4 phage consists of a head and a tail (Figure 2.11). The head is an elongated pyramidal (with two triangles having a common base), hexagonal (six sided), prism-shaped structure. Its capsid is made of proteins while core contains a long double stranded DNA. A straight tail is attached with head. 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.

Bacteriophages are used as carriers in genetic engineering. The gene of interest is Inserted into the DNA of bacteriophage, which carries it to the target bacterial cell. When virus incorporates its DNA into bacterial chromosome, the gene of Interest also becomes a part of bacterial DNA. Such transgenic bacteria (transgenic: whose genome has DNA of some other organism) can be grown to get copies of the gene of interest and to get the required protein.

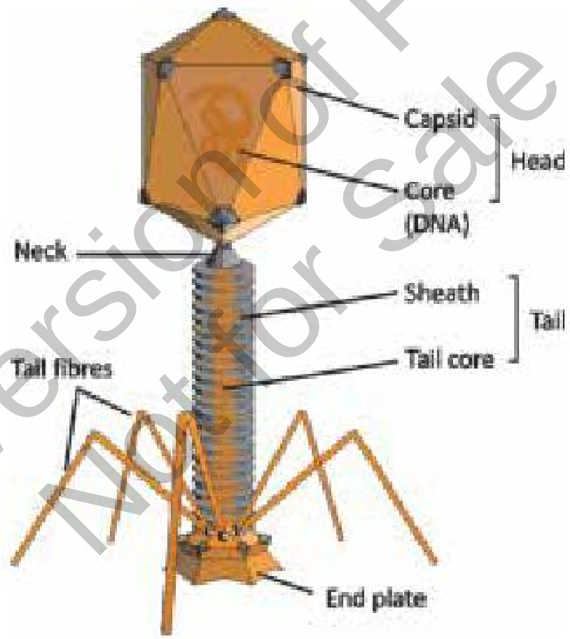

Figure 2.11: Structure of a bacteriophage (T4 phage)

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. These structures are surrounded by lipid rich envelops. 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. 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.

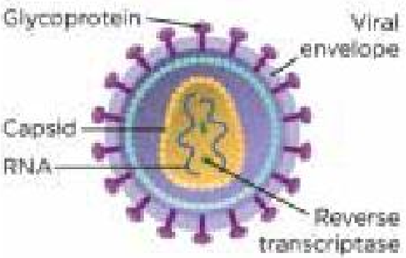

Figure 2.12: Structure of HIV

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.

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. 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.

EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS

1. Which of the following component is not found in all kinds of bacteria?
   (a) Ribosomes (b) Cell membrane
   (c) Nucleoid (d) Capsule
2. The bacterial chromosome is typically:
   (a) Linear, double-stranded DNA (b) Circular, single-stranded RNA
   (c) Circular, double-stranded DNA (d) Linear, single-stranded DNA
3. In bacterial cells, respiration occurs at:
   (a) Mitochondria (b) Cell membrane
   (c) Ribosomes (d) Endoplasmic reticulum
4. Which group of bacteria is known as a good source of antibiotics?
   (a) Omnibacteria (b) Spirochaetes
   (c) Pseudomonads (d) Actinomycetes
5. What is the primary function of flagella in bacterial cells?
   (a) DNA replication (b) Cell division

(c) Motility
(d) Protein synthesis

6. Which type of motility in bacteria is mediated by pili?
(a) Brownian movement
(b) Gliding motility
(c) Twitching motility
(d) Swarming motility

7. Which of the following bacterial structures is responsible for detecting and responding to chemicals?
(a) Capsule
(b) Pili
(c) Flagella
(d) Ribosomes

8. Which one of the following are not Nitrifying bacteria?
(a) Nitrosomonas
(b) Nitrobacter
(c) Azotobacter
(d) Pseudomonas

9. The enzyme responsible for converting HIV RNA into DNA is:
(a) RNA polymerase
(b) Reverse transcriptase
(c) DNA helicase
(d) Integrase

10. The HIV capsid contains:
(a) Single-stranded DNA and reverse transcriptase
(b) Single-stranded RNA and reverse transcriptase
(c) Double-stranded DNA and integrase
(d) Double-stranded RNA and RNA polymerase

SECTION 2: SHORT QUESTIONS

1. Write about the structural components of a bacterial cell wall and their arrangement.
2. Write the composition of the peptidoglycan layer in bacterial cell walls.
3. What are mesosomes? What are their functions?
4. How can plasmids be used in genetic engineering?
5. Define sporulation.
6. What is the function of the bacterial capsule?
7. Write the role of pili in bacterial cells. How do they differ from flagella?
8. What are plasmids, and how do they contribute to enabling bacteria to resistance against unfavourable conditions?
9. Write about the role of endospores in bacterial survival.
10. What is the significance of lipopolysaccharides and lipoproteins in Gram-negative bacteria?
11. How do spirochetes achieve motility?
12. Differentiate between twitching and gliding movements in bacterial motility.
13. How do bacteria without flagella achieve motility?

14. What is the difference between swimming motility and swarming motility in bacteria?

SECTION 3: LONG QUESTIONS

1. Compare and contrast the cell wall of Gram-positive and Gram-negative bacteria.
2. Explain different methods of movement in bacteria.
3. Explain the structure of bacterium flagellum.
4. State the formation of endospore in bacteria.
5. Briefly describe the ecological and economic importance of bacteria.
6. Explain the use of bacteria in research and technology.
7. Define the term normal flora. State the benefits which we get from normal bacterial flora.
8. Explain the structure of a model bacteriophage and HIV.

INQUISITIVE QUESTIONS

1. Why do bacteria have ribosomes even though they do not have membrane-bound organelles?
2. If bacteria do not have mitochondria, how do they generate energy for survival?
3. Why do certain bacteria exhibit twitching motility using pili instead of flagella?
4. Give reasons in favour of the statement "Prevention is better than cure" and present your arguments in the class.
5. Correlate the social and cultural values of a country with the prevalence of AIDS.