CHAPTER-6
PROKARYOTES

Q1. Outline the bacterial ecology and diversity.

Ans: Bacteria are found almost everywhere in environment and show great diversity.

Occurrence of bacteria:

Bacteria occur in the widest range of habitats. Bacteria are found almost everywhere in air, water, soil, food and in the bodies of plants and animals including human beings. In fact, many bacteria species are extremophiles, which are adapted variously to extreme temperature, pressure, pH, salinity and other abiotic factors.

Major groups of bacteria:

Historically, bacteria have been subdivided taxonomically into groups based on their cell wall types (Gram-positive or Gram-negative), presence of endospore, metabolism, growth and nutritional characteristics, physiological characteristics and other criteria.

Cyanobacteria - The Most Prominent Photosynthetic Bacteria:

Introduction:

Cyanobacteria (Gk. *kyanoa*, blue and *bacterion*, rod) are the most prominent photosynthetic bacteria which are found in any damp place. Majority of them are free living while some are found as epiphytic or symbiotic forms.

Structure and organization:

Cyanobacteria have Gram-negative type of cell wall. The body may be unicellular and solitary or in the form of filaments which may form colonies. In filamentous forms the cells are arranged in linear row, the trichome which is embedded in mucilage sheath e.g., *Anabaena, Nostoc* etc.

Photosynthesis:

Photosynthesis takes place in the extensive system of membrane (thylakoid membranes), which is located in the outer zone of the cytoplasm inner to the cell membrane.

Photosynthetic events:

Like algae and plants they use carbon dioxide as a source of carbon, water as hydrogen donor, both photosystems (non-cyclic photophosphorylation) to harvest light energy and release oxygen during photosynthesis. They are believed to be responsible for first introducing oxygen into the primitive atmosphere.

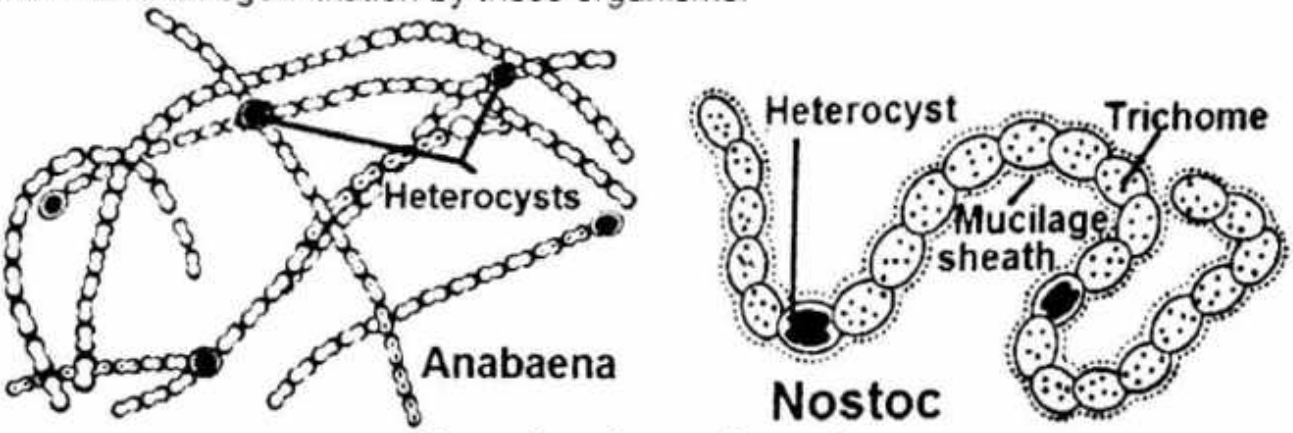
Pigment composition:

In addition to chlorophyll-a, cyanobacteria also use phycobilins as accessory pigment. **Phycocyanin,** a blue pigment is their predominant phycobiiins.

Nitrogen fixer:

About one third of cyanobacteria are able to fix atmospheric nitrogen. In most cases nitrogen fixation occurs in **heterocycts,** which are without nuclei, thick walled cell found at certain intervals in the **trichome.** In Pakistan cyanobacteria,

e.g., ***Nostoc* and *Anabaena*** are purposely cultivated to increase the soil fertility, because of nitrogen fixation by these organisms.



Examples of cyanobacteria

Q2. What are the components of bacterial cell envelop?

Ans: The cell envelop is the outer wrapping of bacterial cell which consist of:

(i) Glycocalyx **(ii)** Cell wall **(iii)** Cell membrane

Note: However, cell membrane sometime considered as the part of bacterial protoplasm.

Critical Thinking

Although many bacteria can cause dangerous diseases in general, bacteria make life on earth possible. Why?

Ans: Bacteria serve as **recyclers of nature** as they are involved in decomposition of dead/complex organic matter in the environment. If the dead bodies are not decomposed, **the** organic nutrients present in their bodies would not be released in the environment.

The organic carbon present in dead bodies might diminish all the carbon dioxide from the atmosphere. If there were no decomposer present on earth there would have been no photosynthesis an as a result no food would have been produce by plants.

Science Titbits

Gram staining is a method of differentiating bacterial species into two large groups (Gram-positive and Gram-negative). The name comes from the Danish bacteriologist Hans Christian Gram, who developed the technique.

Gram staining differentiates bacteria by the chemical and physical properties of their cell walls. In a Gram stain test, Gram-positive bacteria retain the crystal violet iodine or CVI complex (primary dye), while safranin or fuchsine, a counterstain (secondary dye) is then added which gives all Gram-negative bacteria a red or pink colouring.

Peptidoglycan:

The term peptidoglycan is derived from the peptide and sugars (glycan) that make up the molecule. Synonyms for peptidoglycan are **murein** and mucopeptide.

Science Titbits

Recently, some microbiologists have divided the growth curve into six phases by the letters a to f as follows;

(a) Lag phase- Growth rate is zero.
(b) Acceleration phase- Increasing growth rate.
(c) Exponential phase — Constant growth rate.
(d) Retardation phase- Growth rate is decreasing.
(e) Maximum stationary phase- Growth rate is zero.
(f) Decline phase- Growth rate is negative (death).

Teacher's Point

Teacher would guide the student draw a graph to present the time taken in each phase of bacterial growth and the number of bacteria.

Phases of growth (Escherichia coli):

Phase	Time taken in phases of growth	Number of Bacteria
Lag Phase	10 minutes	1
Log Phase	210 minutes	1024
Stationary Phase	210 to 310 minutes	2304
Death Phase	310 to 510 minutes	0

Teacher's Point

Teacher would ask the students to relate the causes of food poisoning and the sanitation conditions in restaurants.

Science, Technology and Society Connections

♦ **List some biotechnologies utilizing bacteria.**

Escherichia coli has been used to produce protein products of recombinant DNA technology, such as insulin, human growth hormone, etc. Genetic engineers often use a plasmid vector to -introduce new genes into plant cells. The plasmid they use is from soil bacterium *Agrobacterioum tumefaciens*. *Saccharomyces ceresvisiae* (yeast) has been used to produce hepatitis B vaccine, alpha and gamma interferons.

Science, Technology and Society Connections

♦ **Narrate how bacterial diseases have affected human societies in the past.**

The plague, or "Black Death" which killed 100 million people during the mid-fourteenth century, is caused by highly infections bacteria, *Yersinia pestis*, spread by the fleas carried by infected rats. In 1994, an outbreak of plague occurred in India

for the first time in 30 years. Tuberculosis, a bacterial disease has killed millions of peoples in the past and also thousands of people all over the world including Pakistan. *Streptococcus pneumoniae*, causes pneumonia has killed a large number of people in the past.

Science, Technology and Society Connections

♦ **Suggest how can we stop any epidemic to occur in future?**

Prevention is better than cure, so the measure to prevent any epidemic are:

Massive programs of immunization for vaccine preventable diseases, e.g., tuberculosis, hepatitis B, polio etc., must be launched. Detection of cases at the earliest and to treat them properly is the goal. Complete quarantine of persons or domestic animals, which have been exposed to communicable diseases. Supply of safe drinking water. Control of vector disease, e.g., mosquitoes, house flies at larval stages and adult stage. To educate people for improving hygiene practices like washing of hands. If any communicable disease occurs it should be notified immediately, e.g., pneumonia, polio, etc.

Science, Technology and Society Connections

♦ **Justify why it is important to disinfect articles of food and utensils before use?**

It's very important to disinfect articles of food and utensils before use because, if they aren't properly clean, bacteria could spread to food and make you ill.

OR

Cleaning and sanitizing the utensils are essential because it helps us to be more secured, far from bacteria and other causes of illnesses. It is also important to store the utensils properly for us to avoid accidents. Because if the utensils are not clean, sanitized or stored properly, it can cause a lot of trouble. If the children will use the utensils and they are not clean and sanitized, it can make them sick.

Activity

1. Identification of bacteria from curd, mouth, or bacterial culture and observation of bacterial culture for different shapes and sizes.
2. Staining bacteria using Grams staining technique
3. Preparation and observation of the temporary mount of root nodule bacteria.
4. Study of *Nostoc, Ocillatoria and Anabaena* from fresh or preserved material.

EXERCISE

MCQs

1. Select the correct answer.

(i) Cyanobacteria

(A) are poisoned by oxygen (B) are not widely distributed
(C) have chlorophyll (D) have chloroplast

(ii) Cyanobacteria, unlike other types of bacteria that photosynthesise, do

(A) not give off oxygen (B) give off oxygen
(C) not have chlorophyll (D) not have a cell wall

(iii) Pili are made up of pilin, which is

(A) carbohydrates (B) lipids
(C) protein (D) triglycerides

(iv) Most pathogenic bacteria cause disease by

(A) directly destroying individual cells of the host
(B) depriving the host of their nutrients
(C) producing toxins
(D) depriving the host of oxygen

(v) Chemosynthetic bacteria

(A) are autotrophic
(B) use the sun rays
(C) oxidize inorganic compounds to acquire energy
(D) both A and C are correct

(vi) A bacterium with flagella all around is

(A) monotrichous (B) lophotrichous
(C) amphitrichous (D) peritrichous

(vii) Conjugation is facilitated by

(A) capsule (B) pili
(C) flagella (D) both pili and flagella

(viii) Bacterial membrane differ from eukaryotic membrane in

(A) lacking proteins (B) lacking lipids
(C) lacking polysaccharide (D) lacking cholesterol

(ix) Bacterial membrane also contains enzymes for

(A) respiration (B) photosynthesis
(C) protein synthesis (D) secretion

(x) Facultative anaerobes

(A) require a constant supply of oxygen
(B) are killed in an oxygenated environement
(C) do not always need oxygen
(D) are photosynthetic

Answers

(i) C	(ii) B	(iii) C	(iv) A	(v) D
(vi) D	(vii) B	(viii) D	(ix) A	(x) C

SHORT QUESTIONS

2. Write the differences between bacteria and archaea?

Ans: Differences between bacteria and archaea:

Main Features	Bacteria	Archaea
rRNA sequences	Many unique to Eubacteria	Many match eukaryotic ones
RNA polymerase	Relatively small and simple	Complex similar to eukaryotic
Introns (noncoding parts of genes)	Absent	Present in some genes
Antibiotic sensitivity (to streptomycin. chloramphenicol)	Inhibited	Not inhibited
Peptidoglycan in cell wall	Present	Absent
Membrane lipids	Carbon chains unbranched	Carbon chains branched

3. What are the photosynthetic pigments of bacteria?

Ans: With exception to the cyanobacteria all the other photosynthetic bacteria contain unique type of chlorophyll called bacteriochlorophyll.

Photosynthesis takes place in the extensive system of membrane (thylakoid membranes), which is located in the outer zone of the cytoplasm inner to the cell membrane. In addition to chlorophyll-a, cyanobacteria also use phycobilins as accessory pigment. **Phycocyanin,** a blue pigment is their predominant phycobiiins.

4. How nitrogen fixation takes place in bacteria?

Ans: Nitrogen from the atmosphere can be available to the plants through the process of **nitrogen fixation.** This process takes place with the help of nitrogen fixing bacteria like ***Rhizobium*** and ***Cyanobacteria*** in the soil. These species of bacteria convert the atmospheric nitrogen into nitrates and nitrites as a part of their metabolism, and make it available to the plants.

5. What is the chemical composition of cell wall of bacteria?

Ans: Cell wall is the part of bacterial envelop. It is situated outer to the cell membrane. It is composed of an inner layer of **peptidoglycan** and an outer **lipoprotein membrane** (found only in Gram negative bacteria).

6. What are the morphological forms of bacteria?

Ans: Bacteria have three main shapes

(i) **Spherical** (ii) **Rod shaped** (iii) **Spiral**

Cocci: Cocci (singular *coccus, kok-us)* are spherical bacteria.

Examples:

The examples of cocci are: *Streptococcus pneumoniae, Neisseria meningitidis.*

Answers

(i) C	(ii) B	(iii) C	(iv) A	(v) D
(vi) D	(vii) B	(viii) D	(ix) A	(x) C

SHORT QUESTIONS

2. Write the differences between bacteria and archaea?

Ans: Differences between bacteria and archaea:

Main Features	Bacteria	Archaea
rRNA sequences	Many unique to Eubacteria	Many match eukaryotic ones
RNA polymerase	Relatively small and simple	Complex similar to eukaryotic
Introns (noncoding parts of genes)	Absent	Present in some genes
Antibiotic sensitivity (to streptomycin. chloramphenicol)	Inhibited	Not inhibited
Peptidoglycan in cell wall	Present	Absent
Membrane lipids	Carbon chains unbranched	Carbon chains branched

3. What are the photosynthetic pigments of bacteria?

Ans: With exception to the cyanobacteria all the other photosynthetic bacteria contain unique type of chlorophyll called bacteriochlorophyll.

Photosynthesis takes place in the extensive system of membrane (thylakoid membranes), which is located in the outer zone of the cytoplasm inner to the cell membrane. In addition to chlorophyll-a, cyanobacteria also use phycobilins as accessory pigment. **Phycocyanin,** a blue pigment is their predominant phycobiiins.

4. How nitrogen fixation takes place in bacteria?

Ans: Nitrogen from the atmosphere can be available to the plants through the process of **nitrogen fixation.** This process takes place with the help of nitrogen fixing bacteria like ***Rhizobium*** and ***Cyanobacteria*** in the soil. These species of bacteria convert the atmospheric nitrogen into nitrates and nitrites as a part of their metabolism, and make it available to the plants.

5. What is the chemical composition of cell wall of bacteria?

Ans: Cell wall is the part of bacterial envelop. It is situated outer to the cell membrane. It is composed of an inner layer of **peptidoglycan** and an outer **lipoprotein membrane** (found only in Gram negative bacteria).

6. What are the morphological forms of bacteria?

Ans: Bacteria have three main shapes

(i) **Spherical** (ii) **Rod shaped** (iii) **Spiral**

Cocci: Cocci (singular *coccus, kok-us)* are spherical bacteria.

Examples:

The examples of cocci are: *Streptococcus pneumoniae, Neisseria meningitidis.*

Bacilli: Bacilli are straight or rod shaped organisms.

Examples: The examples of rod shaped bacteria are *Escherichia coli*, *Pseudomonas*.

Spirilli: Spirilli are spiral shaped bacteria.

Examples: *Treponema pallidum*. Relatively, thick and rigid spiral shaped bacteria are called spirillum e.g., *Spirillum minus*, whereas, curved or comma shaped bacteria which are intermediate to spiral and rod shape, are called **vibrio** e.g., *Vibrio cholarae*.

7. What are the differences between cell wall of Gram positive and Gram negative bacteria?

Ans: Difference between Gram positive and Gram negative cell wall:

	Character	Gram positive	Gram negative
1.	Number of layers	One	Two
2.	Thickness	Thick (20-80 nm)	Thin (8-10 nm)
3.	Outer membrane	Absent	Present
4.	Periplasmic space	Present in some	Present in all
5.	Chemical composition	Peptidoglycan, Teichoic acid and lipotechoic acid	Lipopolysaccharide, lipoporteins and peptodoglycan
6.	Porins proteins	Absent	Present
7.	Lipid	Less	More
8.	Peptidoglycan	More	Less
9.	Permeability of molecules	More penetrable	Less penetrable
10.	Resistance to molecules	less	More

8. How do bacteria survive under unfavourable condition?

Ans: Under unfavorable certain bacteria form resistant and metabolically dormant bodies. Depending on the type of bacteria, these bodies are divided into:

(i) Endospores **(ii)** Exospores **(iii)** Cysts

(i) Endospores:

In endospore the spores develops within the vegetative cell inside the cell wall, so it has been named **endospore.**

Endospores are characterized by a complex structure and resistance to high temperatures. That is why this dormant form is capable of surviving for periods longer than thousand years.

Example: Clostridium butulinium.

(ii) Exospores:

Some bacteria form long tubules called **filaments.** Under nutrient poor conditions these filaments differentiate into round thick walled resting structures termed **exospores.** They develop outside cell wall.

Example: Actinomycetes.

(iii) Cysts:

Cysts, which are dormant cells with thickened cells walls. Encystment (cyst formation) occurs by changes in the cell wall; the cytoplasm contracts and the cell wall thicken. Cysts are resistant to desiccation and some chemicals, but cannot withstand high temperatures.

Example: *Azotobacter species.*

9. Describe arrangements of bacterial flagella.

Ans: Bacterial flagellum is non-contractile, and lacks microtubules unlike eukaryotic flagellum. It is about 20 ηm diameter and up to 20 μm in length.

It consists of three parts:

(i) Basal body. **(ii)** Hook. **(iii)** Filament.

(i) Basal body:

The **basal body** originates from cytoplasm just beneath the cell membrane.

(ii) Hook:

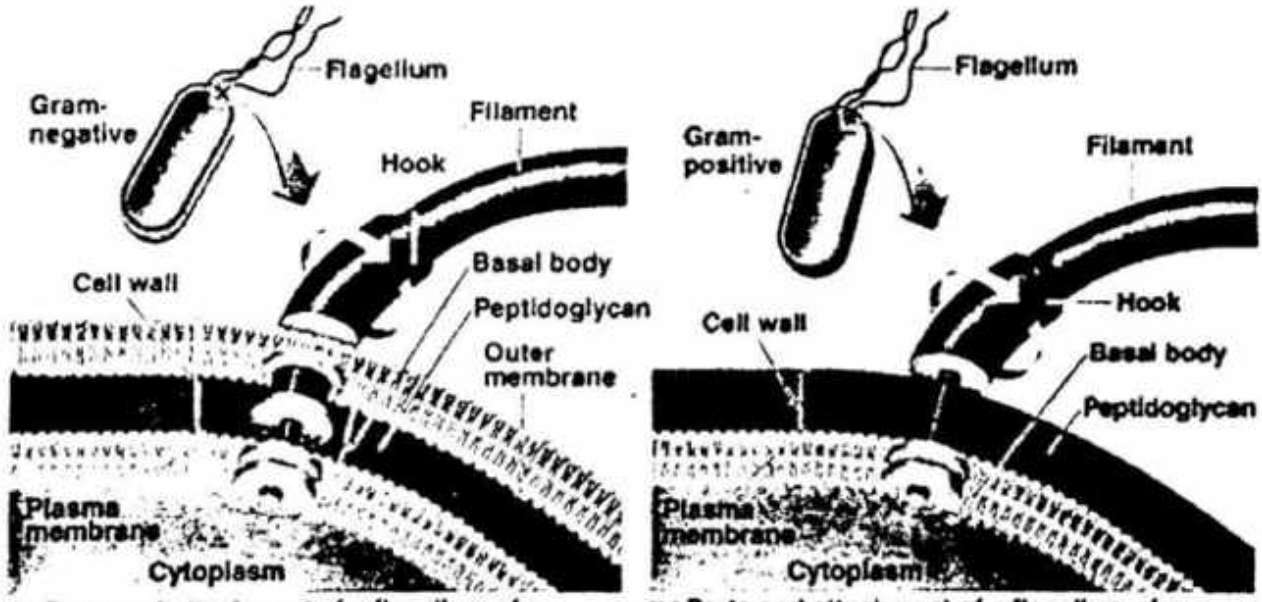
The **hook** is curved structure which connects the basal body to the filament. It is projected from the cell surface.

(iii) Filament:

The **filament** is a hollow structure which originates from the hook. The filament is composed of the globular protein **flagellin,** which is arranged in several intertwined chains that form a helix around a hollow core.

10. Draw and label structure of bacterial flagellum.

Ans:



(a) Parts and attachment of a flagellum of a gram-negative bacterium

(b) Parts and attachment of a flagellum of a gram-positive bacterium

Structure of flagellum of bacteria

11. Give the functions of following in bacteria.

(a)	**ribosomes**	**(b)**	**cell membrane**	**(c)**	**nucleoid**
(d)	**plasmid**	**(e)**	**mesosomes**	**(f)**	**slime capsule**
(g)	**flagella**	**(h)**	**cell wall**	**(i)**	**pili**

Ans: (a) Ribosomes:

Non-membranous organelles involve in protein systhesis.

(b) Cell membrane:

Outer covering of animal cells present in all cells, involved in transportation of materials , protection , and mechanical support.

(c) Nucleoid:

Nuclear region of bacteria, consist of large circular double stranded DNA. It controls growth and metabolic activities.

(d) Plasmid:

They are extra nuclear, small circular DNA molecules. They are involved in antibiotic resistance, drug resistance and heavy metal resistance.

(e) Mesosomes:

An organelle of bacteria that appears as an invagination of the plasma membrane and functions either in DNA replication , cell division , excretion of exoenzymes , cell wall formation, photosynthesis and ETC.

(f) Slime capsule:

The function of the slime layer is to protect the bacteria cells from environmental dangers such as antibiotics and desiccation. Help to form glycocalyx enclosed population e.g. biofilms.

(g) Flagella:

Flagella are thread like organelle the primary role of the flagellum is locomotion, but it also often has function as a sensory organelle, being sensitive to chemicals and temperatures outside the cell.

(h) Cell wall:

(i) It covers bacterial cell.
(ii) Protect cell internal components
(iii) Provide support.
(iv) Maintain cell characteristic shape.

(i) Pili:

(i) Allow bacterial cell to adhere to tissue.
(ii) Help bacterial cell to resist attack from immune system.

12. Classify bacteria on the basis of methods of obtaining energy and carbon.

Ans: Bacteria can be classified on the basis of method of obtaining energy and carbon. They may be either heterotrophic, which make their organic compounds from other organic sources, or autotrophic, which make their organic compounds from inorganic sources i.e., carbon dioxide.

13. How chemosynthetic bacteria are autotrophic in nature?

Ans: Chemoautotrophs:

The **chemoautotrophic bacteria** make carbohydrates from inorganic substance. They do not use light energy. They oxidize inorganic substance. The energy produced by this oxidation is then used to make carbohydrates. Sulphur bacteria oxidize sulphur to produce energy.

$$2H_2S + CO_2 \xrightarrow{\text{Energy}} (CH_2O)_n + H_2O + 2S$$

$$2H_2S + O_2 \longrightarrow 2S + H_2O + \text{Energy}$$

The energy thus produced is used by bacteria to make carbohydrate $(CH_2O)_n$. The examples of chemoautotrophic bacteria are nitrifying bacteria, sulphur bacteria.

14. What is binary fission? Explain with reference to bacteria.

Ans: Binary Fission:

Binary fission is the commonest type of reproduction under favourable conditions in which cell divides or splits into two similar daughter cells. During the process, the bacterial DNA gets attached to the cell membrane and undergoes replication. As the cell enlarges the daughter DNA gets separated. A cross wall is

formed between the separating daughter DNA. It divides the cell into two daughter cells. The daughter cells soon grow to maturity within 20 minutes and divide again.

15. Name any five diseases caused by bacteria in man.

Ans: Bacterial diseases in man:

Bacteria cause many diseases in man such as, tetanus, diphtheria, meningitis, plague, typhoid fever, cholera, typhoid, pulmonary tuberculosis and pneumonia.

16. Name any two bacteria that cause diseases in plants.

Ans: Following are the names of bacteria that cause diseases in plants.

(i) Leaf spot is caused by ***Xanthomonas campestris*** on tomato and pepper. Other genera cause the disease in tobacco and potato.

(ii) **Erwina anylovora** causes soft rot in potato. ***Corynebacterium*** causes ear rot of wheat.

(iii) ***Pseudomonas solanocaerum*** causes wilt disease in potato.

17. List five ways in which bacteria are beneficial to man?

Ans: Following are the ways in which bacteria are beneficial to man.

(i) The economic importance of bacteria refers to the role of bacteria in research and technology.

(ii) Streptomyces is used in making antibiotics.

(iii) Rhizobium are helpful bacteria found in the soil. They convert nitrogen in the soil.

(iv) E•Coli are found in the intestines of humans and aid in digestion.

(v) Hydrocarbon-oxidizing bacterias aid in the decomposition of petroleum, and they are used by industry when cleaning oil spills.

(vi) Harmless bacteria are used to treat some bacterial infections in the human body by interfering with the colonization of the harmful bacteria.

18. What are the benefits of bacterial flora to human?

Ans: Benefits of the bacterial flora to humans:

The members of some normal flora play a role in the maintenance of health and the causation of disease in the following significant ways.

(i) They constitute a protective host defence mechanism. The nonpathogenic resident bacteria occupy attachment sites on the skin and mucosa that can interfere with colonization by pathogenic bacteria. The ability of members of the normal flora to limit the growth of pathogens is called **colonization resistance**. If the normal flora is suppressed, pathogens may grow and cause diseases.

(ii) They may serve a nutritional function. The intestinal bacteria produce several B vitamins and vitamin K. Poorly nourished people who are treated with oral antibiotics can suffer vitamin deficiencies as a result of the reduction in the normal flora.

Note: They can cause disease, especially in having an impaired immune system and weak, feeble individuals. Although these organisms are nonpathogens in their usual location, they can be pathogens in other parts of the body.

19. Which chemical methods are used to control microbes?

Ans: Chemical methods to control microbes:

Antiseptics, disinfectants and chemotherapeutic agents are used as chemical methods for microbial control.

Antiseptics:

The chemical substances used on living tissues that inhibit the growth of microorganisms are called **antiseptics**.

Disinfection:

Oxidizing and reducing agents are important chemical agents for disinfection.

Examples:

Disinfectants that is halogens and phenols, hydrogen peroxide, potassium permanganate, alcohol and formaldehyde etc these chemicals inhibit the growth of vegetative cells and are used on nonliving material.

Chemotherapeutic:

Chemotherapeutic agents are chemicals and antibiotics that destroy the natural defense and stop the growth of bacteria and other microbes in the living tissue.

Example: Sulphonamide, tetracycline, penicillin etc.

20. What are the physical methods to control microbes?

Ans: Following are the physical methods to control microbes.

(i) Sterilization:

Sterilization process is the process in which physical agents like steam, dry heat, gas, filtration and radiation are used to control bacteria. Sterilization is destructive to all life forms.

Uses:

(a) This process is used to sterilize surgical apparatus.

(b) It is also used to preserve food items on large-scale e.g., milk, meat etc.

(c) High temperature is usually used in microbiological labs for control of microbes.

(ii) Pasteurization:

Pasteurization is the process to kill microorganisms by heating at temperature enough to kill nonspore forming bacteria,

Examples:

Milk is pasteurized by heating at 71 °C for 15 seconds and at 62 °C for 32 minutes.

Food can be preserved for several days by keeping it at a temperature between 10 to 15°C e.g. milk, vegetables, cheese and meat.

(iii) Freezing method:

Food can be **frozen** at -10 °C to 18 °C for several weeks to several months, e.g., meat, vegetables. Food is dehydrated so that in **dry condition** bacteria may not grow, e.g., dried milk and dried meat.

(iv) Preservatives:

Adding preservatives inhibit the growth of bacteria. Acid is added to lower the pH. The contents of salt are increased so that water in the food is not enough for bacterial growth. Some chemicals like potassium metabisulphite are added.

Pickles, candies, jam and breads are preserved by such methods.

Note: Certain electromagnetic radiations below 300 nm are effective in killing of microorganisms. Gamma rays are in general used for sterilization process. Heat sensitive compounds like antibiotics, seras, etc., can be sterilized by means of membrane filters.

21. Explain genetic variability in bacteria.

Ans: Genetic Variability in Bacteria:

(I) Bacteria, as asexual organisms, inherit identical copies of their parent's genes (i.e., they are clonal).

(ii) All bacteria can evolve by selection on changes to their genetic material (DNA) caused by different methods of genetic recombination or mutations.

(iii) Mutation rates vary widely among different species of bacteria and even among different clones of a single species of bacteria.

(iv) Genetic changes in bacterial genomes come from random mutation due to different factors during replication.

22. Describe bacteria as recyclers of nature.

Ans: Bacteria serve as **recyclers of nature** as they are involved in decomposition of dead/complex organic matter in the environment. If the dead bodies are not decomposed, the organic nutrients present in their bodies would not be released in the environment. The organic carbon present in dead bodies might diminish all the carbon dioxide from the atmosphere.

23. What is the role of bacteria in causation of diseases and spoilage of food?

Ans: Role of bacteria in causation of diseases and spoilage of food:

(i) Parasitic bacteria attack plants and cause various diseases, e.g., fire blight in apple, ring diseases in potatoes, crown gall etc.,

(ii) Many human diseases are caused by bacteria e.g., diphtheria, tetanus, leprosy, meningitis, sore throat, whooping cough (also called: pertussis) etc.

(iii) Bacteria cause decay of wood, leather, fabrics etc.

(iv) Bacteria spoil the food materials by decomposition.

24. List the important bacteria that make the normal bacterial flora residing in the oral cavity, respiratory and urinogenital tracts and large intestine of man.

Ans:

Members of Normal Flora	Anatomic Location
Clostridium species	Colon
Escherichia coli and other conforms	Colon, vagina, outer urethra
Lactobacillus species	Mouth, colon, vagina
Staphylococcus aureus	Nose, skin
Enterococcus faecalis	Colon
Viridans streptococci	Mouth, nasopharynx

25. Define/ Describe /Explain/ briefly:
methanogens, halophile, thermoacidophile, phycocyanin, heterocyst, trichome, glycocalyx, porins, pleomorphic, endospore, cyst, plasmids, bacteriochlorophyll, fission, pansexuality,

transduction, nitrogen fixation, bioremediation, biogradable plastic, normal flora, antiseptic agent, pasteurization

Ans: Methanogens:

The methanogens (methano, methane, gen, producer), e.g., *Methanobacterium formicum* are found in anaerobic environments in swamps, marshes and in the intestinal tracts of human and other animals where they produce methane from hydrogen gas and carbon dioxide coupled to the formation of ATP. This methane, is also called biogas.

Halophile:

The halophiles *(halo,* salt, *philes,* lover) grow where nothing else can live, such as on fish and meat that have been heavily salted to keep most bacteria away. The halophiles require high salt concentrations for growth, e.g., *Halobacterium halobium.*

Thermoacidophile:

The thermoacidophiles (heat and acid lovers) are isolated from extremely hot, acidic environments such as hot springs, geysers, submarine thermal vent and around volcanoes e.g., *Pyrolobus fumarii.*

Phycocyanin: Phycocyanin, a blue pigment is their predominant phycobiiins.

Heterocyst:

A large transparent thick-walled cell that is found in the filaments of some cyanobacteria and is the site of nitrogen fixation

Trichome:

The body of cynobacteria may be unicellular and solitary or in the form of filaments which may form colonies. In filamentous forms the cells are arranged in linear row called the trichome which is embedded in mucilage sheath e.g., *Anabaena, Nostoc* etc.

Glycocalyx

The glycocalyx is an outer coating that covers the outside of bacterial cell wall.

Porins:

The Gram-negative cell wall contains a protein, the **porins** in outer membrane which act like pores for particular molecules.

Pleomorphic:

The bacteria which exist in more than one form is called **Pleomorphic.**

Example: Helicobacter pylori exists as both a helix-shaped form and a spherical form. Such bacteria are called **pleomorphic.**

Endospore:

In endospore the spores develops within the vegetative cell inside the cell wall, so it has been named **endospore.**

Example: Clostridium butulinium.

Cyst:

Cysts, which are dormant cells with thickened cells walls. Cysts are resistant to desiccation and some chemicals, but cannot withstand high temperatures.

Example: *Azotobacter species*

Plasmids:

Some bacteria have one or more copies of an extra nuclear small circular double stranded DNA called **plasmids** which contain genes for antibiotic resistance.

Bacteriochlorophyll:

Photosynthetic bacteria contain unique type of chlorophyll called bacteriochlorophyll.

Fission:

Fission is the commonest type of reproduction under favourable conditions in which cell divides or splits into two similar daughter cells.

Parasexuality:

In bacteria, there is no true sexual reproduction because there is no meiosis, formation of gametes and zygote. Instead, it involves transfer of a portion of genetic material (DNA) from a donor cell to a recipient cell. This process is called genetic recombination or parasexuality.

Transduction:

The transfer of genetic material from one bacterium to another bacterium through the third party, the bacteriophage virus, is called **transduction.**

Nitrogen fixation:

The process by which atmospheric nitrogen is converted into nitrites and nitrates by the help of micro-organism is called nitrogen fixation.

Examples: Rhizobium and Cyanobacteria help in nitrogen fixation.

Bioremediation:

Removal or degradation of environmental pollutants by using living organisms is called **bioremediation.**

Biogradable plastic:

Biodegradable plastic is made by using two bacterially produced molecules, Poly-B-hydroxybuterate and Poly-B-hydroxyvalerate. These molecules make a polymer just like ordinary plastic but having the essential difference that once left out in the compost or in a landfill they can be broken down by bacteria and fungi to become part of the cycle of life again.

Normal flora:

Normal flora is the term used to describe the various bacteria (and fungi) that are permanent residents of certain body parts, especially the skin, oropharynx, colon and vagina.

Antiseptic:

The chemical substances used on living tissues that inhibit the growth of microorganisms are called **antiseptics**.

Chemotherapeutic agent:

Chemotherapeutic agents are chemicals and antibiotics that destroy the natural defense and stop the growth of bacteria and other microbes in the living tissue.

Example: Sulphonamide, tetracycline, penicillin etc.

Pasteurization:

Pasteurization is the process to kill microorganisms by heating at temperature enough to kill nonspore forming bacteria,

Examples: Milk is pasteurized by heating at 71 °C for 15 seconds and at 62 °C for 32 minutes. Food can be preserved for several days by keeping it at a temperature between 10 to 15°C e.g. milk, vegetables, cheese and meat.

26. Distinguish between:

(a) lysosome and mesosome
(b) peptidoglycan and muramic acid
(c) Gram positive and Gram negative bacteria
(d) lytic and lysogenic bacteria
(e) pathogenic and non-pathogenic bacteria
(f)) autotrophy and heterotrophy in bacteria
(g) photosynthetic and chemosynthetic bacteria
(h) chemotaxis and phototaxis in bacteria
(i) chromosome and a bacteriophage
(j) bacteria and mitochondria
(k) prokaryotes and eukaryotes
(l) cyanobacteria and bacteria

Ans: (a) lysosome and mesosome:

Lysosome	Mesosome
An organelle found in all types of animal cells which contains a large range of digestive enzymes capable of splitting most biological macromolecules.	A folded invagination in the plasma membrane of bacteria, produced by the chemical fixation.

(b) peptidoglycan and muramic acid:

Peptidoglycan	Muramic acid
Peptidoglycan is a polymer comprising of sugars and amino acids	Muramic acid is an amino sugar originated in the peptidoglycan layer of the cell walls of many bacteria.
It is a polymer.	It is a monomer.
It is composed of: (i) N-acetylglucosamine (NAG) (ii) N-acetylmuramic acid(NAM) (iii) Peptide chain amino acids.	It is composed of: (i) Lactic acid (ii) glucosamine

(c) Gram positive and Gram negative bacteria:

	Character	Gram positive	Gram negative
1.	Number of layers	One	Two
2.	Thickness	Thick (20-80 nm)	Thin (8-10 nm)
3.	Outer membrane	Absent	Present
4.	Periplasmic space	Present in some	Present in all
5.	Chemical composition	Peptidoglycan, Teichoic acid and lipotechoic acid	Lipopolysaccharide, lipoporteins and peptodoglycan
6.	Porins proteins	Absent	Present
7.	Lipid	Less	More
8.	Peptidoglycan	More	Less
9.	Permeability of molecules	More penetrable	Less penetrable
10.	Resistance to molecules	less	More

(d) lytic and lysogenic bacteria:

lytic bacteria	lysogenic bacteria
Bacteria which undergoes lytic cycle is called lytic bacteria.	Bacteria which undergoes lysogenic cycle is called lysogenic bacteria.
Lytic bacteria develops slave-master relationship with phage virus.	Lysogenic bacteria develops guest - host relationship with phage virus.
Cell of lytic bacteria gets disintegrated.	Cell of lysogenic bacteria does not get disintegrated unless it undergoes lytic cycle.

(e) pathogenic and non-pathogenic bacteria:

Pathogenic bacteria	Non-pathogenic bacteria
Disease causing bacteria is called Pathogenic bacteria.	The bacteria which don't cause disease is called Non-pathogenic bacteria.
They are harmful for living things.	They are beneficial for living things.
Examples: Vibrio cholerae, Salmonella typhi.	**Examples:** Thiobacillus ferrooxidans, T.thiooxidans.

(f) autotrophy and heterotrophy in bacteria:

Autotrophy bacteria	Heterotrophy bacteria
They synthesize their own organic food from inorganic substances.	They do not synthesize their own food but depend on other organisms or on dead organic matter for food.
Autotrophic bacteria are of two types **(i) Photoautotrophic:** (photosynthetic) which make use of light energy. **(ii) Chemoautotrophic:** (chemosynthetic) which utilize chemical energy.	They may be parasites, saprophytes or symbiontes.
They are not most abundant in nature.	They are most abundant in nature.

(g) photosynthetic and chemosynthetic bacteria:

Photosynthetic bacteria	Chemosynthetic bacteria
They do photosynthesis to obtain energy in the form of organic carbohydrates	They oxidize inorganic substances the energy produce by this oxidation is use to make carbohydrates.
They use carbon dioxide as source of carbon and water as source of hydrogen.	They use elemental sulphur which is then oxidize to produce energy.
They use light energy and have complex photosystem	They do not use light energy and lack photosystem
Example: cyanobacteria	**Example:** sulphur bacteria, nitrifying bacteria.

(h) chemotaxis and phototaxis in bacteria:

chemotaxis	Phototaxis
The type of purposeful movement in response to chemical stimuli is called **chemotaxis.**	Movement in response to light stimuli is called **phototaxis.**

(i) chromosome and a bacteriophage:

Chromosome	Bacteriophage
Chromosomes are the structures that are formed during cell division by condensation and coiling of chromatinfibres.	Bacteriophage are the viruses which attack bacteria it is a DNA virus with polyhedral tail.
They can be seen with a light microscope.	They can not be seen with light microscope.

(j) bacteria and mitochondria:

Bacteria	Mitochondria
Bacteria is a prokaryotic organism.	Mitochondria is a double membrane bounded organelle.
Outer covering of bacteria is cell wall.	Outer covering of mitochondria is lipid bilayer.
Their diameter may range from 100 ηm to 80 μm.	Its diameter ranges from 0.5 to 1.0 μm.

(k) prokaryotes and eukaryotes:

	Character	Eukaryotes	Prokaryotes
1.	**Nucleus**	Present	Absent
2.	**Number of chromosomes**	More than one	One--but not true chromosome: Plasmids
3.	**Cell Type**	Usually multicellular	Usually unicellular (some cyanobacteria may be multicellular)
4.	**True Membrane bound Nucleus**	Present	Absent
5.	**Example**	Animals and Plants	Bacteria and Archaea
6.	**Genetic Recombination**	Meiosis and fusion of gametes	Partial, undirectional transfers DNA
7.	**Lysosomes and peroxisomes**	Present	Absent
8.	**Microtubules**	Present	Absent or rare
9.	**Endoplasmic reticulum**	Present	Absent
10.	**Mitochondria**	Present	Absent
11	**Cytoskeleton**	Present	May be absent
12	**DNA wrapping on proteins.**	Eukaryotes wrap their DNA around proteins	Multiple proteins act together to fold and

		called histones	condense prokaryotic DNA. Folded DNA is then organized into a variety of conformations that are supercoiled and wound around tetramers of the HU protein.
13	**Ribosomes**	larger	smaller
14	**Vesicles**	Present	Present
15	**Golgi apparatus**	Present	Absent
16	**Chloroplasts**	Present (in plants)	Absent, chlorophyll scattered in the cytoplasm
17	**Flagella**	Microscopic in size, membrane bound usually arranged as nine doublets surrounding two singlets	Submicroscopic in size, composed of only one fiber
18	**Permeability of Nuclear Membrane**	Selective	not present
19	**Plasma membrane with steroid**	Yes	Usually no
20	**Cell wall**	Only in plant cells and fungi (chemically simpler)	Usually chemically complexed
21	**Vacuoles**	Present	Present
22	**Cell size**	10-100um	1-10um

(I) cyanobacteria and bacteria:

Bacteria	Cyanobacteria
The cells are comparatively smaller.	The cells are comparatively larger
The cell wall is 1—2 layered.	The cell wall is four layered.
Plasmodesmata and pores do not occur in cell wall.	They are often present.
They exhibit lesser structural elaboration.	They show higher degree of morphological complexity as well as structural elaboration.
Bacteria are both autotrophic and heterotrophic.	Cyanobacteria are generally autotrophic.
Autotrophic bacteria possess bacteriochlorophyll.	Cyanobacteria contain chlorophyll a as found in eukaryotic autotrophs.
Photosynthesis is an-oxygenic.	Photosynthesis it's oxygenic.
Flagella may be present.	Flagella are absent.
Carbohydrate reserve food is glycogen.	Carbohydrate reserve food is a special starch known as cyanophycean starch.

EXTENSIVE QUESTIONS

27. Describe the taxonomic position of prokaryotes.

Ans: Discovery of bacteria:

The Dutch scientist **Antonie van Leeuwenhoek** first discovered bacteria in 1674, using a single-lens microscope of his own design. He called them **"animalcules".**

Bacterium:

Ehrenberg introduced the name **bacterium** in 1882. It is derived from the **Greek** word **bacterion-a**, meaning **"small stuff.**

Taxonomic Position Prokaryotes:

The taxonomic position of prokaryotes has been continuously changed since their discovery. There are two separate system of classification are followed in which the prokaryotes are accommodated in different ways.

Taxonomic Position of Prokaryotes as "Kingdom Monera":

(i) In traditional two kingdom system of classification all microorganisms including prokaryotes were placed in plant kingdom.

(ii) In 1861, **John Hog** proposed kingdom **Protista** to accommodate microorganism so prokaryotes were also placed in this kingdom.

(iii) In 1866, **Ernst Haeckel** made a separate group, the **Monera** for prokaryotes within the same **kingdom Protista.**

(iv) In 1938, **Herbert Copland** elevated the status of Monera to kingdom level, so first time prokaryotes were recognized as a separate kingdom **"Monera".**

(v) In 1969, American biologist **Robert H. Whittaker** proposed five-kingdom system that incorporated the basic prokaryotic-eukaryotic distinction which has been modified by **Lynn Margulis** and **Karlene V. Schwartz** in 1988. They also assigned a separate kingdom "Monera" for all the prokaryotes.

Taxonomic Position of Prokaryotes as "Domain Bacteria" and "Domain Archaea":

The term **"bacteria"** was traditionally applied to all microscopic, **single-celled** prokaryotes. However, molecular systematics studies, showed prokaryotic life to consist of two separate domains, (group of kingdom, i.e., a taxonomic category above the kingdom level) originally called **Eubacteria** and **Archaebacteria**, but now called **Bacteria** and **Archaea** that evolved independently from an ancient common ancestor.

These two domains, along with Eukarya, are the basis of the three-domain system, which is currently the most widely used classification system in bacteriology.

Phylogenetic position of prokaryotes:

The evolutionary relatedness among various groups of organisms (e.g., species, populations) is called **phytogeny.**

A major step forward in the study of phylogeny of bacteria was the recognition in 1977 that archaea has a separate line of evolutionary descent from bacteria. This new phylogenetic taxonomy was based on the discovery that the

genes encoding ribosomal RNA are ancient and distributed over all lineages of life with little or no lateral gene transfer.

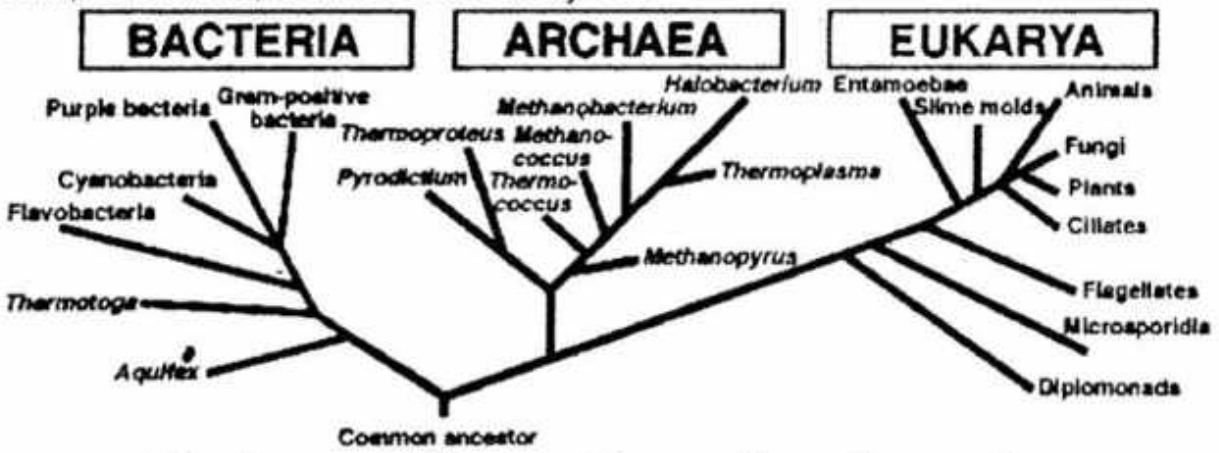
Therefore rRNA are commonly recommended as **molecular clocks** for reconstructing phytogenies, and divided prokaryotes into two evolutionary domains as part of the three-domain system, eubacteria, archaea and eukaryotes.

Gene sequences can be used to reconstruct the bacterial phylogeny, and these studies indicate that bacteria diverged first from the archaeal/eukaryotic lineage. The most recent common ancestor of bacteria and archaea was probably a hyperthermophile that lived about 2.5 billion to 3.2 billion years ago.

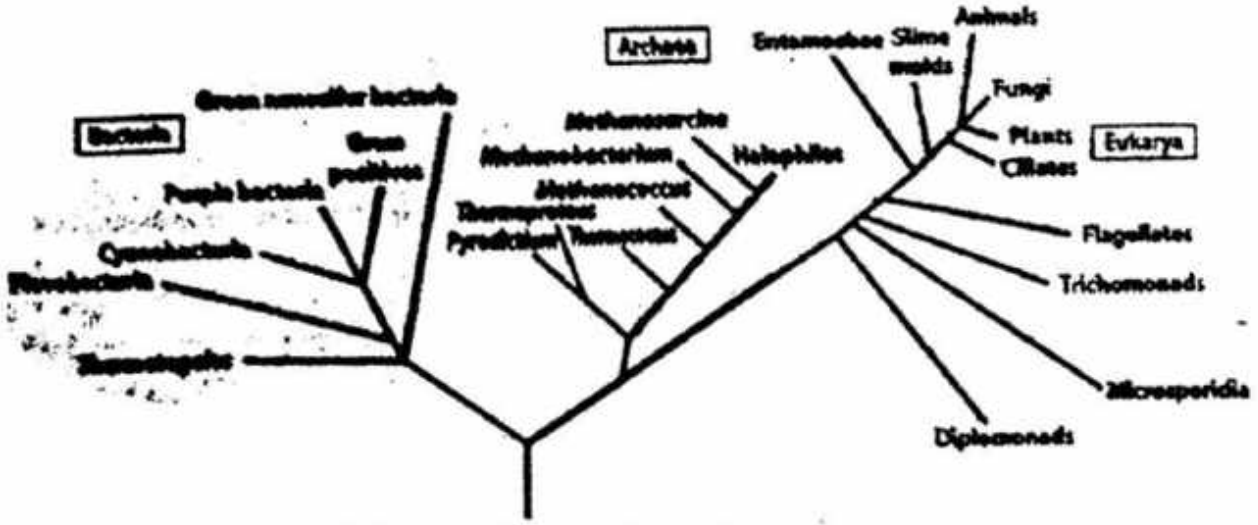
28. Explain the phylogenetic position of prokaryotes.

Ans: Phylogenetic position of prokaryotes:

The evolutionary relatedness among various groups of organisms (e.g., species, populations) is called **phytogeny.** A major step forward in the study of phylogeny of bacteria was the recognition in 1977 that archaea has a separate line of evolutionary descent from bacteria. This new phylogenetic taxonomy was based on the discovery that the genes encoding ribosomal RNA are ancient and distributed over all lineages of life with little or no lateral gene transfer. Therefore rRNA are commonly recommended as **molecular clocks** for reconstructing phytogenies, and divided prokaryotes into two evolutionary domains as part of the three-domain system, eubacteria, archaea and eukaryotes.



Phylogenetic position of prokaryotes



Phylogenetic position of prokaryotes

Gene sequences can be used to reconstruct the bacterial phylogeny, and these studies indicate that bacteria diverged first from the archaeal/eukaryotic lineage. The most recent common ancestor of bacteria and archaea was probably a hyperthermophile that lived about 2.5 billion to 3.2 billion years ago.

29. What are the unifying archaeal features that distinguish them from bacteria?

Ans: Archaea:

The microorganisms Archaea were previously called archaeobacteria (GK; *archaios*, ancient). Archaea shares certain traits with bacteria and other traits with eukaryotes. However, archaea also have unique characteristics and are different enough from bacteria to be incorporated into their own domain, archaea.

Unifying Features of Archaea:

The unifying features of archaea are:

Composition of cell wall:

The cell walls of archaea do not contain peptidoglycan. In some archaea the cell wall is largely composed of polysaccharides and in others, the wall is pure protein. In a few there is no cell wall

Composition of cell membrane:

The plasma membranes of archaea contain unusual lipids that allow them to function at high temperatures. Lipids of archaea contain glycerol linked to branched chain hydrocarbons in contrast to lipids of bacteria that contain glycerol linked to fatty acids.

Methanogenesis:

Methanogenesis the ability to form methane is one type of metabolism that is performed only by some archaea.

Mode of nutrition:

Most archaea are autotrophs and use molecular hydrogen and reduced elemental sulphur, carbon dioxide and water. There is no photosynthetic archaea.

Ribosomal RNA sequence:

The most fundamental difference between archaea and eubacteria is in their nucleic acid, e.g., rRNA. For instance, near nucleotide number 910 (out of 1500) in one type of rRNA researchers have found the following difference.

Eubactera: AAACUCAAA Archaea: AAACUUAAA

30. How are most Archaea inhabiting extreme environments?

Ans: Most Archaea Inhabit Extreme Environments:

The first prokaryotes that were classified in domain Archaea are species that live in extreme environments.

Archaea includes

(a) Methanogens. **(b)** Halophiles. **(c)** Thermoacidophiles.

(a) Methanogens:

The methanogens (methano, methane, gen, producer), are found in anaerobic environments in swamps, marshes and in the intestinal tracts of human and other animals where they produce methane from hydrogen gas and carbon dioxide coupled to the **formation of ATP**. This methane, is also called **biogas**.

Example: *Methanobacterium formicum*

(b) Halophiles:

The halophiles *(halo,* salt, *philes,* lover) grow where nothing else can live. such as on fish and meat that have been heavily salted to keep most bacteria away. The halophiles require high salt concentrations for growth

Example: *Halobacterium halobium.*

(c) Thermoacidophiles:

The thermoacidophiles (heat and acid lovers) are isolated from extremely hot, acidic environments such as hot springs, geysers, submarine thermal vent and around volcanoes.

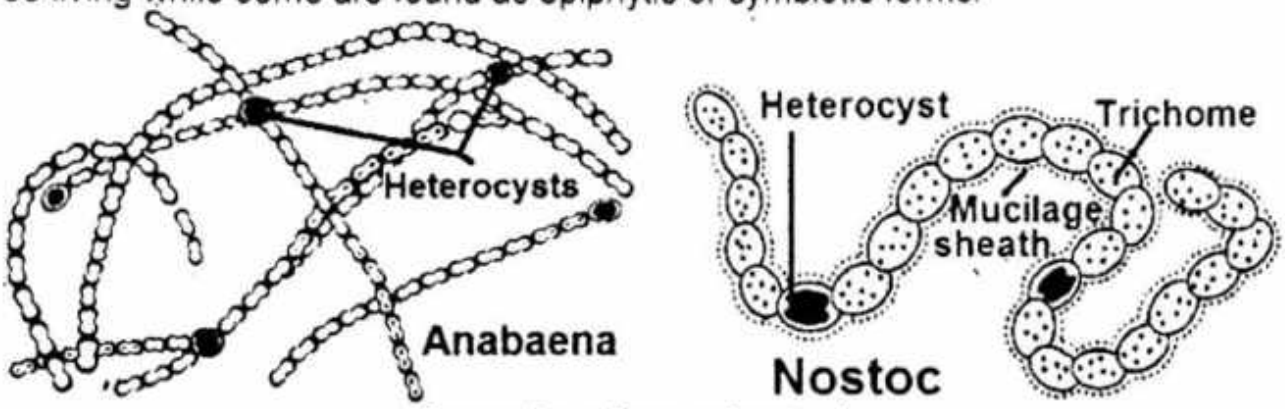
Example: *Pyrolobus fumarii.*

31. Why cyanobacteria are considered as the most prominent of the photosynthetic bacteria?

Ans: Cyanobacteria - The Most Prominent Photosynthetic Bacteria:

Introduction:

Cyanobacteria (Gk. *kyanoa,* blue and *bacterion,* rod) are the most prominent photosynthetic bacteria which are found in any damp place. Majority of them are free living while some are found as epiphytic or symbiotic forms.



Examples of cyanobacteria

Structure and organization:

Cyanobacteria have Gram-negative type of cell wall. The body may be unicellular and solitary or in the form of filaments which may form colonies. In filamentous forms the cells are arranged in linear row, the trichome which is embedded in mucilage sheath e.g., *Anabaena, Nostoc* etc.

Photosynthesis:

Photosynthesis takes place in the extensive system of membrane (thylakoid membranes), which is located in the outer zone of the cytoplasm inner to the cell membrane

Photosynthetic events:

Like algae and plants they use carbon dioxide as a source of carbon, water as hydrogen donor, both photosystems (non-cyclic photophosphorylation) to harvest light energy and release oxygen during photosynthesis. They are believed to be responsible for first introducing oxygen into the primitive atmosphere.

Pigment composition:

In addition to chlorophyll-a, cyanobacteria also use phycobilins as accessory pigment. **Phycocyanin,** a blue pigment is their predominant phycobiiins.

Nitrogen fixer:

About one third of cyanobacteria are able to fix atmospheric nitrogen. In most cases nitrogen fixation occurs in **heterocycts,** which are without nuclei, thick walled cell found at certain intervals in the **trichome.** In Pakistan cyanobacteria, e.g., ***Nostoc* and *Anabaena*** are purposely cultivated to increase the soil fertility, because of nitrogen fixation by these organisms.

32. Give an account of glycocalyx. What are the functions of glycoalyx?

Ans: Glycocalyx:

The glycocalyx is an outer coating that covers the outside of bacterial cell wall.

Forms of glycocalyx:

The glycocalyx exist in two forms i.e., capsule and slime.

Capsule:

The **capsule** is a condensed layer that is relatively tightly associated with the underlying cell wall and gives sticky or gummy nature to the cell,

Slime:

Slime is a more loosely attached layer that gives slimy or slippery nature to the cell and can be removed from the cell more easily.

Structure and chemical composition:

Structure and chemical composition of glycocalyx is variable, depending upon the growth conditions and availability of nutrients. Generally, the glycocalyx is made of polysaccharide. However, in some cases, protein can also be present.

Functions of the glycocalyx:

There are two prominent functions of the glycocalyx. In the form of **slime** it prevents the phagocytosis of bacteria by the cells of immune system called **macrophages.** This is because the presence of a glycocalyx increases the effective diameter of a bacterium and also covers up components of the bacterium that the immune system would detect and be stimulated by.

Thus, in a sense, a bacterium with a glycocalyx becomes more invisible to the immune system of a host and becomes more pathogenic.

The second function of a bacterial glycocalyx is to promote the **adhesion** of the bacteria to living and inert surfaces and the subsequent formation of adherent, glycocalyx-enclosed populations that are called **biofilms.**

Biofilm bacteria can become very hard to kill, partly due to the presence of the glycocalyx material.

33. Describe the detailed structure and chemical composition of bacterial cell wall.

Ans: Bacterial cell wall:

Cell wall is the part of bacterial envelop (to cover by wrapping, noun: envelope: something which wraps or covers).

Location: It is situated outer to the cell membrane.

Composition:

It is composed of an inner layer of **peptidoglycan** and an outer **lipoprotein membrane** (found only in Gram negative bacteria).

Function:

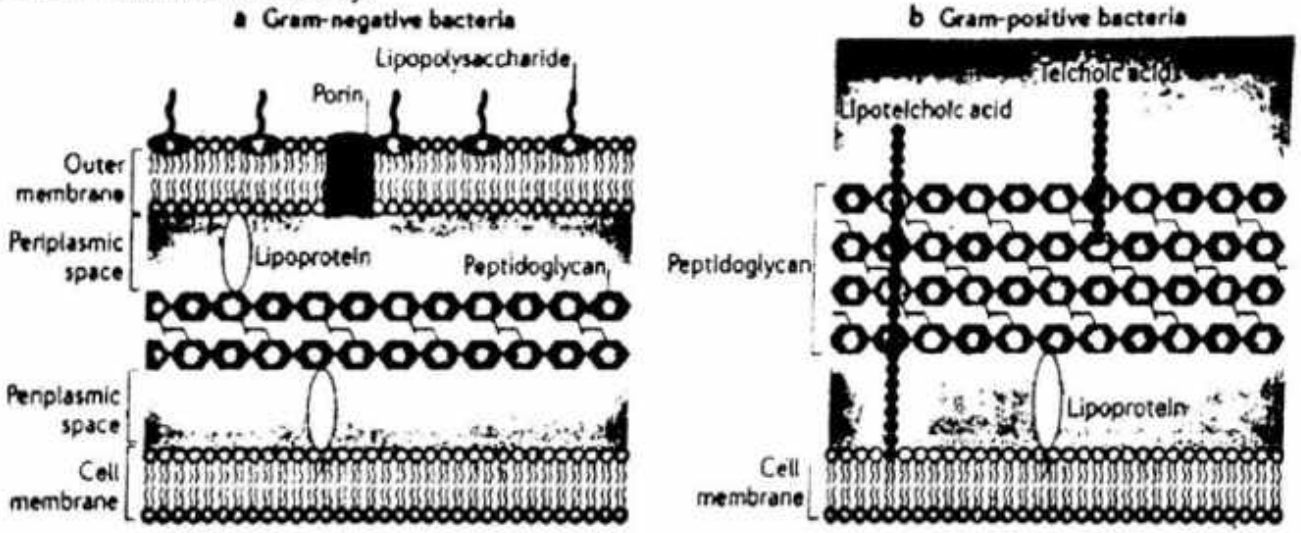
The peptidoglycan provides structural support and maintains the characteristic shape of the cell.

Comparison of Gram-positive and Gram-negative cell wall:

The peptidoglycan layer is much thicker in Gram-positive than in Gram-negative bacteria. Some Gram-positive bacteria also have fibre of **teichoic acid** that protrudes outside the peptidoglycan, whereas Gram-negative bacteria do not have it. In contrast, the Gram-negative have a complex outer layer consisting of lipopolysaccharide and lipoprotein.

The Gram-negative cell wall also contains a protein, the **porins** in outer membrane which act like pores for particular molecules. Lying between the peptidoglycan layer of cell wall and the cytoplasmic membrane in Gram-negative bacteria is the, **periplasmic space** which is the site of enzymes called β-lactamases that degrade penicillins and other β-lactam drugs (antibiotics).

Pilus is present only in Gram negative bacteria. They allow bacterial cell to adhere to tissue and can help the bacterial cell resist attack from immune system cells in the human body.



34. Explain the great diversity of shapes and sizes found in bacteria.

Ans: Diversity in Size of Bacteria:

The smallest known bacteria belong to the type called *Phytoplasma*, which infect plants and *Mycoplasmas*, which infect animals. They are spherical bacteria and have approximate diameter of 100 to 200 ηm (0.1 to 0.2 μm).

Escherichia coli, the bacteria used in testing water for faecal contamination, have rod shape and are about **7 μm long and 1.8 μm in diameter**. Many bacteria are long but narrow. One of the larger species is ***Spirochaeta plicatilis*, 250 μm** long by **0.75 μm thick**. For comparison, a human red blood cell is 8 μm in diameter. Among the largest bacteria, *Epulopiscium fishelsoni*, an organism that only lives in the gut of a brown surgeonfish found in the Red Sea, is an extraordinary kind of bacteria. Individual specimens have been measured at **80 mm thick** and more than **600 μm long** (more than half a millimeter, making them visible to the naked eye).

Diversity in Shapes of Bacteria:

Bacteria have three main shapes: spherical, rod shaped and spiral. However it has recently been shown that certain bacteria are capable of dramatically changing shape, for example *Helicobacter pylori* exists as both a **helix-shaped** form and a spherical form. Such bacteria are called **pleomorphic.**

Cocci:

Cocci (singular *coccus, kok-us)* are spherical bacteria. Cocci *(kok-si)* generally appear in groups which can be distinguished on the basis of plane of cell division and number of cells.

Diplococci and streptococci:

As a result of single (vertical) plane of cell division, bacteria appear in pairs, called **diplococci** or in chain of many cells, called **streptococci.**

Tetrad:

As a result of two plane of cell divisions (first vertical then again vertical but at right angle to the first), bacteria appear in a square of four cells, called **tetrad.**

Sarcinae:

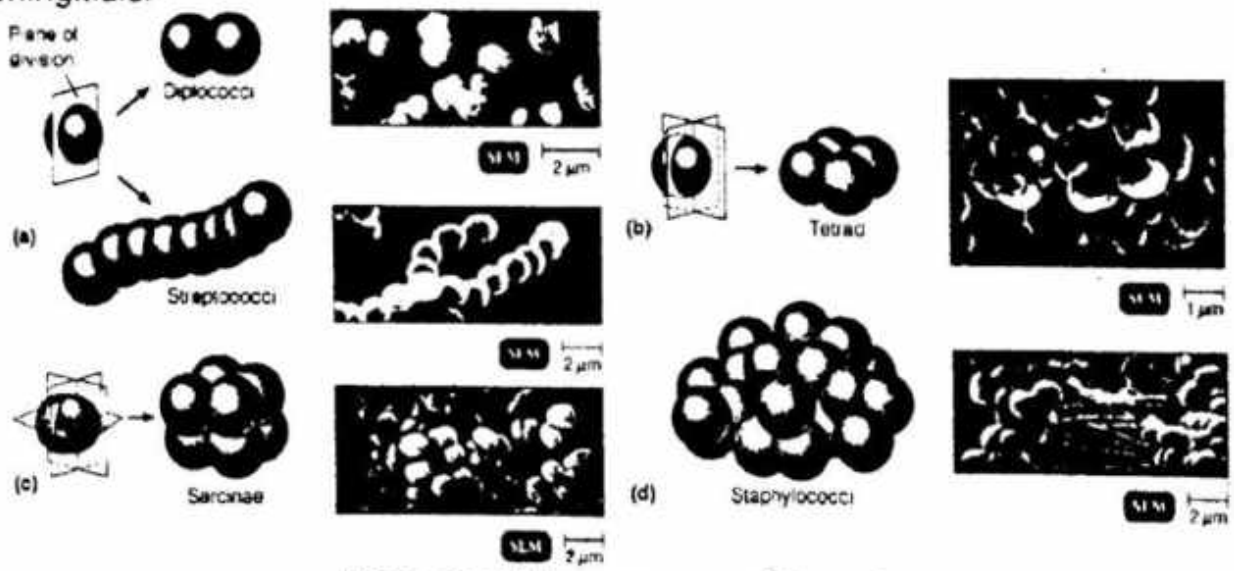
As a result of three plane of cell divisions (first vertical then again vertical but at right angle to the first and then horizontal), bacteria appear in a cubical arrangement of eight cells, called **sarcinae.**

Staphylococci:

If plane of cell division becomes irregular and many bacteria are produced which arrange like bunches of grapes, called **staphylococci.**

Examples of cocci:

The examples of cocci are: *Streptococcus pneumoniae, Neisseria meningitidis.*



Shapes and arrangement of cocci

Bacilli:

Bacilli are straight or rod shaped organisms.

Diplobacilli and streptobacilli:

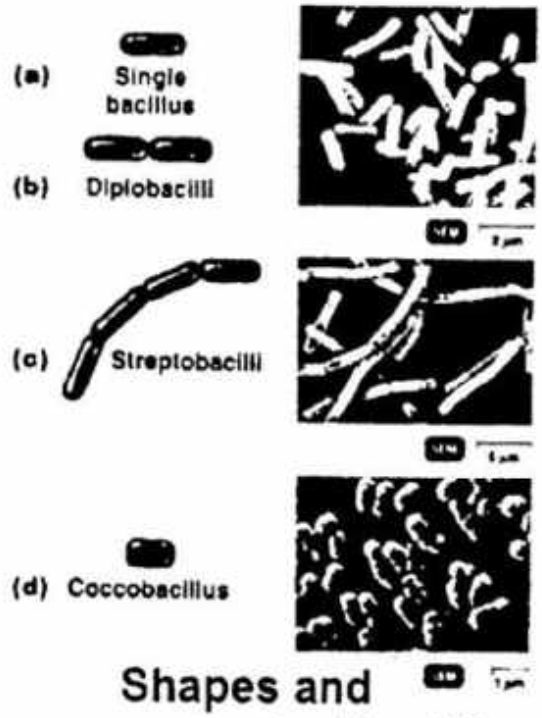
They always divide in vertical plane so they are found either in pairs, called **diplobacilli** or in chains of many cells, called **streptobacilli.**

Coccobacilli:

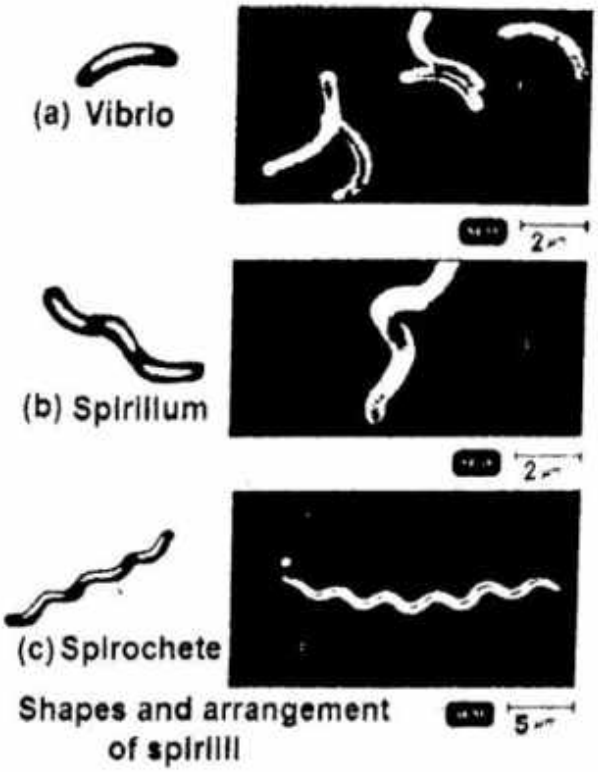
Some rod shape bacteria have spherical ends like cocci. Such bacteria are called **coccobacilli.**

Examples:

The examples of rod shaped bacteria are *Escherichia coli, Pseudomonas.*



Shapes and arrangement of bacilli



Shapes and arrangement of spirilli

Spirilli:

Spirilli are spiral shaped bacteria.

Spirochetes:

They usually occur singly, seldom form colonies. Thin and flexible spiral shaped bacteria are called **Spirochetes,**

Example: *Treponema pallidum.*

Spirillum:

Relatively, thick and rigid spiral shaped bacteria are called spirillum

Example: *Spirillum minus*

Vibrio:

Curved or comma shaped bacteria which are intermediate to spiral and rod shape, are called **vibrio**

Example: *Vibrio cholarae.*

35. Describe the bacterial spores and cyst.

Ans: Bacterial Spores and Cysts:

During late stage of growth, when essential nutrients are depleted in the environment and other conditions such as temperature, pH of the medium and availability of water become unfavourable certain bacteria form resistant and metabolically dormant bodies. Depending on the type of bacteria, these bodies are divided into endospores, exospores, and cysts.

Endospores:

Especially endospores are characterized by a complex structure and resistance to high temperatures. That is why this dormant form is capable of surviving for periods longer than thousand years. The spores develops within the vegetative cell inside the cell wall, so it has been named **endospore.**

The original cell forms a copy of its chromosome and surrounds it with a tough wall, forming the endospore. Water is removed from the endospore. The metabolism inside it stops. The rest of the original cell then disintegrates. The endospores germinate when their environmental conditions become favourable.



Endospore

Exospores:

On the other hand the *Actinomycetes*, which are a large group of spore-forming, Gram-positive bacteria that grow by forming long tubules called **filaments.** Under nutrient poor conditions these filaments differentiate into round thick walled resting structures termed **exospores.**

Cysts:

In contrast to endospores, these structures are part of the reproductive process and are formed outer to the cell wall. *Azotobacter* species and several others are known to form **cysts,** which are dormant cells with thickened cells walls. Encystment (cyst formation) occurs by changes in the cell wall; the cytoplasm contracts and the cell wall thicken.

Cysts are resistant to desiccation and some chemicals, but cannot withstand high temperatures as endospores can.

36. Explain motility in bacteria.

Ans: Motility in Bacteria:

Motility or movement is an important aspect of bacterial life in that the organism can swim toward optimal concentrations of nutrients and away from toxic substances.

Chemotaxis:

The type of purposeful movement in response to chemical stimuli is called **chemotaxis.**

Phototaxis:

Sometime bacteria show movement toward optimal light concentration or away from strong light. Such movement in response to light stimuli is called **phototaxis.**

Motility in bacteria is achieved by any of several mechanisms, such as flagellar movement, spirochaetal movement and gliding motility.

Flagellar movement:

The most widespread mechanism is flagellar movement which allows travel in a liquid medium and is mediated by special threadlike organelles extending from the cell surface called **flagella.**

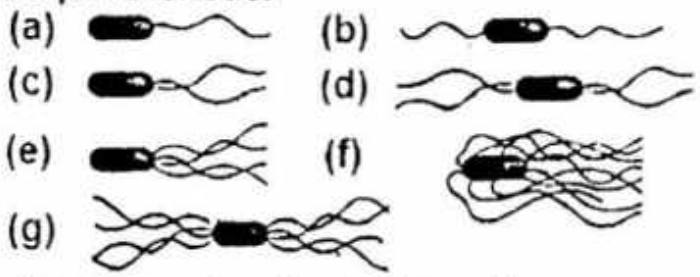
Most rods and spirilli such as *Pseudomonas, Vibrio, Salmonella* etc., are motile by means of flagella; cocci are usually non-motile.

The presence of flagella, as well as their number and distribution on the cell, are important characteristics for purposes of identification and classification of bacteria. When one or more flagella arise only from one or both ends of a rod or spiral-shaped cell, the arrangement is termed **polar.**

For example: if a bacterium possesses single flagellum at one end, called **monopolar monotrichous;** if the bacterium possesses single flagellum at both ends, is called **bipolar monotrichous** or **amphitrichous.** Similarly, if a bacterium possesses a pair of flagella at one end, called **monopolar bitrichous;** if the bacterium possesses a pair of flagella at both ends, is called **bipolar bitrichous** or

amphibitrichous. But, if a tuft (more than two) of flagella is present at one end of a bacterium, called iophotrichous, and if a tuft of flagella is present at both ends of a bacterium, called **amphilophotrichous.**

When, flagella arise randomly over the entire surface of the cell, the arrangement is termed **peritrichous.**



Arrangements of bacterial flagella:
(a) Monopolar monotrichous, (b) Bipolar monotrichous, (c) Monopolar bitrichous, (d) Bipolar bitrichous, (e) Lophotrichous, (f) Peritrichous, (g) Amphilophotrichous.

Spirochaetal movement:

A somewhat modified version of the bacterial flagellum is responsible for the movement of the bacteria known as spirochetes. These organisms possess flagella-like axial filament buried in space between inner and outer membrane of the cell wall along the length of the cell. Spirochetes can perform flexing, swimming, creeping or spinning type of movements with the help of axial filament.

Gliding motility:

Like spirochaetal movement, the gliding motility is also represented by some genera of the cyanobacteria and myxobacteria such as *Oscillatoria, Myxococcus.* These organisms can move slowly over solid surfaces. They do not have filamentous structures either internally like axial filament of spirochetes or externally flagella of bacilli but they secrete a slimy substance like garden snails during locomotion. The exact mechanism of gliding motility is still unknown but spme scientists have suggested generation of contractile waves or surface tension orpushing by secreted slime as possible mechanism of gliding.

37. Describe the structure of bacterial flagellum.

Ans: Structure of Bacterial Flagellum:

General characteristics:

Bacterial flagellum is non-contractile, and lacks microtubules unlike eukaryotic flagellum. It is about 20 nm diameter and up to 20 urn in length.

Parts of flagellum: It consists of three parts:

(i) Basal body **(ii)** Hook **(iii)** Filament

(i) Basal body:

The **basal body** originates from cytoplasm just beneath the cell membrane. It consists of two pairs of discs/rings (Gram positive bacteria have only one pair) which are connected by a central rod. The basal body anchors the flagellum in cell envelop.

(ii) Hook:

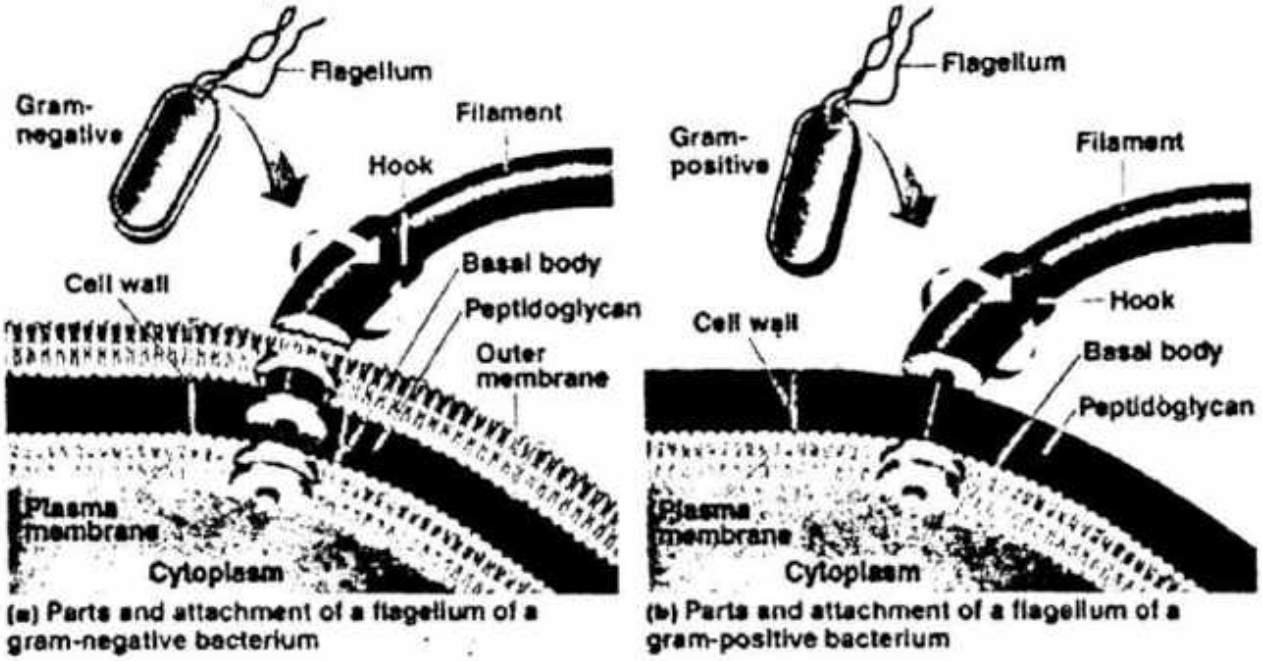
The **hook** is curved structure which connects the basal body to the filament. It is projected from the cell surface.

(iii) Filament:

The **filament** is a hollow structure which originates from the hook. The filament is composed of the globular protein **flagellin**, which is arranged in several intertwined chains that form a helix around a hollow core.

Mechanism:

The mechanism of movement of bacteria flagella is quite different from eukaryotic flagella. Its basal body produces rotatory motion. The 360° rotation of paired discs or rings of basal body enable the flagellum to rotate which in turn causes the cell to spin and move forward.



Structure of flagellum of bacteria

38. Describe the genomic organization of bacteria.

Ans: Genomic Organization of Bacteria:

Bacteria have a single circular double stranded DNA which is not enclosed by any membrane even though; it is called **nuclear DNA** because it controls growth and metabolic activities

However, it is not organized like typical eukaryotic chromosomes but often it is also referred as **bacterial chromosome.** Since bacteria have only one chromosome therefore, they are supposed to be **haploid organisms.**

A brief diploid phase comes in their life only during cell division when they duplicate their DNA. Apart from nuclear DNA some bacteria also have one or more copies of an extra nuclear small circular double stranded DNA called **plasmids** which contain genes for antibiotic resistance.

39. Describe autotrophic and heterotrophic nutrition in bacteria.

Ans: Modes of Nutrition in Bacteria:

Bacteria can be classified on the basis of method of obtaining energy and carbon. They may be either heterotrophic, which make their organic compounds from other organic sources, or autotrophic, which make their organic compounds from inorganic sources i.e., carbon dioxide

Autotrophic Bacteria:

There are two major groups of autotrophs:

Photoautotrophs and Chemoautotrophs.

Photoautotrophs:

Photoautotrophic bacteria are generally called photosynthetic bacteria. With exception to the cyanobacteria all the other photosynthetic bacteria contain unique type of chlorophyll called bacteriochlorophyll. The chlorophyll is incorporated in the membrane of their mesosomes. Unlike green plants, algae, and cyanobacteria, they do not use water as their reducing agent, and so do not produce oxygen. Instead they use hydrogen sulphide, which is oxidized to produce granules of elemental sulphur. This in turn may be oxidized to form sulphuric acid. However, like green plants, the photosynthetic bacteria use the energy of sunlight to make carbohydrates from CO_2

$$2H_2S + CO_2 \xrightarrow[\text{Chlorophyll}]{\text{Light}} (CH_2O)_n + H_2O + 2S$$

The examples of anoxygenic photosynthetic bacteria are green sulphur bacteria, green non-sulphur bacteria and purple sulphur bacteria.

Chemoautotrophs:

The **chemoautotrophic bacteria** make carbohydrates from inorganic substance. They do not use light energy. They oxidize inorganic substance. The energy produced by this oxidation is then used to make carbohydrates. Sulphur bacteria oxidize sulphur to produce energy.

$$2H_2S + CO_2 \xrightarrow{\text{Energy}} (CH_2O)_n + H_2O + 2S$$

$$2H_2S + O_2 \longrightarrow 2S + H_2O + \text{Energy}$$

The energy thus produced is used by bacteria to make carbohydrate $(CH_2O)_n$. The examples of chemoautotrophic bacteria are nitrifying bacteria, sulphur bacteria.

Heterotrophic Bacteria:

Heterotrophic bacteria cannot synthesize their organic compounds from simple inorganic compounds, so they depend on the organic compounds present in the environment. There are two types of heterotrophic bacteria: saprotrophs and parasites.

Cellular respiration is the breakdown of complex compounds into simpler for the release of energy which may be aerobic or anaerobic, accordingly bacteria are known as aerobic bacteria, e.g., *Pseudomonas* and anaerobic bacteria e.g., *Spirochete* Some are facultative bacteria e.g., *E.coli* which grow either in the presence or absence of oxygen. The bacteria which require a low -concentration of oxygen for growth are known as microaerophilic, e.g., *Campylobacter*.

Saprotrophs:

Saprotrophic bacteria contain extensive enzyme system that breakdown the complex substances of humus (decaying dead organic matter) to simpler compounds. The bacteria then absorb the simpler compounds, for example many soil bacteria, e.g., *Pseudomonas, Azobacter*.

Parasites:

Parasitic bacteria obtain their food from the host. Parasitic bacteria include pathogenic (disease causing) bacteria, e.g., *Streptococcus pneumoniae*.

40. Explain the phases of growth of bacteria.

Ans: Growth and Reproduction in Bacteria:

Microbes that are provided with nutrients and the required environmental factors become metabolically active and grow.

Phases of Bacterial Growth:

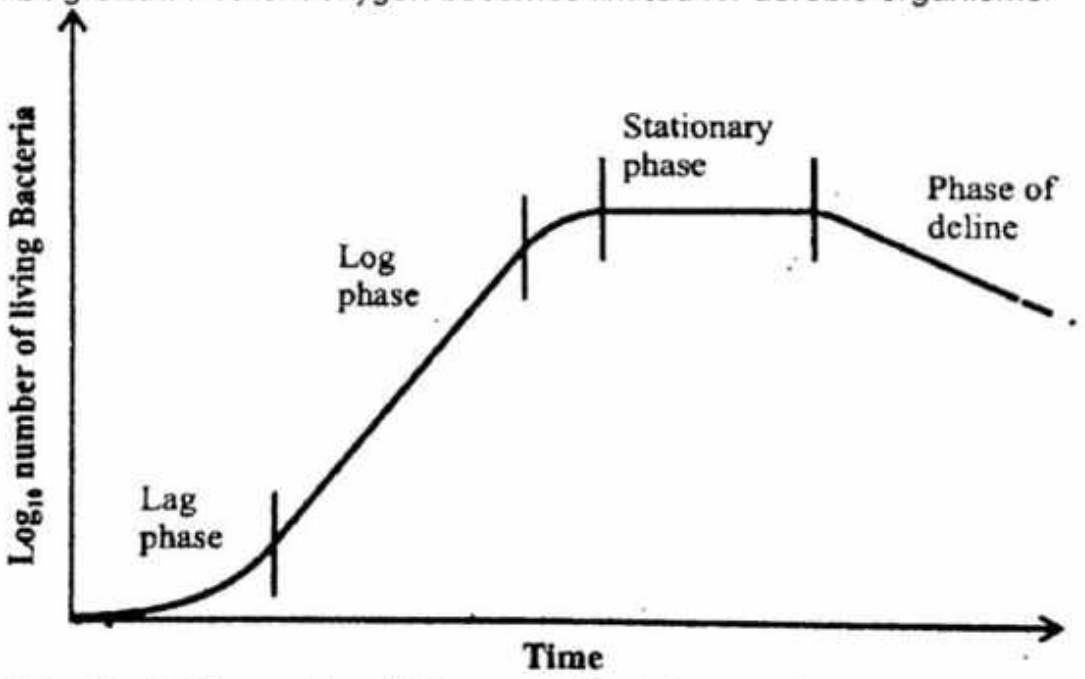
Bacterial growth takes place on two levels. On one level, a cell builds up protoplasm and increases its size; on the other level, the number of cells in the population increases. Bacterial growth occurs in four major phases which can be represented by bacterial growth curve.

Lag phase:

In this phase there is increase in cell size but not multiplication. Time is required for adaptation (synthesis of new enzymes) to new environment. During this phase vigorous metabolic activity occurs but cells do not divide. Enzymes and intermediates are formed and accumulate until they are present in concentration that permits growth to start.

Log or Exponential phase:

In log or exponential phase, the number of cells increases exponentially with respect to time, i.e., the number of cells doubles with each doubling time. The average time required for the population, or the biomass, to double is known as the **generation time** or **doubling time.** The cells multiply at the maximum rate in this exponential phase, i.e., there is linear relationship between time and logarithm of the number of cells. This continues until one of two things happens: either one or more nutrients in the medium become exhausted, or toxic metabolic products, accumulate and inhibit growth. Nutrient oxygen becomes limited for aerobic organisms.



Typical Growth of Curve of a Bacterial Population

Stationary phase:

In this phase, due to exhaustion of nutrients or accumulation of toxic products death of bacteria starts and the growth cease completely. The count remains stationary due to balance between multiplication and death rate

Death or Decline phase:

In this phase there is progressive death of cells. The rate of cell division is gradually decreased and eventually cells stop multiplying. However, some bacteria may survive by forming resistant spores or cysts during this phase.

41. Describe asexual and sexual methods of reproduction in bacteria.

Ans: Reproduction in Bacteria:

Bacteria generally reproduce by asexual method. In true sense sexual reproduction is absent in bacteria but various methods of genetic recombination are misleadingly called sexual reproduction.

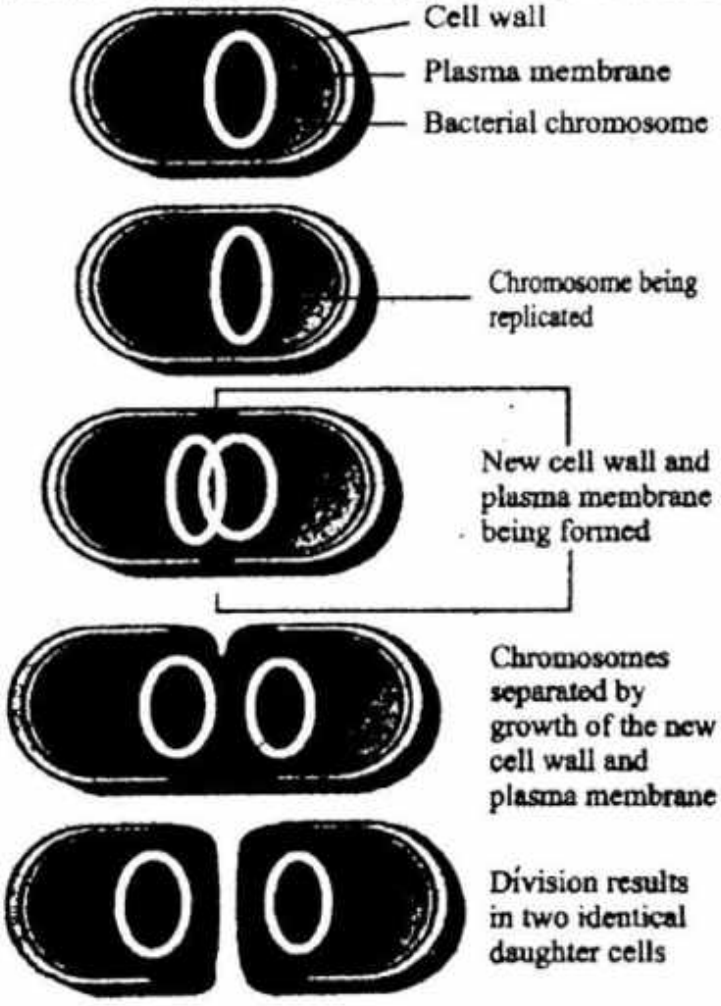
Asexual reproduction:

Most common method of asexual reproduction in bacteria is binary fission. However, some bacteria reproduce by budding.

Binary fission:

Binary fission is the commonest type of reproduction under favourable conditions in which cell divides or splits into two similar daughter cells. During the process, the bacterial DNA gets attached to the cell membrane and undergoes replication.

As the cell enlarges the daughter DNA gets separated. A cross wall is formed between the separating daughter DNA. It divides the cell into two daughter cells. The daughter cells soon grow to maturjty within 20 minutes and divide again.



Binary Fission in Bacteria

Budding:

In case of budding, 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.

Sexual reproduction:

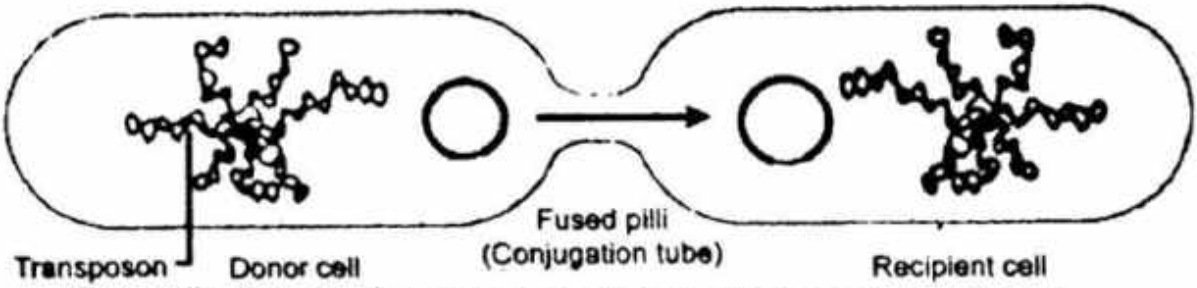
In bacteria, there is no true sexual reproduction because there is no meiosis, formation of gametes and zygote. Instead, it involves transfer of a portion of genetic material (DNA) from a donor cell to a recipient cell. This process is called genetic recombination or parasexuality.

It occurs in three ways:

(i) Conjugation **(ii)** Transduction **(iii)** Transformation

(i) Conjugation:

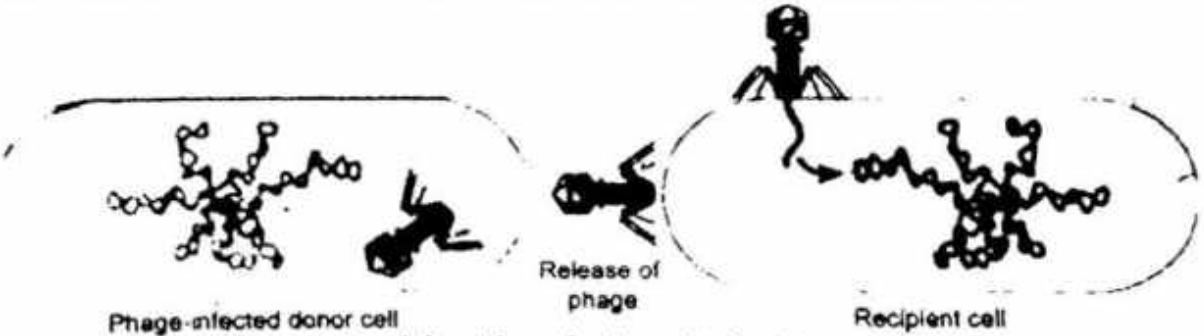
Conjugation takes place only between bacteria of the same or closely related species. Two bacteria of different mating types come together. Sex pilus forms a conjugating bridge, which temporarily joins the two cells together. The bacterium that will give the DNA is called **donor** and the bacterium that will receive the DNA is called the recipient. Often a plasmid rather than the main bacterial DNA is transferred.



Genetic recombination in bacteria (conjugation)

(ii) Transduction:

The transfer of genetic material from one bacterium to another bacterium through the third party, the bacteriophage virus, is called **transduction.** Actually it occurs when a bacteriophage is replicated in a bacterial cell, at the time of assembly of its components a portion of host bacterium may be enclosed into the viral capsid. When such viruses cause infection to other bacterial cells the DNA fragment of the previous host bacterium is thus transferred to the new host bacterium.

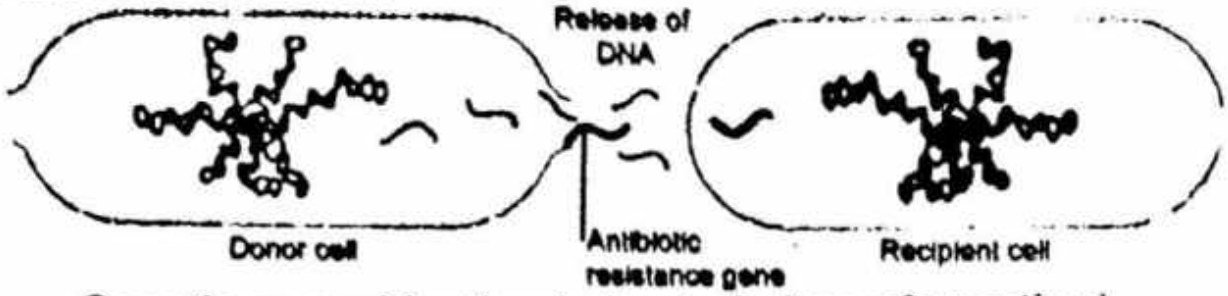


Genetic recombination in bacteria (transduction)

(iii) Transformation

When bacteria die or when they are reproducing very rapidly, they release fragments of their DNA into their immediate environment. Such DNA fragments may

be up taken by other bacteria by means of diffusion in that environment. This process of absorption of DNA into a cell from its immediate environment is called **transformation.** As a result the cell is transformed into new type of cell. These cells are called transformed cells



Genetic recombination in bacteria (transformation)

42. What is the ecological importance of bacteria?

Ans: Ecological Importance of Bacteria:

Ecological Importance refers to the role of bacteria in environment, such as decomposition of dead/complex organic matter, humus formation to increase the fertility **of soil,** bioremediation etc.

Role of bacteria in decomposition of dead/complex organic matter:

Recyclers:

Bacteria serve as **recyclers of nature** as they are involved in decomposition of dead/complex organic matter in the environment. If the dead bodies are not decomposed, **the** organic nutrients present in their bodies would not be released in the environment. **The** organic carbon present in dead bodies might diminish all the carbon dioxide from the atmosphere if there were no decomposers present on earth. There would have been no photosynthesis in the plants and as a result no food would have been produced by plants.

Environment role:

Bacteria play a very crucial role in environment through the decomposition of dead organic matter. Bacteria use them as a source of nutrients, and in turn help in recycling the organic compounds trapped in the dead matter. Through this process, other organisms also get benefited, who can use the simpler forms of organic compounds/ nutrients released from the dead matter by various bacteria.

Role of bacteria to increase soil fertility by humus formation and nitrogen fixation:

Humus:

The partially decaying organic matter of dead organisms is called **humus.** It contains nutrients and increases soil fertility for the growth of plants. It also increases the water retaining capacity of the soil. Bacteria and fungi are the only organisms that decompose dead animals and plants and thus, take part in humus formation.

Nitrogen fixers:

Nitrogen is the most important element for plants for their growth and metabolic activities. Soil is the only source of nitrogen for plants as they cannot inhale nitrogen directly from the atmosphere. Nitrogen from the atmosphere can be available to the plants through the process of **nitrogen fixation.**

This process takes place with the help of nitrogen fixing bacteria like ***Rhizobium* and *Cyanobacteria*** in the soil. These species of bacteria convert the

atmospheric nitrogen into nitrates and nitrites as a part of their metabolism, and make it available to the plants Some plants (leguminous plants) have a mutualistic association with the bacteria (root nodulus bacteria) living into their tissues for this purpose.

Role of bacteria in removal or degradation of environmental pollutants:

Removal or degradation of environmental pollutants by using living organisms is called **bioremediation.** It involves the use of many bacteria that either naturally love to eat contaminants or have been genetically altered to give them the taste for toxins. Scientists are designing or deploying microbes to purge sites of contaminants such as oil, radioactive waste, gasoline and mercury, and new bioremediation research appears regularly.

43. What is the economical importance of bacteria?

Ans: Economic Importance of Bacteria:

The economic importance of bacteria refers to the role of bacteria in research and technology, plant diseases and in human diseases.

Role of bacteria in research and technology:

When we think of bacteria, we usually think about the illness it can cause and our need to get rid of it However, bacteria play a lot of positive roles in our lives which are unknown to many of us.

Bacteria play an important role in many technological fields, mainly in biological research, mining, medicine, production of food products, plastics synthesis and sewage treatment. The overall commercial worth of bacteria in these operations is immense.

Biological research:

Bacteria have been used and being continuously used in the study of genetics and **genetic engineering**. Bacteria were used as model organism in number of famous experiments such as the discovery of DNA **as heredity material**, discovery of semi **conservative replication** of DNA and etc. Many components of bacterial cell are also being used as tools in genetic engineering experiments.

Mining:

The miners can extract metal from low grade ores in a relatively ecologically friendly **way** by using certain bacteria. The bacterium ***Thiobacillus ferrooxidans*** is the important organism here.

It works by catalysing the oxidation of metal sulphides, particularly copper sulphate so that they are soluble in water i.e., CU_2S **to** $2Cu^{2+}$ and SO_4^{2-}. This allows the copper to be leached out of the rock. *T.* ***ferrooxidans*** is also used in the organic leaching of gold and uranium with the help of other bacteria such as ***T. thiooxidans*** and ***Leptospirillum ferrooxidans***.

Medicine:

Bacteria are useful to mankind is in the production of complex organic molecules that are of use in small amounts as part of the normal process of living, these include antibiotics, vitamins, amino acids and enzymes.

Production of food products:

In addition to these compounds, the dairy products such as yogurt, cheese, butter etc. are also produced with the help of bacteria.

Plastics synthesis:

Now a days biodegradable plastic is made by using two bacterially produced molecules, Poly-B-hydroxybuterate and Poly-B-hydroxyvalerate. These molecules make a polymer just like ordinary plastic but having the essential difference that once left out in the compost or in a landfill they can be broken down by bacteria and fungi to become part of the cycle of life again.

Sewage treatment:

Owing to their characteristics of degrading harmful chemicals and pollutants, bacteria naturally (as well as deliberately used by industries), help in treatment of waste water.

Role of bacteria in causation of diseases and spoilage of food:

Beside lot of benefits some bacteria are harmful for us. Parasitic bacteria attack plants and cause various diseases, e g., fire blight in apple, ring diseases in potatoes, crown gall etc., many human diseases are caused by bacteria e.g., diphtheria, tetanus, leprosy, meningitis, sore throat, whooping cough (also called: pertussis) etc.

Bacteria cause decay of wood, leather, fabrics etc. Bacteria spoil the food materials by decomposition.

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

Ans: Role of bacteria in research and technology:

When we think of bacteria, we usually think about the illness it can cause and our need to get rid of it. However, bacteria play a lot of positive roles in our lives which are unknown to many of us.

Bacteria play an important role in many technological fields, mainly in biological research, mining, medicine, production of food products, plastics synthesis and sewage treatment. The overall commercial worth of bacteria in these operations is immense.

Biological research:

Bacteria have been used and being continuously used in the study of genetics and genetic engineering. Bacteria were used as model organism in number of famous experiments such as the discovery of DNA as heredity material, discovery of semi conservative replication of DNA and etc. Many components of bacterial cell are also being used as tools in genetic engineering experiments.

Mining:

The miners can extract metal from low grade ores in a relatively ecologically friendly **way** by using certain bacteria. The bacterium *Thiobacillus ferrooxidans* is the important organism here. It works by catalysing the oxidation of metal sulphides, particularly copper sulphate so that they are soluble in water i.e., CU_2S to $2Cu^{2+}$ and SO_4^{2-}. This allows the copper to be leached out of the rock. *T. ferrooxidans* is also used in the organic leaching of gold and uranium with the help of other bacteria such as *T. thiooxidans* and *Leptospirillum ferrooxidans*.

Medicine:

Bacteria are useful to mankind is in the production of complex organic molecules that are of use in small amounts as part of the normal process of living, these include antibiotics, vitamins, amino acids and enzymes.

Production of food products:

In addition to these compounds, the dairy products such as yogurt, cheese, butter etc. are also produced with the help of bacteria.

Plastics synthesis:

Now a days biodegradable plastic is made by using two bacterially produced molecules, Poly-B-hydroxybuterate and Poly-B-hydroxyvalerate. These molecules make a polymer just like ordinary plastic but having the essential difference that once left out in the compost or in a landfill they can be broken down by bacteria and fungi to become part of the cycle of life again.

Sewage treatment:

Owing to their characteristics of degrading harmful chemicals and pollutants, bacteria naturally (as well as deliberately used by industries), help in treatment of waste water.

45. Describe symptoms, causative bacteria, treatments and preventive measures of the following bacterial diseases in man:

(a) Cholera **(b) Typhoid**

(c) Pulmonary tuberculosis **(d) Pneumonia**

Ans: Bacterial diseases in man:

Bacteria cause many diseases in man such as, tetanus, diphtheria, meningitis, plague, typhoid fever, etc. Here we will discuss only cholera, typhoid, pulmonary tuberculosis and pneumonia.

(a) Cholera:

Symptoms: Watery diarrhoea in large volume is the hallmark of cholera.

Cause: It is caused by *Vibrio cholerae*.

Treatment: It consists of prompt, adequate replacement of water and electrolytes, either orally or intravenously.

Prevention: It is achieved mainly by public health measures that ensure a clean water supply.

(b) Typhoid:

Symptoms: High fever, tender abdomen and enlarged spleen occur.

Cause: It is caused by *Salmonella typhi*.

Treatment: Antibiotics should be used.

Prevention: It is prevented mainly by public health and personal hygiene measures. Vaccines are available for the prevention of typhoid.

(c) Pulmonary tuberculosis:

Symptoms: The symptoms include mild fever lasts for 7-14 days and mild dry cough. Later on night sweats, weight loss, anorexia, and weakness, dry hacking cough with blood stained sputum.

Cause: The causative agent is *Mycobacterium tuberculosis*.

Treatment: Multiple-drug therapy is used during the long 6 to 9 month duration of treatment or DOTS (directly observed treatment short course) of only two months duration.

Prevention: A vaccine containing a strain of live *Mycobacterium bovis* (Bacillus Calmette-Guerin or BCG) can be used to induce partial resistance to tuberculosis.

(d) Pneumonia:

Symptoms: Pneumonia often begins with sudden chill, cough and pleuritic pain. Sputum is red brown "rusty" colour.

Cause: The causative agent is *Streptococcus pneumoniae*
Treatment: Antibiotics are used.

46. Describe the symptoms, causative bacteria, and preventive measures of the following bacterial diseases in plants:

(a) Leaf spots **(b) Soft rots**
(c) Wilting **(d) Galls**

Ans: Bacterial diseases in plants:

The important bacterial plant diseases are leaf spots, blights, soft rots, wilts and galls.

(a) Leaf spots:

Symptoms: The most common symptoms of plant diseases are discrete or spreading type lesion on leaf blade.

Cause: It is caused by *Xanthomonas campestris* on tomato and pepper. Other genera cause the disease in tobacco and potato

Prevention: Prevention of contact between the pathogen and the host, use of disease free seeds.

(b) Soft rots:

Symptoms: When the cells of plant tissue die because of the action of pathogen, produce, rot type symptoms. Rotting may affect any organ of plant. The necrotized tissue becomes wet to touch and soft inconsistency hence termed soft rot.

Cause: *Erwina anylovora* causes soft rot in potato. *Corynebacterium* causes ear rot of wheat.

Prevention: For preventing removal of diseased plants by physical method is done.

(c) Wilting:

Symptoms: Loss of turgidity in the leaf blade increased with time and ultimately leads to wilting of leaf and drying.

Cause: *Pseudomonas solanocaerum* causes wilt disease in potato.

Prevention: Selection of disease free seeds and allowing proper spacing between the plants.

(d) Galls:

Symptoms: These are localised outgrowth mostly small but may be very large in some diseases.

Cause: *Rhizobium leguminosarum* causes small galls called **root nodule** in legumes.

Prevention: Crop rotation, removal of diseased plants etc.