Bacteria

They are tiny, unicellular, microscopic, prokaryotic organisms. They are cosmopolitan in distribution. They are found in air, in water, in soil etc. They are prokaryotes. (and they lack true nucleus.) Usually bacterial nucleus lacks nuclear membrane and nucleolus. Such type of nucleus is called as incipient nucleus.

- A Dutch scientist Anton Van Leeuwenhoek discovered the bacteria in 1675.
- The name bacterium was given by Ehrenberg in 1829.
- The detailed study of bacteria was made by Louis Pasteur (1822 – 1895).
- Disease caused by bacteria was first found by Robert Koch in 1881.
- The study of bacteria is known as bacteriology.

Characteristics of Bacteria

1. These are simple, primitive unicellular, microscopic, prokaryotic organism.
2. They are cosmopolitan in distribution found everywhere except burning fire.
3. They have rigid cell wall made up of peptidoglycan.
4. They contain circular double stranded naked DNA as genetic materials.
5. Membrane bound organelles are absent.
6. They have autotrophic and heterotrophic mode of nutrition.
7. Photosynthetic pigments are bacteriochlorophyll and chlorobium chlorophyll.
8. Reserve food material is in the form of glycogen and lipid.
9. Gas vacuole is present instead of true sap filled vacuole.
10. Flagella, if present, are single stranded.
11. Ribosome is of 70s type.
12. Common mode of reproduction is of binary fission. Sexual reproduction is totally absent.

Structure of Bacteria:

The bacterial cell is externally surrounded by cell wall which is made up of peptidoglycan. The cell wall may contain lipids and polysaccharides. It provides the shape and protection against injuries.

Just below the cell wall, there may contain slime layer in some bacteria which is followed to cell membrane. Cell membrane is made up of phospholipid and lipoprotein. It is semi-permeable in nature. It forms infolding towards cytoplamic side of the cell forming a complex structure known as mesosome.

Cell membrane is followed innerward colourless, viscous substance named as cytoplasm. It composed of complex proteins, lipids, minerals, nucleic acid and water. The reserve food material is glycogen found in cytoplasm.

It contain 70s type of ribosome.

In photosynthetic bacteria, chromatophores are present in cytoplasm. It contains different colour pigments like bacteriochlorophyll and carotenoids. Gas vacuoles are present in cell that helps the bacterial cells in floatation. Other cell organelles like endoplasmic reticulum, mitochondria, golgi apparatus etc. are absent.

The incipient nucleus is present that contain single naked chromosome (only DNA). Except this, there is also found additional circular DNA known as episome or plasmid. It carries gene that increase resistance against antibodies.

Except these, flagella may present in some motile bacteria. The number and position of flagella differs on the basis of species. Sex pilli or fimbriae also found in some bacteria. It helps the cell attachment during conjugation.
Figure:

Classification of bacteria

Bacteria are classified on different basis.

A. On the basis of shape of the cell, bacteria are of following types.

1. **Spherical bacteria:** These bacteria are called cocci (sing. Coccus). Being they do not contain flagella, they are non-motile in nature. They may occur singly or in the form of group. Eg: Monococcus, Diplococcus, Tetracoccus, Streptococcus (in the form of chain), Staphylococcus (in the form of grape-like clusters).
2. **Rod shaped bacteria:** They are short, straight or slightly curved with blunt ends. They are called bacilli (sing. Bacillus). Some of them contain flagella whereas some of them do not. They may occur singly or in the form of group. Eg: Monobacillus, Diplobacillus, Streptobacillus (in the form of chains or filament), Palisade (in the form of stacks).
3. **Helical bacteria:** They posses spirally coiled body. Eg: Spirilla (in the form of cork screw), Vibrios (in the form of curved, comma shaped or C-shaped).
4. **Filamentous bacteria:** They are thread or filament like structure. Eg: Caulobacter (stalked bacteria), Rhodomicrobacterium (in the form of budding), Actinomyces (in the form of mycelium).

B. On the basis of flagellation, bacteria are of following types.

1. **Atrichous:** These bacteria lack flagella. Hence, they are non-motile. eg: Lactobacillus, *Bacillus anthracis*, etc.
2. **Monotrichous:** Bacteria having only one flagellum at one end of cell. eg: *Vibrio cholerae*, *Psuedomonas*, etc
3. **Amphitrichous:** Bacteria having one flagellum at both end of cell. eg: *Nitrosomonas*.
4. **Cephalotrichous:** Bacteria having tuft of flagella at one end of cell. eg: *Pseudomonas fluorescens*.
5. **Lophotrichous:** Bacteria having tuft of flagella at both end of cell. eg: *Spirillum volutans*.
6. **Peritrichous:** Bacteria having flagella distributed all over the cell. *Salmonella typhii*, *Clostridium tetani*, etc

C. On the basis of staining capacity, bacteria are of following types.

1. **Gram positive:** Bacteria that retain the colour of crystal violet is called gram positive bacteria. It contain violet colour after staining. eg: *Bacillus*, *Streptococcus*, etc.
2. **Gram negative:** Bacteria that lose the colour of crystal violet is called gram negative bacteria. It contains pink or red colour after staining. eg: *Salmonella*, *Rhizobium*, etc.

D. On the basis of nutrition, bacteria are of following types.

1. **Autotrophic Bacteria:** They synthesize their own food, carbohydrate, from inorganic substances, carbondioxide and water. On the basis of source of energy for food preparation, they are of two types.
   a. **Photoautotrophic bacteria:** They trap solar energy for utilization carbondioxide and use hydrogen sulphide instead of water. Thus, oxygen is never released. For this, they have pigments like bacteriochlorophyll and chlorobium chlorophyll.
      They are of following types.

i. **Green sulphur bacteria:** They contain chlorobium chlorophyll as photosynthetic pigments. They reduce carbondioxide by using hydrogen sulphide. Here, carbohydrate is synthesized and produce sulphur as biproduct. It is deposited extracellularly. Eg: *Chlorobium, Calthrochloris* etc

$$12H_2S + 6CO_2 \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6H_2O + 12S$$

ii. **Purple sulphur bacteria:** They contain bacteriochlorophyll and carotenoids as photosynthetic pigments. They reduce carbondioxide by using hydrogen sulphide or thiosulphite. Here, carbohydrate is synthesized and produce sulphur as byproduct. It is deposited intracellularly. Eg: *Chromatium* etc

$$12H_2S + 6CO_2 \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6H_2O + 12S$$

iii. **Non sulphur bacteria:** They contain bacteriochlorophyll as photosynthetic pigments. They reduce carbondioxide by using organic substrates. Here, carbohydrate is synthesized but sulphur is not produce as byproduct. Eg: *Rhodospirillum* etc

$$6CO_2 + 24CH_3CHOCH_3 \xrightarrow{\text{Light}} C_6H_{12}O_6 + 24CH_3COCH_3 + 6H_2O$$

b. Chemoautotrophic bacteria: They are non photosynthetic bacteria due to lack of chlorophyll at all but they can prepare their own food. They use carbondioxide as the source of carbon. They reduce carbondioxide with the help of derived energy from oxidation of simple inorganic compounds like ammonia, nitrates, nitrites, hydrogen sulphides etc.

They are of following types.

i. **Nitrifying bacteria:** These bacteria use the energy from oxidation of nitrogen compounds. These bacteria are generally found in soil. Eg: *Nitrosomonas, Nitrosococcus, Nitrobacter, Bactoderma* etc

$$2NH_3 + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2HNO_2 + 2H_2O + \text{energy}$$

$$2HNO_2 + O_2 \xrightarrow{\text{Nitrobacter}} 2HNO_3 + \text{energy}$$

ii. **Hydrogen bacteria:** They obtained energy from the oxidation of hydrogen. Eg: *Hydrogenononas*

$$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O + \text{energy}$$

iii. **Methane bacteria:** They oxidize methane to release energy. Eg: *Methanosomonas*.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{energy}$$

iv. **Sulphur bacteria:** They convert hydrogen sulphide to sulphur and then sulphur to sulphuric acid to release energy. Eg: *Thiobacillus, Beggiatoa* etc

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

$$2S + 4O_2 + 2H_2 \longrightarrow 2H_2SO_4 + \text{energy}$$

v. **Iron bacteria:** They oxidize ferrous compound to ferric compounds and release energy. Eg: *Leptothrix, Cladothrix, Ferobacillus* etc

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

2. Heterotrophic bacteria: These bacteria cannot synthesize their own food. They obtain their food from other organisms. They are of three different types.

a. Saprophytic bacteria: These bacteria obtain their food from the dead organic decaying substances such as leaves, fruits, vegetables, meat, animal faeces, leather, humus etc. They secrete enzymes to digest the food and absorb it.

The anaerobic breakdown of carbohydrates is known as fermentation and of proteins the putrefaction. The former produces alcohols, acetic and other organic acids by fermentation of carbohydrates. Putrefaction decomposes proteins into ammonia, methane, H_2S, carbonic acids. The enzymes secreted break down the complex compounds into simpler soluble compounds, which are easily absorbed. Eg: *Pseudomonas*

b. Symbiotic bacteria: These bacteria live in close association with other organisms as symbionts. They are beneficial to the organisms. The common examples are the nitrogen-fixing bacteria, e.g., *Bacillus azotobacter*, *Rhizobium*, *Clostridium* etc. *Rhizobium* spp. and *B. azotobacter* live inside the roots of leguminous plants and form bacteria nodules for fixation of nitrogen from the air.

c. Parasitic bacteria: These bacteria obtain their food from the tissues of living organisms, the hosts. They may be harmless or may cause serious diseases. The disease-producing bacteria are pathogenic which cause various diseases in plants and animals. Examples are *Bacillus typhosus*, *B. anthracis*, *B. tetani*, *B. diplheriae*, *B. tuberculosis*, *B. pneumoniae*, *Vibrio cholerae*, *Pseudomonas citri* etc.

Difference between Gram positive and Gram negative bacteria

Gram positive bacteria	**Gram negative bacteria**
1. They contain deep blue or purple colour after washing by alcohol.	1. They lose the colour when washed by alcohol.
2. Cell wall is thick.	2. Cell wall is thin.
3. Cell wall contains high amount of peptidoglycan and fewer amounts of polysaccharides and lipid.	3. Cell wall contains high amount of lipid and polysaccharides with less amount of peptidoglycan.
4. They are sensitive to antibiotics.	4. They are resistant to antibiotics.
5. They donot bear sex pilli.	5. They bear sex pilli.
6. Mesosome is present.	6. Mesosome is absent.

Factors affecting bacterial growth

There are various factors that affect the bacterial growth.

1. **Temperature:** Basically bacteria can grow at all temperature between freezing point of water to high temperature. But the best grow of bacteria takes place in optimum temperature. Temperature below the minimum stops bacterial growth but do not kill organism whereas temperature above maximum kill the bacteria. (Fire-15 seconds kill bacteria)
2. **Nutrients:** Bacteria need nutrients for their growth. Bacteria normally feed on organic matter that contains necessary energy. Such matter must be soluble in water and of low molecular weight. Hence they need water to transport nutrients.
3. **Water:** Bacteria cannot grow without water. Many bacteria are quickly killed by dry condition whereas other can tolerate dry conditions for months. Water activity is used as an indicator of the availability of water for bacterial growth. If water activity less than 0.8, cell growth is reduced.
4. **Oxygen:** Aerobic bacteria need oxygen for their growth whereas anaerobic bacteria doesnot need oxygen. Anaerobic organisms are responsible for both beneficial reactions and spoilage of food materials.

Some bacterial can live either with or without oxygen are known as facultative anaerobic bacteria.

5. **Acidity:** The acidity is expressed in pH value. Different bacterial species response different pH values. Most bacteria prefer pH value above 7 i.e. neutrality.

Koch Postulates:

Koch postulates are four criteria designated to establish a causal relationship between a microbe and a disease. The postulates were formulated by Robert Koch and Friedrich Loeffler in 1884 and refined and published by Koch in 1890.

Koch postulates are

1. The micro-organism or other pathogen must be present in all cases of the disease.
2. The pathogen can be isolated from the diseased host and grown in pure culture.
3. The pathogen from the pure culture must cause the disease when inoculated into a healthy, susceptible (sensitive) laboratory animal.
4. The pathogen must be re-isolated from the new host and shown to be the same as the originally inoculated pathogen.

Economic Importance of Bacteria

Bacteria are both friend and foe (friend of earth) to the human race.

Useful Activities:

1. **Soil fertility:** It participates in nitrogen fixation and increases the soil fertility, e.g. *Azotobacter, Clostridium* etc.
2. **Nitrifying bacteria:** These bacteria convert ammonia to nitrate, e.g. *Nitrosomonas* and *Nitrobacter*.
3. **Ammonification:** These bacteria convert protein into ammonia. Such bacteria are therefore, also called bacteria of decay or putrefying bacteria, e.g. *Bacillus* spp.
4. **In dairy:** These bacteria convert lactose sugar of the milk into lactic acid. The preparation of cheese and curd are based on these principles, e.g. *Lactobacillus*.
5. **In Industries:** Many useful products of economic importance are manufactured by using bacteria.
6. **Antibiotics:** Antibiotics cure disease competitive inhibition which is obtained mostly from bacteria.
7. **Symbiosis in human intestine:** The bacteria like *E. coli* found inside human intestine is mostly helpful in digestion.
8. **Preparation of alcohol:** Ethyl alcohol and butyl alcohol are manufactured by the activity of Clostridium acetobutylicum in sugar solution.
9. **Preparation of vinegar:** By the activity of Acetobacter in sugarcane juice.
10. **Curing of tea, coffee, tobacco:** Curing and flavouring of tea, coffee and cocoa are done by *Bacillus* bacteria.
11. **Preparation of leather and tanning:** The hair and fats are removed from the skin by the activity of *Clostridium.*
12. **Sewage disposal:** Faecal matter collected in sewage digested by a number of aerobic bacteria.

Harmful Activities:

1. **Food Poisoning:** Some bacteria excrete toxic substance and cause food poisoning e.g. *Clostridium, Salmonella* etc.

2. **Food Spoilage:** Some saprophytic bacteria cause rotting of vegetables, fruits, meat, bread etc. eg: *Bacillus* spp., *Psuedomonas* etc.
3. **Denitrification:** Bacteria reduce soil fertility by releasing free nitrogen, e.g. *Thiobacillus*.
4. **Human disease:** They cause various diseases infect the human body, e.g. *Bacillus vibrio*.
5. **Plant diseases:** Many serious plants diseases are caused by bacteria, e.g. *Xanthomonas, Pseudomonas* etc.

Toxin: It is poison produced by a living organism.

Cyanobacteria:

They are commonly known as blue green algae. Hence, are previously classified under myxophyceae of algae. These are multicellular, long, slender and filamentous in nature. They are either aquatic or terrestrial in nature. Being they contain photosynthetic pigments, they are autotrophic in nature.

Characteristics of cyanobacteria:

1. They are cosmopolitan in distribution. They are generally fresh water form.
2. They are either unicellular or multicellular in nature.
3. The multicellular forms are either colonial or filamentous.
4. The outermost layer is cell wall made up of peptidoglycan.
5. Photosynthetic pigments are found in thylakoid membrane. Hence, are of autotrophic.
6. Mesosomes are present instead of mitochnodria.
7. 70s types of ribosomes are only found.
8. Nucleus present which is not covered by any membrane. Such kind of nucleus is known as incipient nucleus.
9. Reserve food material is cyanophycean starch.
10. Reproduction takes place vegetatively and asexually. Sexual reproduction is absent.
11. Eg: *Nostoc, Oscillatoria, Anabaena* etc.

Nostoc:

It is found in water either floating freely or submersed. Some are terrestrial and some lead symbiotic life with fungus and higher plants.

It is a thallus, which appears like a simple and unbranched filament. The filament structure of *Nostoc* is called 'trichome'. Trichomes are formed by joining of numerous cells in a linear fashion. The cells are spherical, oval or round.

Nostoc is commonly found in colony where several trichomes unified with each other.

Figure:

The vegetative structure of Nostoc contains three different types of cells.

1. **Vegetative cells:** These are normal cells which are transparent in nature. It is simple, oval or spherical in shape. It contains different cellular organelles in it.
2. **Heterocysts:** It is thick walled, round, barrel shaped cells. These are slightly larger than other vegetative cells. These are either intercalary or terminal in position. They are connected to adjoining vegetative cells through their polar nodes. It helps in nitrogen fixation.
3. **Akinete:** It is greatly elongated cells. It is thick walled which store huge amount of food materials.