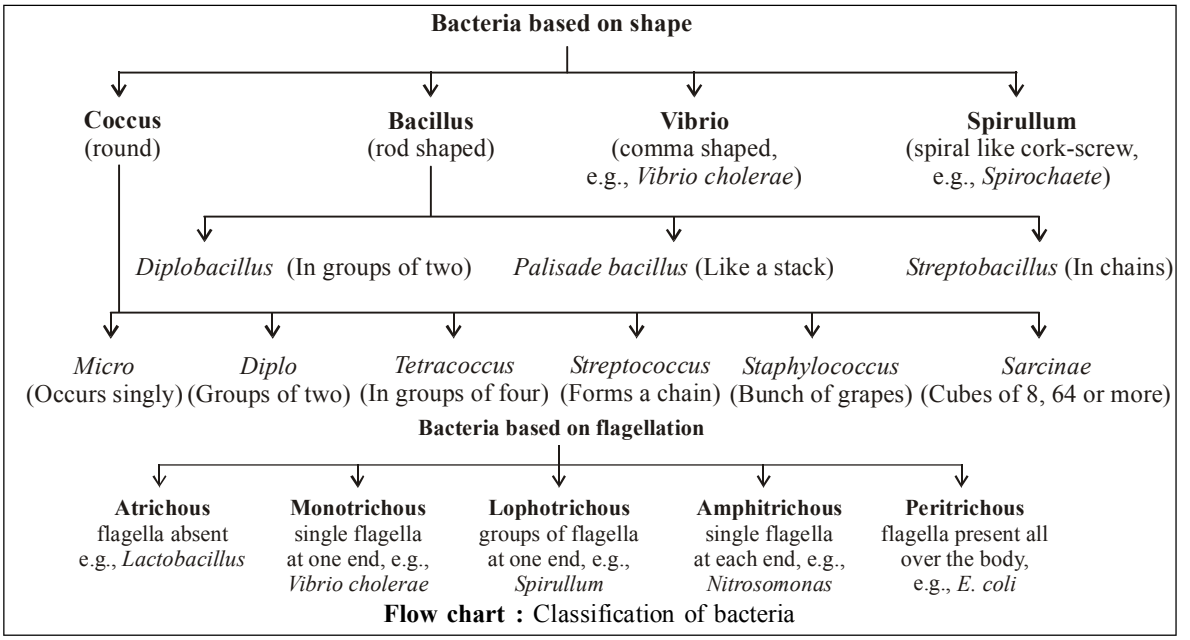
Chapter 3

Kingdom Monera

- **Monera** are the group of all prokaryotes.
- They are basically unicellular, may be mycelial, colonial and filamentous.
- Cell wall is made up of **peptidoglycan**, **polysaccharides** and **cellulose**.
- They do not contain any organised nucleus with distinct membrane.
- **DNA is naked**, *i.e.,* not associated with histone proteins. It is called **nucleoid**.
- All the membrane bound **cell organelles are absent** like mitochondria, lysosomes, golgi bodies, plastids etc.
- In photoautotrophic forms thylakoids are present - without chloroplasts.
- Spindle apparatus do not develop at the time of cell division.
- Single stranded flagella, **composed of flagellin**, is present.
- Ribosomes are **70S type** (subunit 30S and 50S).
- Reproduction is by **binary fission or budding**.
- They have a **various modes of nutrition** like saprobic, parasitic, chemoautotrophic, photoautotrophic, symbiotic.
- Some are capable of nitrogen fixation.
- Monera occur in all environment, eg archaebacteria live in extreme climates.
- The kingdom includes all prokaryotes like **bacteria**, **actinomycetes**, **mycoplasma** and **cyanobacteria**.

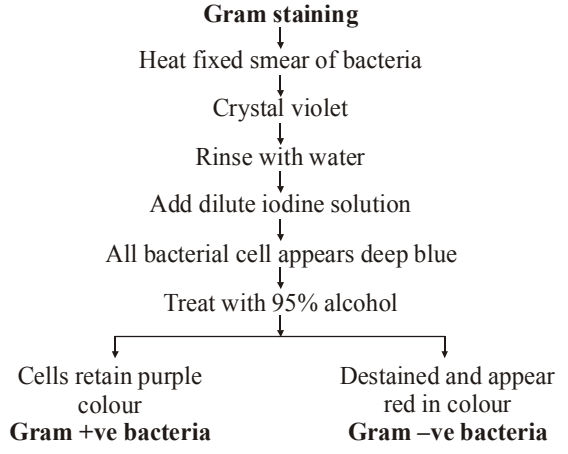
BACTERIA

- Bacteria are the **smallest of free living organism**, **mostly unicellular.**
- Bacteria possess various forms and shapes, and are of **4 different types – coccus**, **bacillus**, **vibrio**, and **spirullum**.



Flow chart : Classification of bacteria

- Bacteria possess a distinct cell wall, with different wall layers like capsule or slime layer, plasma membranes, flagella and pilli.
- Slime layer or capsule is made up of **polysaccharides** and **amino acids** and acts as osmotic barrier.
- Cell wall is made up of **polysaccharides**, **proteins** and **lipids** and **peptidoglycan** or **murein**.
- Plasma membrane is **tripartite** in nature.
- **Mesosomes** are simple infolding of plasma membrane containing respiratory enzymes, like oxidases and dehydrogenase.
- Flagella is made up of **flagellin**.
- **Pili** are small hair like outgrowth present on bacterial cell surface made up of **pilin protein**.
- Pilin **helps in formation of conjugation tube and agglutination**.
- **Based on the nature of staining**, bacteria **may be Gram + ve** (retains the blue stain) or **Gram –ve** (does not retain the stain).



- Inner to the wall layers, there is present matrix or protoplasm which includes **nucleoid**, **plasma**, **episomes**, **ribosomes**, **and granules**.
- In the centre of the bacterial cell, there is present **nuclear material** (DNA) **without any nuclear membrane** (naked). **DNA in bacteria is double helical and circular**.
- This incipient nucleus or primitive nucleus is named as **nucleoid** or **genophore** (sometimes called single naked chromosome).
- Besides this nuclear DNA, there is some extranuclear or extrachromosomal DNA, which is known as **plasmid**.

Table : Difference in the cell walls of gram +ve & gram –ve bacteria

	Gram +ve bacteria	Gram –ve bacteria
1.	Cell wall more thick, thickness varies from 25-30 nm.	Cell wall thin.Thickness varies 10-15 nm.
2.	Cell wall is a homogenous layer.	Three layered.
3.	High content of peptidoglycan (20-80% of the dry weight of the cell).	Less content of peptidoglycan (10-20% of the dry weight of the cell).
4.	Teichoic acids may be present.	Teichoic acids absent.
5.	Very little lipid content (0-2%).	High lipid content (10-20%).
6.	Only a few aminoacids are associated with the muramic acid complex.	Large variety of aminoacids are associated.
7.	Lipopolysaccharide layer (LPS) absent.	Present.
8.	Periplasmic space is absent.	Present.

- The plasmid are **small**, **circular**, **double-stranded DNA molecules** that are separate from main bacterial chromosome and replicate independently.
- The term plasmid was given by **Lederberg (1952)**.
- Plasmids have an independent existence.
- Plasmids **carry genes for fertility**, **antibiotic resistance** (**R-factor**) and **bacterium** (**Colicin**) **production** (**colicinogenic factor**).
- **F-factor** or **fertility factor** is responsible for transfer of genetic material.
- **R-factor** or **resistance factor** provides resistance against drugs.
- **Colicinogenic factor** produces '**colicines**' which kill other bacteria (other than which produces these colicines).
- The term **episome** is applied to extranuclear genetic material which may remain in integrated or free state, e.g., F-factor, temperate phage, etc.
- Ribosomes are evenly distributed in the matrix. Ribosomes are of 70S type (50S + 30S).
- Ribosome are the seat of protein synthesis and are made up of r-RNA and protein.

- There are present different types of granules like volutin granules, fatty acid granules (lipid granules), glycogen and sulphur granules.
- **According to the mode of respiration**, bacteria can be **aerobic** or **anaerobic**. Each of them is further of two types, obligate and facultative.
- **Obligate aerobes** are bacteria which can respire only aerobically. They generally get killed under anaerobic mode of respiration, e.g., *Bacillus subtilis*.
- **Facultative aerobes** are bacteria which respire anaerobically under normal conditions but can respire aerobically when oxygen is available. Most of the photosynthetic bacteria belong to this group.
- **Obligate anaerobes** are bacteria that respire only anaerobically. They generally get killed under aerobic condition, e.g., *Clostridium botulinum*.
- **Facultative anaerobes** are bacteria which generally respire only aerobically but switch over to anaerobic mode of respiration if oxygen becomes deficient.

Nutrition

- Bacteria show both **autotrophic** and **heterotrophic nutrition**.
- **Autotrophic nutrition** consists of manufacture of organic materials from inorganic raw materials with the help of energy obtained from outside sources. It is of two types – **chemosynthesis** and **photosynthesis**.
- The bacteria possess photosynthetic pigments of two types, **bacteriochlorophyll** and **bacteriophaeophytin** (chlorobium chlorophyll). The two types of pigments respectively occur in purple bacteria (e.g., *Thiopedia rosea, Rhodopseudomonas*) in membranes of thylakoids.
- **No oxygen is evolved in bacterial photosynthesis**. Such type of photosynthesis is known as **anoxygenic photosynthesis**.
- Water is not used as a source of reducing power. Instead, hydrogen is obtained either directly (some purple bacteria) or from various types of inorganic and organic compounds, *e.g.*, H_2S (green bacteria), aliphatic compounds (purple nonsulphur bacteria).
- **Chemoautotrophic bacteria** are bacteria which are able to manufacture their organic food from inorganic raw materials with the help of energy derived from exergonic chemical reactions involving oxidation of an inorganic substance present in the external medium. They are of various types.
- **Nitrifying bacteria**, *Nitrosomonas* and *Nitrosococcus* obtain energy by oxidising ammonia to nitrite.
  $NH_4^+ + 2O_2 \rightarrow NO_2^- + 2H_2O + \text{Energy}$
  Nitrocystis and *Nitrobacter* oxidise nitrites to nitrates.
  $2NO_2^- + O_2 \rightarrow 2NO_3^- + \text{Energy}$
- **Sulphur oxidising bacteria**, *Beggiatoa*, a colourless sulphur bacterium, oxidises hydrogen sulphide to sulphur in order to obtain energy for chemosynthesis.
  $2H_2S + O_2 \xrightarrow{\text{Beggiatoa}} 2S + 2H_2O + \text{Energy}$
  Thiobacillus thioxidans, another sulphur bacterium, oxidises sulphur to sulphate state.
  $2S + 2H_2O + 3O_2 \xrightarrow[\text{Thioxidans}]{\text{Beggiatoa}} 2H_2SO_4 + \text{Energy}$
- **Iron bacteria**, *Ferrobacillus ferro-oxidans* obtains energy by oxidising ferrous compounds to ferric forms.
  $4FeCO_3 + 6H_2O + O_2 \rightarrow 4Fe(OH)_3 + 4CO_2 + \text{Energy}$
- Other chemosynthetic bacteria, bacterium *Methanomonas* oxidises methane into CO_2 and H_2O.
  $CH_2 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Energy}$
- **Heterotrophic bacteria** may be **saprophytic**, **parasitic or**, **symbiotic**.
- **Saprophytic** are **living bacteria which obtain their food from organic remains**, *e.g.*, corpses, animal excreta, fallen leaves, vegetables, fruits, meat, jams, jellies, bread and other products of plant and animal origin.
- **Symbiotic bacteria** live in mutually beneficial association with other organisms. Enteric bacterium *Escherichia coli*, live as a symbiont in human intestine.
- **Parasitic bacteria**, live in contact with other living beings for obtaining nourishment or special organic compounds required for growth (growth factors).
- Bacteria **show four major phases of growth** in a fresh nutrient rich medium – (i) **lag phase**, (ii) **log phase** (logarithmic or exponential phase), (iii) **stationary phase**, and (iv) **decline phase** (death phase). These phases constitute the standard bacterial growth curve.

Reproduction

- Bacteria show **3 methods of reproduction** – **vegetation reproduction**, **asexual reproduction**, **sexual reproduction**.

- **Vegetative reproduction** includes **budding** and **binary fission**.
- **Binary fission** takes place during favourable conditions. The bacterial cell divides by a constriction into 2 halves. The nuclear material also divides into 2 equal halves.
- **Asexual reproduction** takes place by **endospore formation**, **conidia** and **zoospores**.
- During unfavourable condition, highly resistant single spore is formed inside the bacterial cell, which is known as **endospore**. (*Endo means inside or within + spore*).
- Endospore is having a characteristic structure *i.e.*, having outer thin **exosporium** followed by one or many layered **spore coat**, followed by many **concentric layers of cortex**, which is followed by **cell wall**, **cell membrane** and **matrix**.
- Endospore is **highly resistant to very high and very low temperature**, **strong chemicals and acids**, **etc**. **due to calcium**, **dipicolinic acid and peptidoglycan in cortex**. Dipicolinic acid (DPA) **helps in stabilizing its proteins**.
- DPA and Ca ions provide resistance to heat.
- When favourable conditions come, outer layers rupture and active bacterial cell comes out. So this is a method of perennation (*i.e.*, to tide over unfavourable condition) and some people say it **"reproduction without multiplication"**.
- **Sexual reproduction** occurs in the form of **genetic recombination**.
- There are **there main methods of genetic recombination – transformation**, **transduction**, **conjugation**.
- **Transformation** : Here genetic material of one bacterial cell goes into another bacterial cell by some unknown mechanism and it converts one type of bacterium into another type (non-capsulated to capsulated form).
- This was **first studied by Griffith** (1928) in *Diplococcus pneumoniae* and hence is known as **Griffith effect**.
- **Transduction** : In this method, genetic material of one bacterial cell goes to other bacterial cell by agency of bacteriophages or phages (viruses, infecting bacteria).
- Transduction was first of all reported in *Salmonella typhineurium* by **Zinder and Lederberg (1952)**.
- In abortive transduction the new gene does not integrate with the recipient genome and is lost.
- **Conjugation** : Cell to cell union occurs between two bacterial cells and genetic material (DNA) of one bacterial cell goes to another cell lengthwise through conjugation tube which is formed by sex pili.
- Conjugation was **first reported by Lederberg and Tatum (1946)** in *E. coli* bacteria.
- Conjugation **occurs between donor cell and recipient cell**. Donor cell is having sex pili and F-factor whereas recipient cell is having both.
- In donor cell, F-factor may unite with main genome or nuclear DNA and this donor cell is called **Hfr-donor cell** (High Frequency donor cell) and here transfer of DNA is rapid.

Importance of bacteria

Useful activities

- **Role of bacteria in agriculture in increasing soil fertility**
  - Some free living nitrogen fixing bacteria like *Azotobacter* and *Clostridium* have the capacity of fixing atmospheric nitrogen into nitrogenous substances, hence increases soil fertility.
  - Similarly symbiotic bacteria *Rhizobium* also fix atmospheric nitrogen.
  - *Nitrosomonas* converts ammonia into nitrites, which is further converted into nitrates by *Nitrobacter* (nitrification).
- **In dairy industry**, lactic acid bacteria (*Bacterium lacticiacidi* and *Bacterium acidi-lactici*) convert lactose of milk into lactic acid and hence milk turns sour.
- **In other industries**
  - In vinegar industry, *Acetobacter aceti* converts sugar solution into acetic acid.
  - Butyl alcohol and acetone are produced by activity of *Clostridium acetobutyricum*.
  - Retting or separation of fibres from stalks, *e.g.*, in jute, sunhemp, *Linum* (flax), etc. is done by water inhabiting bacteria *Clostridium butyricum*.
  - Flavouring of tobacco leaves is done by *Bacillus megatherium*.
  - Curing of leaves of tea is done by *Micrococcus condisans*.

- **Role of bacteria in sewage disposal**
  - For the breakdown of sewage in simple substances, bacteria and algae play important role.
  - Sewage oxidation ponds or tanks have luxuriant growth of bacteria and algae.
- **Role of bacteria in petroleum pollution** : Petroleum pollution in water bodies is checked upto some extent by *Pseudomonas*.
- **Role of bacteria in human being** : *E. coli* (gram-ve) bacteria live in colon region of intestine of man and other animals and play an important role in digestion process.
- Many antibiotic are produced from bacteria. **Antibiotics** are substances produced by micro-organisms which in low concentration are antagonistic to the growth of other micro-organisms. Medicinally antibiotics are those organic secretions which destroy or check the growth of different pathogens without harming the host.

Table : Role of bacteria in medicine

	Antibiotics	Bacteria from which obtain
1.	Subtelin	*Bacillus subtilis*
2.	Polymyxin	*Bacillus polymyxa*
3.	Streptomycin and Cycloheximide	*Streptomyces griseus*
4.	Chloromycetin (Chloramphenicol)	*Streptomyces venezuelae*
5.	Terramycin (Oxytetracycline)	*S. rimosus*
6.	Aureomycin	*S. aurefaciens*
7.	Erythromycin	*S. erythraeus*
8.	Neomycin	*S. fradiae*

Harmful activities

- **Spoilage of food** : Saprophytic bacteria causes rotting of vegetables, fruits, meat, bread, souring of milk, cheese, butter, spoilage of jams, jellies and pickles.
- **Destruction of Penicillin** by *Bacillus brevis*.
- **Cotton spoilage** is done by bacteria called *Clostridium botulinum*.
- **Desulphurification of soils** : Soil sulphates is changed to hydrogen sulphide by *Desulfouibrio desulfuricans*.
- **Reduction of soil fertility** : There are some denitrifying bacteria in soil, which convert nitrates into free nitrogen (denitrification), *e.g.*, *Bacillus denitrificans*, *Micrococcus denitrificans* and *Thiobacillus denitrificans*.

Table : Bacterial diseases of plants, animals and humans

Name of disease		Causal organism
Human beings		
Pneumonia	–	*Diplococcus pneumoniae*
Typhoid	–	*Salmonella typhosa*
Cholera	–	*Vibrio cholerae*
Plague	–	*Pasteurella pestis*
Meningitis	–	*Neisseria meningitides*
Gonorrhoea	–	*Neisseria gonorrhoeae*
Syphilis	–	*Treponema pallidum*
Diarrhoea	–	*Bacillus coli*
Gastroenteritis	–	*E. coli*
Diphtheria	–	*Corynebacterium diphtheriae*
Tuberculosis	–	*Mycobacterium tuberculosis*
Gangarin	–	*Clostridium perfringens*
Jaundice	–	*Leptospira icterohaemorrhagae*
Whoophing cough	–	*Haemophilus pertussis* or *Bordetella pertussis*
Tetanus (lockjaw)	–	*Clostridium tetani*
Bacterial dysentry	–	*Shiegella dysentirae*
Leprosy	–	*Mycobacterium leprae*
Animals		
Anthrax	–	*Bacillus anthracis*
Black leg disease	–	*Clostridium chauvi*
Plants		
Soft rot of potato	–	*Pseudomonas solanacearum*
Citrus canker	–	*Xanthomonas citri*
Bacterial blight of paddy	–	*Xanthomonas oryzae*
Tundu disease in wheat	–	*Corynebacterium tritici*
Potato wilt	–	*Pseudomonas solanacearum*
Fire blight of apple and peach	–	*Erwinia amylovora*
Crown gall of beet sugar	–	*Agrobacterium*
Black rot of cabbage	–	*Xanthomonas campestris*

Some other types of bacteria

- **Spirochaetes** are free inhabitants of mud and water and are **chemoheterotrophic** bacteria. Many diseases are caused by them as *Treponema pallidum* causes syphilis, *Leptospira* causes infectious jaundice and *Borrelia* causes relapsing fever. Besides some spirochaetes are found in teeth.
- **Rickettsiae** are Gram negative obligate pleomorphic but walled intracellular parasites which are resident of or are transmissible from arthropods. They are **intermediate between true bacteria and viruses**.
- **Chlamydiae** are Gram negative intracellular parasites of about 0.25 μm size, often grouped along rickettsiae but differ from them in reproductive cycle that involves formation of initial or **reticulate bodies** (RB) and **elementary bodies** inside host phagosome. *Chlamydia trachomatis* causes conjuctivitis, sexually transmitted nongonococcal urethritis, epididymitis, cervicitis, proctitis and lymphogranuloma venereum. *C. pneumoniae* causes pneumonia and bronchopneumonia.

ACTINOMYCETES

- Actinomycetes are **mycelial (aseptate branched filaments) bacteria which form radiating colonies in culture**. Because of this, actinomycetes were **formerly called ray fungi**.
- Mycelial form is reduced in *Mycobacterium* and *Corynebacterium*.
- Mycelia have a diameter of 1mm or less.
- Wall contains mycolic acid (fatty acid), lipid and wax.
- Different **modes of reproduction** are by **conidia**, **sporangiospores** and **arthrospores** or **oidia** and **fragmentation**.
- Most of the actinomycetes are saprotrophic and constitute an important component of decomposers, e.g., *Actinomyces, Streptomyces*.
- A few are pathogenic in plants, animals and humans, e.g., *Mycobacterium*.
- In pathogenic actinomycetes or *Mycobacterium* a derivative of mycolic acid called **mycoside**/cord factor is involved in causing disease.
- A **number of antibiotics are produced** by actinomycetes, especially the genus *Streptomyces* (streptomycin, chloramphenicol, tetracyclines, terramycin, erythromycin, viomycin, novobiocin, nystatin).

The term **antibiotic was given by Abraham Selman Waksman** (1888 - 1973) **who also extracted first antibiotic** from *Streptomyces griseus* and named it streptomycin. For this Waksman was given Nobel Prize in 1952.

ARCHAEBACTERIA

- They are a group of most primitive prokaryotes which are believed to have evolved immediately after the evolution of the first life. They are also called living fossils.
- Archaebacteria are characterised by **absence of peptidoglycan in their wall**.
- Instead the wall contains **protein and non-cellulosic polysaccharides**. It has **pseudomurein in some methanogens**.
- The **cell membranes** are characterised by the **presence of a monolayer of branched chain lipids**.
- Archaebacteria even now live under extremely hostile conditions where very few other organisms can dare subsist, e.g., salt pans, salt marshes, hot sulphur springs.
- Their rRNA nucleotides are quite different from those of other organisms.
- The archaebacteria are of two broad categories – obligate anaerobes and facultative anaerobes or aerobes.
- Archaebacteria are of **three types – methanogens**, **halophiles** and **thermoacidophiles**.

Archaebacteria are **also known as living fossils because** they represented one of the earliest forms of life which experimented on the absorption of solar radiations for the first time, lived comfortably under anaerobic conditions and developed techniques to oxidise the chemicals present in the substratum on the availability of oxygen.

Methanogens

- These archaebacteria are **strict anaerobes**.
- Nutritionally they are "**autotrophs**" which obtain both energy and carbon from decomposition products.
- They occur in marshy areas where they convert formic acid and carbon dioxide into methane.
- This capability is commercially exploited in the production of methane and fuel gas inside gobar gas plants. E.g., *Methanobacterium, Methanococcus*.

- Some of the methanogen archaebacteria live as symbionts (e.g., *Methanobacterium*) inside rumen cow, buffalo and helpful to the ruminants in fermentation of cellulose.

Halophiles

- Halophiles are named so because they usually occur in salt rich substrata (2.5 - 5.0 M) like salt pans, salt beds, and salt marshes, e.g., *Halobacterium*, *Halococcus*.
- They are **aerobic chemoheterotrophs**.
- Their cell membranes have **red carotenoid pigment** for **protection against harmful solar radiations**.
- Under anaerobic conditions, halophiles cannot use external materials.
- At this time they subsist on ATP, synthesized by membrane pigmented system from solar radiations.
- Halophiles growing in salt pans and salts beds gives offensive smell and undesirable pigmentation to the salt.
- Halophiles are **able to live under high salt conditions due to the following reasons** –
  - **Presence of special lipids** in the cell membranes.
  - **Occurrence of mucilage covering**.
  - **Absence of sap vacuoles** and hence plasmolysis.
  - High internal salt content.

Thermoacidophiles

- These archaebacteria **have dual ability to tolerate high temperature as well as high acidity** due to two reasons - branched chain lipids in the cell membranes and presence of special resistant enzymes capable of operating under acidic conditions.
- They often live in hot sulphur springs where the temperature may be as high as 80°C and pH as low as 2, e.g., *Thermoplasma, Thermoproteus*.
- Basically these archaebacteria are **chemosynthetic** *i.e.*, they obtain energy for synthesis of food from oxidising sulphur.
- Under aerobic conditions they usually oxidise sulphur to sulphuric acid.
  $2S + 2H_2O + 3O_2 \rightarrow 2H_2SO_4$.
- If the conditions are anaerobic, the thermoacidophiles may reduce sulphur to H_2S.
- Bicarbonates are also precipitated into the carbonate form by their activity.

MYCOPLASMA (PPLO)

- Mycoplasmas or **mollicutes** are the **simplest and the smallest of the free living prokaryotes**.
- They were **discovered in pleural fluid of cattle**, suffering from pleuropneumonia **by Nocard and Roux**, (**1898**).
- The organisms are **often called MLOs** (*Mycoplasma like Organisms*) **or PPLOs** (*Pleuropneumonia like Organisms*).
- The size ranges from 0.1 - 0.15 mm.
- Plasma membrane forms the outer boundary of the cell. A substantial amount of **polysaccharides** having even **acetyl glucosamine** are associated with cell membrane which is rich in **cholesterol**.
- A cell wall is absent. Due to the absence of cell wall the organisms can change their shape and are pleomorphic – **cocoid**, **cocobacillus**, **helical**, **fine unbranched or branched**.
- Like other prokaryotes, mycoplasmas **possess one envelope system**.
- They **lack organised nucleus, endoplasmic reticulum**, **plastids**, **mitochondria**, **golgi bodies**, **lysosomes**, **centrioles**, **flagella** etc.
- The genetic material is represented by a **single DNA duplex which is naked because of absence of histone association**.
- The **DNA duplex is not compacted as in other prokaryotes but instead lies coiled throughout the cytoplasm**.
- Ribosomes are 70s. Granules of various types occurs here and there in the cytoplasm, mesosomes absent.
- Enzymes lie both freely in the cytoplasm as well as associated with the plasma membrane.
- DNA **possesses a replicating disc at one end to assist in replication** and **separation of the genetic material**.
- Some of them **live as saprophytes** but majority parasites plants and animals.
- The **parasitic habit is due to the inability of most mycoplasmas to synthesize the required growth factors**, e.g., *Mycoplasma gallisepticum*.
- Electron transport system is rudimentary or absent.
- Reproduction occurs by fission or first forming a branching filament with numerous nuclear bodies followed by constriction in between the nuclear bodies and separation of cells as new individuals.

- They mostly produce pleuropneumonia in domestic animals, atypical pneumonia and mycoplasmal urethritis in humans, little leaf disease of brinjal and witches broom in plants.
- Mycoplasmas are not affected by penicillin (inhibitor of wall formation) but are inhibited by tetracyclines.

CYANOBACTERIA (BLUE GREEN ALGAE)

General characters

- Cyanobacteria are **gram –ve prokaryotes** which **perform oxygenic photosynthesis like plants**.
- They were the **first organism to make the atmosphere aerobic**.
- The blue green algae live virtually in all environments that contain water.
- The organisms range from tropics to plains and they occur in soil, fresh water and ocean.
- In lakes and in the ocean they form part of planktons.
- Some cyanobacteria live in the icy water of glaciers others in hot springs where temperatures reach 85°C or more (due to homopolar bonds).
- Some blue-green algae live as symbionts with other organisms, e.g., lichens.
- Cyanobacteria can be **unicellular** (*e.g., Spirulina*), **colonial** (*e.g., Nostoc*) or **filamentous** (*e.g., Oscillatoria*). Filaments **contain one or more trichomes inside a mucilage sheath**.
- Trichomes may be **homocystous** (without heterocysts, *e.g., Oscillatoria* which shows apical oscillations) or **heterocystous** (with heterocysts, *e.g., Nostoc*, *Anabaena*).
- Nitrogen fixing *Nostoc* and *Anabaena* live freely as well as symbionts (in *Azolla*, *Anthoceros*, *Cycas* roots, *Gunnera* stems amd nodules of *Trifolium alexandrintum*).
- The cell wall possesses an **outer sheath** (outside) which is **jelly like**, **slimy and mucilaginous**.
- The cell contents are divided into two regions – **outer chromatoplasm** having photosynthetic pigments in free thylakoids and **inner colourless centroplasm**.
- The **cell wall is two layered** whose **inner wall is made up of peptidoglycan or mucopeptides** built up from amino sugars (eg., glucosamine) and amino acids (eg., muramic, diaminopimelic).
- In the cytoplasm photosynthetic lamellae are present.
- These lamellae or thylakoids contain dominating pigments phycocyanin allophycocyanin and phycoerythrin (phycobilins) in addition to chlorophyll *a*.
- Bacteria and blue green algae lack mitochondria, true vacuoles and endoplasmic reticulum.
- Sterols are absent in bacteria as well as cyanobacteria.
- **True nucleus is absent**. True fibrils of DNA are either distributed throughout the cell or concentrated in the central part. Its chromosome resembles bacterial chromosomes.
- Gas vacuoles are often present to regulate the buoyancy in water.
- The colour ranges from green to deep purple often blue green.
- These colours are produced by different proportions of several pigments like chlorophyll *a*, carotene, xanthophyll, blue phycocyanin and red phycoerythrin.
- Thylakoid membranes contain chlorophyll *a*, carotenes and xanthophylls. Attached to thylakoids are minute structure called **phycobilisomes**. They have three types of water soluble but protein bound accessory pigments – **phycocyanin**, **allophycocyanin** (both blue) and **phycoerythrin** (red).
- Many forms show **Gaidukov phenomenon or chromatic adaptation** where colour changes according to wavelength of light received by the cyanobacteria. *Trichodesmium erythaeum* is reddish coloured cyanobacterium which occurs in such abundance that a sea is named after its colour – red sea.
- Nucleoid is in contact with a group of coiled membranes called **lamellasome**. Lamellasome develops from plasmalemma. Plasmids or additional small DNA rings may occur. 70 S ribosomes are abundant.
- Cell inclusions are α-granules (cyanophycean starch similar to glycogen), β-granules (lipid droplets), volutin granules and polyhedral bodies.
- The **reserve food** is in the form of **cyanophycean** (**myxophycean**) **starch**.
- **Flagella are absent** in vegetative as well as reproductive phase.

- Well marked reproductive organs, sexual reproduction and motile reproductive bodies are absent in cyanobacteria.
- Reproduction is very simple and takes place by vegetative means only.
- No trace of sexuality has ever been recorded but **gene recombination** can occur through **conjugation**, **transformation** and **transduction**.
- The vegetative reproduction occurs by mere cell division.
- They **reproduce asexually** by **binary fission** (in unicellular forms) and **fragmentation** (by breaking up and regrowth of filaments).
- **Heterocysts** formation is characterized by the presence of thick walls and yellowish contents.
- Each heterocyst is made up of two walls - an inner thin layer and outer thick gelatinous layer.
- Heterocyst develops from recently divided cells, it may be single or paired.
- On germination, it gives rise to a new filaments.
- In many filamentous forms asexual reproduction occurs by **hormogonia formation**.
- They are identified by presence of biconcave discs or separation discs between two adjacent cells.
- The filaments gets broken from such places into many hormogonia and each of them forms a new filaments, eg., *Oscillatoria*.
- Spore formation also occurs (exospores, endospores, akinetes etc).

Nitrogen fixation in cyanobacteria

- Like many bacteria, several forms of blue-green algae have the capacity to fix atmospheric nitrogen into nitrogenous compounds.
- This capacity is **restricted to filamentous heterocystous forms** like *Nostoc, Anabaena, Aulosira* etc.
- Under anaerobic conditions, some non-heterocystous forms can also fix atmospheric nitrogen (*Gloeocapsa, Oscillatoria*).
- This additional capacity of N_2 fixation alongwith CO_2 fixation makes them truely autotrophic plants.
- In this sense, they are considered to be largely responsible for the maintenance of soil fertility in tropical and temperate regions.
- **Some species** of blue green algae **have a great contribution to increase the fertility of rice fields in tropical countries like India** (e.g., *Anabaena, Tolypothrix*, *Aulosira*).

Economic importance of cyanobacteria

Useful aspects

- Some fifty species of cyanobacteria are capable of fixing atmospheric nitrogen in soil, e.g., *Anabaena, Nostoc*.
- *Spirulina* is being used as a **source of protein rich supplement to diet of human**.
- Bolls of *Nostoc* are **used as food by Chinese and South Americans**. Food is called **yoyucho**.
- Cyanobacteria like *Nostoc, Scytonema* are used for **reclamation of usar** (sterile, alkaline) soil.
- In Sambhar lake of Rajasthan, *Anabaena* and *Spirulina* is produced in large number. Local people use it as **green manure**.
- Some species of *Anabaena*, *Tolypothrix* help in conservation of soil, thus **checking soil erosion**.
- Few cyanobacteria located inside lichens help in **plant succession** due to their growth on barren land.
- *Oscillatoria* is used as pollution indicator.

Harmful aspects

- Forms like *Anabaena* **not only spoil the taste of drinking water but also produce toxic effect**.
- Some cyanobacteria appear on buildings during rainy season and cause **damage to bricks** etc.
- **Skin infections** may be caused by cyanobacteria *Lyngbya*.
- **Toxin secreting cyanobacteria** are mainly **responsible for water blooms**. These on death emit foul smell, water gets contaminated with chemoheterotrophic bacteria and unfit for normal use.
- Some cyanobacteria like *Rivularia* **release toxins which is harmful for aquatic fauna**.