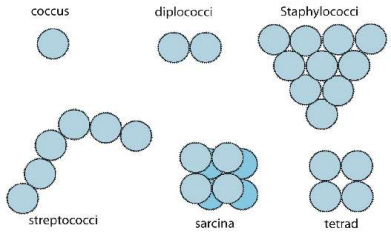
SIZE

1. Smallest eubacteria = **Haemophilus influenzae**
   0.2 – 0.3 × 0.5 – 2.0 micrometer
2. Longest/largest eubacteria = **Epulopiscium fishelsoni**
   600 micrometer
3. Largest/longest Filamentous bacterium = **Beggiatoa mirabilis**
   few mm.

SHAPE

Bacteria have variation in their shape. On the basis of their shape bacteria are of different types.

1. Coccus (Pl. Cocci → Sing. Coccus) –



- These bacteria are spherical
- These are smallest bacteria
- These are highly (Maximum) resistant.

These are following types

A. Monococcus – These spherical bacteria live alone (single sphere)
e.g. Micrococcus, Dialister pneumosintes

B. Diplococcus – These are found in pair.
e.g. Diplococcus pneumoniae, Neisseria

C. Tetracoccus – These are found in group of four cocci.
e.g. Micrococcus luteus

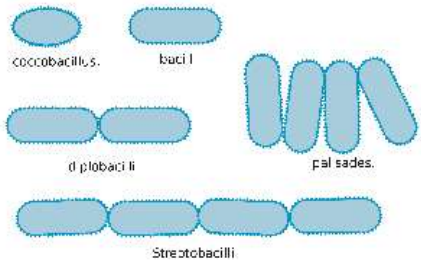
D. Streptococcus – These are found in form of chain
e.g. Streptococcus lactis

E. Sarcinae – 8 to 64 or more bacteria are found in cubical mass form
e.g. Sarcina

F. Staphylococcus – These bacteria are found in a irregular bunch
e.g. Staphylococcus alvus

2. Bacillus (Pl. Bacilli – Sing. Bacillus) –

- This group includes most of the bacteria.
- These are rod shaped



They are of following types

A. Single Bacillus – Only one rod-like structure or bacterium.
e.g. E. coli, Lactobacillus

B. Diplobacillus – They are found in pairs
e.g. Diplobacillus

C. Streptobacillus – They are found in a chain
e.g. Bacillus anthracis
Bacillus subtilis – It is surrounded by mucilagenous sheath that is known as zooglea. It is also known as hay bacteria.

D. Palisade bacillus – These rod shaped bacteria are found in form of stacks
e.g. Corynebacterium diphtheriae

3. Spirillum (Pl. Spirilli – Sing. Spirillum)

- These are spiral shaped bacteria
  e.g. Spirillum volutans, Spirochete, Helicobacter, Treponema


Spirilli

4. Comma (Vibrio) –

- These are comma shaped bacteria
  e.g. Vibrio cholerae, Vibrio comma

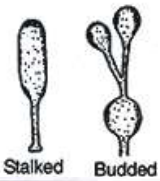

Vibrio

5. Stalked bacteria –

- These are single celled bacteria with narrow stalked
  e.g. Caulobacter

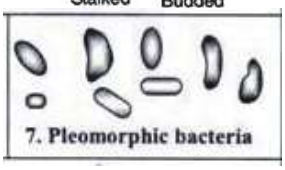
6. Budding bacteria –

- They appear like a beaded cell
  e.g. Rhodomicrobium



7. Pleomorphic bacteria –

- These bacteria change their shape according to the medium.
  e.g. Rhizobium
  Rhizobium bacterium is found in three forms X, Y and Z.


7. Pleomorphic bacteria

MOTILITY IN BACTERIA

Bacteria are motile as well as non motile. Movement in bacteria takes place by means of flagella.

On the basis of flagella bacteria are of following types

1. **Atrichous** – When flagella are absent, it is called atrichous form
   e.g. Micrococcus, Pasteurella
2. **Monotrichous** – When only one flagellum on one end of the bacterium
   e.g. Vibrio, Pseudomonas
3. **Lophotrichous** – When a bunch of flagellum is present on one end of bacterium.
   e.g. Salmonella
4. **Amphitrichous** – When bunch of flagellum or single flagellum are present on both the ends of bacterium.
   e.g. Spirillum, Nitrosomonas
5. **Peritrichous** – When flagella are found on the whole body of bacterium
   e.g. E.coli., Salmonella typhi

A flagellum of bacteria is made up of three parts

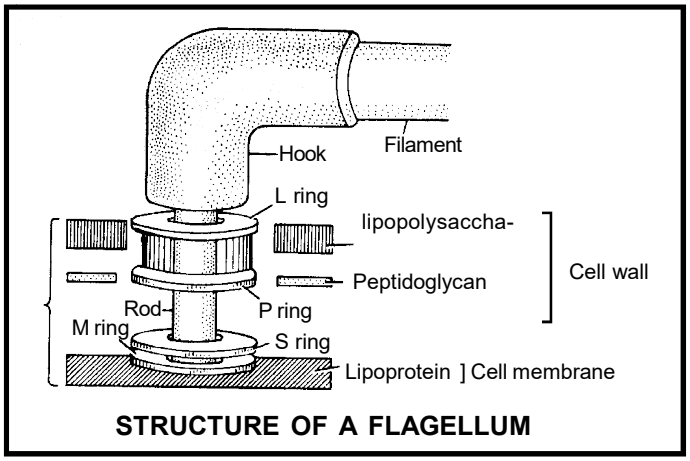
(1) Basal body (2) Hook (3) Filament

1. Basal body –

A. It is the basal part of flagellum and rod shaped in structure.
B. It lies with in the cell wall and cell membrane
C. This proteinaceous rod shaped structure is surrounded by two pairs of rings
(i) Outer pair
(ii) Inner pair
D. Outer pair of ring lies with in the cell wall. One ring of this pair is called **L** and the another called **P**.
E. Inner pair of ring lies with in the cell membrane. One ring of this pair is called **S** and the another is **M**.
F. In Gram (+) bacteria only one pair of rings (inner pair) is found.

2. Hook –

A. It connects the basal body to filament
B. It is the middle part of flagellum
C. It's some part lies with in the cell wall.



STRUCTURE OF A FLAGELLUM

3. Filament –

A. It is cylindrical hollow structure made up of protein monomers.

B. Each monomers is made up of **flagellin** protein. Flagellin is a contractile protein like the tubulin of eukaryotes.

C. These monomers are arranged in 4 + 4 manner.

D. All monomers are joined with each other and so that in bacteria flagella is monofibrillar.

Pili

1. Bacterial cell wall is covered by numerous hair like structures called pili. Pili are smaller than the flagella. (Pl. - Pili → Sing. – Pilus)

2. They are of two types – (A) Longer pili, (B) Shorter pili

3. Longer pili is also known as **'F' pili** or **'sex' pili.** Longer pili occurs in only donar (F^+ or male) bacteria and help in conjugation. These are absent in recipient bacteria or female.

4. The shorter pili take part in attachment. These are also known as **'infective' pili or fimbrae.** These are found only in pathogenic bacteria.

Structure

1. Every pilus is cylindrical hollow structure and composed of protein monomers.

2. Each monomer is made up of '**pilin**' protein. Pilin is non-contractile protein.

Note : Pili have been reported only in Gram negative bacteria.

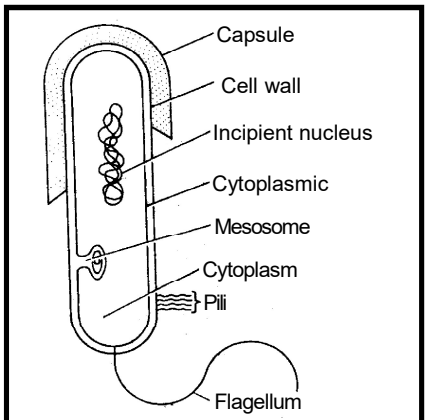
STRUCTURE OF BACTERIAL CELL

1. Capsule or Glycocalyx or Slime layer –

A. When bacteria are surrounded by capsule, called as capsulated bacteria. Formation of capsule is done by cell membrane. Capsulated bacteria are mostly pathogenic.

B. Capsule is made up of unknown **polysaccharides** and **polypeptides**.

C. Capsule protects the bacteria from W.B.C. and also helps in colony formation.



STRUCTURE OF A BACTERIAL

2. Cell membrane

It is also called as plasma membrane. It is situated near to cell wall. It is thin, elastic and permeable membrane. Bacterial cell membrane is made up of lipoprotein (unit membrane) like the eukaryotic membrane.

3. Cell Wall –

All bacterial cells are protected and covered by rigid, strong cell wall.

Bacterial cell wall is made up of mainly **peptidoglycan** or **murein** which is a type of muco-peptide.

They are of two types:

Gram(+) and Gram(-) bacteria :

In Gram(+) bacteria cell wall is single layered and thick. It is made up of peptidoglycan. Lipids are also present but in less quantity.

While **in Gram(-)** bacteria cell wall is double layered. Inner layer is thin and composed of **peptidoglycan** while outer layer is thick and made up of lipopolysaccharide. Some quantity of lipoproteins and phospholipids are also present in outer layer. Proteins (lipoprotein) present in Gram negative bacteria are called **porins** and these proteins function as channels for the entry and exit of hydrophilic low molecular weight substances.

Differences between Gram positive and Gram negative Bacteria

Gram positive	Gram negative
(1) The bacteria remain coloured purple with Gram staining even after washing with alcohol.	The bacteria do not retain the stain when washed with alcohol.
(2) Cell wall is single layered.	Cell wall is bilayered.
(3) Cell wall of peptidoglycan is 20–80 nm. thick.	Cell wall of peptidoglycanis 8–12 nm.thick.
(4) The wall is smooth.	Wall is wavy and comes in contact with plasmalemma only at a few loci.
(5) Murein (Peptidoglycan) content is 70–80%.	Murein (Peptidoglycan) content is 10–20%.
(6) Basal body of the flagellum contains 2 rings (S & M).	Basal body of the flagellum has 4 rings (L, P, S & M).
(7) Mesosomes are quite prominent.	Mesosomes are less prominent.
(8) A few pathogenic bacteria belong to Gram–positive group.	Most of the pathogenic bacteria belong to Gram–negative group.

L – form – Bacterial cell wall can be dissolved by **lysozyme** enzyme. When bacterial cell wall is removed artificially then bacteria are surrounded by only cell membrane. These bacteria are called L - form (Lister form).

Lister form – It is first developed by **Klieneberger** in lister laboratory London.

- **Spheroplast** – When L-form bacteria are Gram(–) called as spheroplast.
- **Protoplast** – When L-form bacteria are Gram(+) called as protoplast

4. Cytoplasm

It is a complex aqueous fluid which consists of carbohydrates, lipids, soluble proteins, enzymes, co-enzymes, vitamins, mineral salts and nucleic acids.

A. In bacterial cytoplasm membrane bound cell organelles viz. Mitochondria, Chloroplast E.R. Lysosome, Golgibody, Microbodies etc. are absent.

B. Bacterial cytoplasm shows no streaming or cyclosis.

CYTOPLASMIC ORGANELLES

1. Mesosomes

A. Mesosome was discovered by F. James. The cell membrane of bacteria invaginates in cytoplasm at different places and form mesosomes or chondrioid.

B. These are **functionally mitochondria** like structures. Oxidative enzymes are found in mesosome. On the basis of position and function mesosomes are of two types

(a) **Peripheral mesosome –** They are situated near the cell membrane in peripheral part and their main function is cell respiration and cell wall secretion.

(b) **Central mesosome –** They are situated deep in cytoplasm and their main function is providing help in DNA replication and cell division. These are connected with nucleoid.

2. Photosynthetic structure –

Some eubacteria (purple bacteria and green bacteria) have capacity of photosynthesis.

In photosynthetic eubacteria no special type of structure is found for photosynthesis. In bacterial cytoplasm many photosynthetic pigments are scattered. The group of pigments are called **chromatophores**.

Pigments –

(a) In purple bacteria (sulphur and non sulphur) – bacteriochlorophyll-a and bacteriochlorophyll-b

(b) In green sulphur bacteria – Bacteriochlorophyll-a and chlorobiumchlorophyll or bacterioviridin

3. Storage granules –

A. Glycogen granules – They store carbohydrate

B. Volutin granules – These are also known as metachromatic granules. They are made up of RNA. They store RNA as a source of nitrogen and phosphorus.

4. Chromatin material (Nucleoid) –

A. Nucleus of bacterial cell is called **nucleoid** or genophore or incipient nucleus or fibrillar nucleus. Nuclear membrane and nucleolus are absent.

B. True chromosomes are also absent in bacterial cells. Instead they contain a single chromosome. It consists of a ds circular naked DNA (without histone),and non histone proteins. Non histone proteins are polyamines. Nucleoid is connected to mesosome.

C. Beside this DNA another small and circular DNA is also present in bacterial cell, which is called **Plasmid**. It is also known as extra chromosomal or extranuclear genetic material. (The term 'plasmid' was given by **Lederberg**).

D. Plasmids have the ability to replicate independently.

On the basis of functions plasmids are of following types

1. F or fertility factor (F-plasmid) On the basis of presence or absence of 'F' factor, there are two mating types of bacteria.

(a) F^+ – Cells, carrying 'F' factor acts as donor and are called F^+ or male.

(b) F^- – Cells, lacking 'F' factor acts as recipient and are called F^- or female.

When 'F" plasmid is attached with main DNA, it is designated as episome and this type of cell is known as Hfr cell. (The word episome was given by Jacob & Wollman)

2. R or Resistance factor (R- plasmid) – Cells, carrying this 'R' factor become resistant to certain drug.

3. Col. or colicinogenic factor – Cells, carrying 'col' factor secrete the colicin, which have an antibiotic effect on other microbes.

Nutrition in Bacteria

Most of the bacteria are heterotrophic but some are autotrophic. On the basis of nutrition bacteria are classified into following three categories.

Autotrophs

These bacteria use light or chemical energy for their own food synthesis.On the basis of **source of energy** autotrophs are of following two types

(i) Photosynthetic autotrophs –

- These bacteria use light energy for food synthesis.
- In these bacteria photosynthesis is non oxygenic.
- Photolysis of water does not take place here, so hydrogen is received from other sources like inorganic sulphur compound (H_2S, Thiosulphate) or organic compound (Amino acids, Isopropyl alcohol Fatty acid). On the basis of **hydrogen donor** , photoautotrophs are further classified into following two categories.

(a) Photo-lithotrophs – Hydrogen donor is inorganic sulphur containing compounds viz. H_2S, Thiosulphate. This category includes only two types of bacteria

- Purple sulphur bacteria – e.g. *Chromatium*
- Green sulphur bacteria – e.g. *Chlorobium, Thiothrix*

(b) Photo-organotrophs – Hydrogen donor is organic compounds viz. Isopropyl alcohol, amino acids, fatty acids.This category involves only one type of bacteria.

- Purple non sulphur bacteria – e.g. *Rhodospirillum, Rhodopseudomonas*

(ii) Chemosynthetic autotrophs –

- These are nonphotosynthetic autotrophs i.e., photosynthetic pigments are absent.
- They use chemical energy instead of light energy for food synthesis.
- Chemical energy is obtained from oxidation of inorganic or organic compounds.

On the basis of **oxidised compound** chemoautotrophs are further classified into following two catagories

(a) Chemo-lithotrophs – These bacteria oxidise the inorganic compounds and release energy which is used for food synthesis.

This category includes following types of bacteria.

- Iron bacteria – These bacteria convert Ferrous compounds into Ferric compounds
  $Fe^{+2} \longrightarrow Fe^{+3}$ + energy
  e.g. Ferrobacillus, Leptothrix
- Sulphur bacteria – Convert Sulphure into H_2SO_4
  $S + H_2O \longrightarrow H_2SO_4$ + Energy
  e.g., Thiobacillus
- Carbon bacteria – Convert CO into CO_2
  $2CO + O_2 \longrightarrow 2CO_2$ + energy
  e.g. Bacillus oligocarbophyllus
- Nitrifying bacteria – They oxidise nitrogenous compounds and obtain energy.
  • Nitrite bacteria – Converts ammonia into Nitrite
  e.g., Nitrosomonas or Nitrococcus
  • Nitrate bacteria – Convert nitrite into nitrates.
  e.g. Nitrobacter

(b) Chemo-organotrophs – These bacteria oxidise the organic compounds and released energy is used for food synthesis. This group includes only one type of bacteria

- Methano bacteria – These are found in the marshy places. They convert CH_4 into CO_2.
  e.g. Methanomonas

Heterotrophs

- Most of the bacteria are heterotrophic i.e., they can not manufacture their own food.
- They receive their own food from **dead organic matter** or **living organism**.

These are of following types

(i) Saprotrophic bacteria – These bacteria obtain food from dead and decaying organic matter.

These are of two types

(a) Obligate saprotrophic – These bacteria obtain food only from dead organic matter. These are completely saprotrophs
e.g. Bacillus vulgaris, Clostridium botulinum

(b) Facultative parasite – These are normally saprophytic in nature, but in the absence of dead organic matter they can become parasitic.
e.g. Pseudomonas, Staphylococcus

(ii) Parasitic bacteria – They obtain their food from living organism

These are of two types

(a) Obligate parasite – They always remain parasitic.
e.g. Mycobacterium leprae

(b) Facultative Saprotrophic – They are normally parasitic in nature but in the absence of living host, they

may become saprotrophs

e.g. Mycobacterium tuberculosis

Symbiotic bacteria

It is a phenomenon in which to organism live in close association in such a manner that both the partners get mutual benefit from association.

These bacteria convert atmospheric nitrogen into nitrogenous compounds like Amino acid, NO_3 or Salts of ammonia.

e.g. Rhizobium

STAINING OF BACTERIA

Simple Staning : It is a procedure of staining or colouration of bacteria by applying a single solution of stain to a fix smear is known as simple staining. These stain can be like methylene blue, gram safranine and gram crystal violet.

Gram Staining technique :

1. First of all **H.C. Gram** differentiated bacteria on the basis of staining.
2. In the first step of this method bacteria are stained with **Crystal violet** and then **KI solution**.
3. After staining, bacteria are washed with Acetone or Ethyl alcohol. After washing some bacteria retain the stain and some bacteria are decolourised.
4. Bacteria which retain stain (violet or purple) are called Gram(+) and bacteria which decolourise are known as Gram (–). Gram(-) bacteria are counter stained by **saffranine**.

RESPIRATION

On the basis of respiration bacteria are of two types

AEROBIC BACTERIA

These are of two types

(A) Obligate aerobic - These are completely aerobic and die in the absence of O_2

eg. *Azotobacter, Arthrobacter, Bacillus subtilis.*

(B) Facultative anaerobic - These are normally aerobic bacteria but can survive in the absence of O_2

eg. *Acetobacter aceti*

Clostridium tetani

ANAEROBIC BACTERIA

These are of two types.

(A) Obligate anaerobic - These are completely anaerobic bacteria and do not have capacity of aerobic respiration.

eg. *Clostridium botulinum*

(B) Facultative aerobic - These are normally anaerobic but also have capacity of aerobic respiration.

eg. Fermentation bacteria except *Acetobacter aceti, Chlorobium limicola.*

REPRODUCTION

Bacteria reproduce by three methods

(1) Vegetative reproduction

(2) Asexual reproduction

(3) Genetic recombination

VEGETATIVE REPRODUCTION

This type of reproduction takes place by two methods.

(i) By budding

(a) This type of vegetative reproduction was discovered by **Bisset** and **Hale** in **Bifidi** bacterium.

(b) Bacterial cell produce a bud like out growth. Genophore of bacterium replicates and one copy is transferred to the bud. Now due to the constriction at the place of bud formation, it separates from the bacterial cell and acts as a new bacterial cell.

(ii) Binary fission –

(a) This is the most common method of bacterial reproduction. Binary fission takes place by amitosis. (Amitosis is characteristic of prokaryotes. Mitosis and Meiosis never occur in prokaryotes.)

(b) First of all DNA replication takes place in bacterial cell. Under favourable conditions bacterial cell divided into two cells due to formation of transverse septum in the centre of the cell. Each daughter cell grows into a new bacterium.

(c) Under favourable conditions, the cells of bacteria divides after every 20 minutes.

ASEXUAL REPRODUCTION

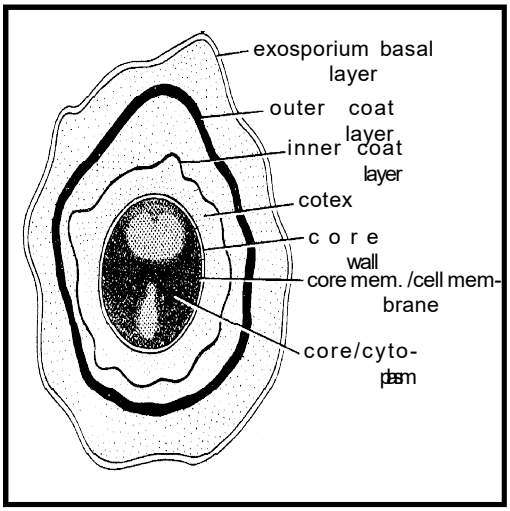
(i) By Endospore – Endospore formation occurs under unfavourable conditions.

(a) It is a highly resistant structure. It is resistant to high temperature, radiations, antibiotics and chemicals.

(b) It is also known as "reproduction with out multiplication".

Note : (1) Endospore is highly resistant structure due to presence of **Ca-dipicolinate** in its wall.

(2) Endospore is stained by **Nigrosin reagent**



Structure of endospore –

1. **Exosporium** → Lipid + Protein
2. **Spore coat** { Outer spore coat → Lipid + protein ; Inner spore coat → Lipid + Protein + Sulphur }
3. **Cortex** → Ca-dipicolinate (Dipicolinic acid) + Peptidoglycan
4. **Core wall** → Lipid + protein
5. **Core membrane/Cell membrane / Inner mem** → Lipid + protein
6. **Core/Cytoplasm** → DNA & other material

Under the favourable conditions protective layers rupture and the cytoplasm with cell membrane comes out side in the form of young bacterium.

e.g. Endospore formation is seen in mostly Bacillus type of bacteria.

(ii) By Cyst –

Under unfavourable conditions some bacteria reproduce by cyst formation. Bacterial cell secretes a thick wall arround it self. Under favourable conditions protective layer breaks and bacterium becomes free.

GENETIC RECOMBINATION

According to Lederberg and tatum (1946), sexual reproduction take place in bacteria. They proved it and got nobel prize for it.

True sexual reproduction is absent in bacteria because it does not involve fusion of male and female gametes to produce a diploid zygote. Genetic recombination involves transfer of some genes from a bacterium to another bacterium. There are two methods of genetic recombination.

(1) Transformation –

(a) In this process one kind of bacterium is transformed into another kind.

(b) Transformation was first of all discovered by **Griffith**(1928) in **Diplococcus pneumoniae** (New name – **Pneumococcus pneumoniae**).

(c) Detailed study was carried out by **Avery, Macleod** and **Mc Carty**

Griffith's experiment :

Griffith selected two strains of *Diplococcus pneumoniae* for his experiment.

S - III strain – This strain was virulent/pathogenic, capsulated, smooth

R - II strain – This strain was non virulent/non pathogenic, non capsulated, rough.

(a) First of all R-II was injected to a Mice → Mice survived and did not show symptoms of pneumonia.
(b) S-III injected to a mice → Mice developed symptoms of pneumonia and died.
(c) S-III Strain heat killed and then injected in mice → Mice did not develop the pneumonia.
(d) Heat killed S-III were incubated with the living R-II for some time. This mixture was then injected in to mice → Mice developed pneumonia and died.

Conclusion –

On the basis of this experiment Griffith concluded that some material of S-III strain transformed the R-II into S-III. But Griffith could not identify the material responsible for transformation. It was later indentified by **Avery, Macleod** and **Mc Carty** as **DNA**.

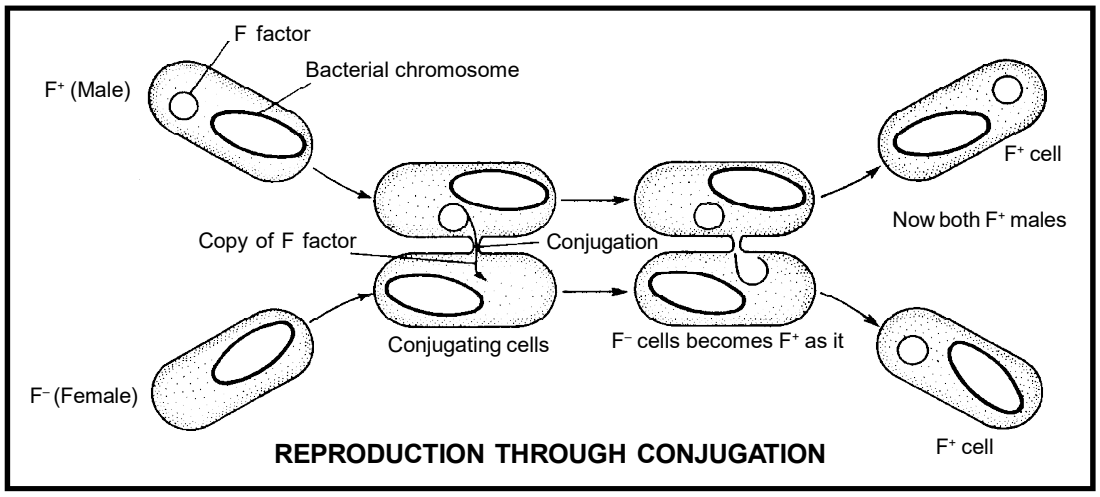
(2) Conjugation –

Conjugation was first discovered in 1946 by **Lederberg** and **Tatum** in **E.coli.**, They were awarded Nobel prize for their work.

Detail study was carried out by Wollman and Jacob in *E.coli*.

(i) Conjugation between F^+ and F^-

(a) First of all donor cell (F^+) is attached to recipient cell (F^-) with the help of sex pili. Sex pili functions as conjugation tube.
(b) The 'F' factor (F plasmid) now replicates and the replica moves to F^- through conjugation tube.
(c) Both the cells are then separated. Due to transfer of 'F' factor F^- bacteria now becomes F^+ bacteria.



(ii) Conjugation between Hfr (male) and F– (female) :-

(Hfr – High frequency or super male)

(Name **Hfr** was given by **Cavalli**)

(a) Some times the 'F' factor (F plasmid) incorporates in genophore then this cell is called Hfr male or high fertility male.
(b) First of all Hfr attached to the F^- cell.
(c) The genophore now replicates and 'F' factor also replicates along with the genophore.
(d) Now the replica of the genophore and 'F' factor moves in to the F^- cell in the linear form. The 'F' factor lies at the last end.

Only a part of genophore can be transfered to F^- because even a slightest distrubance in nature leads to the separation of conjugating bacteria.

(e) DNA segment of Hfr cell now attaches with the homologous segment of F^- genophore.
(f) Transferred DNA of Hfr cell is called exogenote and homologous part (Endogenote) of F^- genophore is called endogenote.
(g) F^- cell is now called **merozygote** (partial diploid) or **partial zygote** (False zyote). F^- cell now develops some characters of F^+ cell.

Economic Importance of Bacteria

HARMFUL ACTIVITIES

1. Disease in Human beings :

Disease		Bacterium
Tuberculosis (T.B.)	–	**Mycobacterium tuberculosis**
Leprosy	–	**Mycobacterium leprae**
Diphtheria	–	**Corynebacterium diphtheriae**
Tetanus	–	**Clostridium tetani**
Typhoid	–	**Salmonella typhi**
Plague	–	**Pasteurella pestis or Yersinia pestis**
Pneumonia	–	**Diplococcus pneumoniae or Pneumococcus pneumoniae**
Jaundice	–	**Leptospira ictero**
Pertussis	–	**Bordetella pertussis**
Meningitis	–	**Neisseria meningitidis**
Gonorrhoea	–	**Neisseria gonorrhoeae**
Cholera	–	**Vibrio cholerae**
Dysentery	–	**Shigella dysenteriae**
Syphilis	–	**Treponema pallidum**

2. Disease in Animals –

Anthrax	–	**Bacillus anthracis**
Black leg	–	**Clostridium chanvei**

3. Disease in plants –

Fire blight of stone fruit (apple and peas)	–	**Erwinia amylovora**
Citrus canker	–	**Xanthomonas citri**
Leaf streak of rice	–	**Xanthomonas oryzicola**
Brown rot or wilt of potatoes	–	**Pseudomonas solanacearum**
Angular leaf spot of cotton	–	**Xanthomonas malvacearum**
Crown gall in many plants	–	**Agrobacterium tumefaciens**
Black leg and soft rot of potato	–	**Erwinia caratovora atroseptica**
Bacterial leaf blight of rice	–	**Xanthomonas oryzae**

4. Denitrification – Denitrifying bacteria

Some bacteria convert soil nitrates into nitrites and then nitrogen. These bacteria reduce the fertility of soil.
e.g. Thiobacillus denitrificans, Pseudomonas denitrificans

5. Food poisoning

Some bacteria are responsible for food poisoning. These are of three types –

A. Salmonella enteridis – These bacteria survive on milk products and also in intestine of man. They secrete toxins. symptoms – Vomiting, Dysentery

B. Staphylococcus aureus – These bacteria survive on milk and egg products. They secrete toxins which damage the central nervous system. These toxins are heat resistant.

C. Botulism – Clostridium botulinum – It is most lethal type of food poisoing. These bacteria survive in absence of O_2.These bacteria grow in canned food.Their toxins damage the parasympathetic nervous system. It leads to paralysis of both smooth and striped muscles, resulting in immediate death.

6. Water pollution

Several bacterial forms cause water pollution. These bacteria spoil the water.
e.g. Vibrio cholerae, Salmonella typhi, Shigella dysenteriae

7. Biological Weapons – Some bacteria are used as bio weapons such as **Anthrax causing, Botulism , Cholera causing bacteria.**

USEFUL ACTIVITIES

1. Ammonification - Ammonifying bacteria –

Some bacteria convert Protein (present in decaying plants & animals) into Ammonia.

e.g., Bacillus vulgaris, Bacillus mycoides, Bacillus ramosus

2. Nitrification - Nitrifying bacteria –

These bacteria convert Ammonia in to Nitrite and later into Nitrate.

$$NH_3 \xrightarrow{Nitrosomonas} NO_2 \text{ (Nitrite)} \xrightarrow{Nitrobacter} NO_3 \text{ (Nitrate)}$$

3. Nitrogen fixation - Nitrogen fixing bacteria –

These bacteria convert the atmospheric nitrogen into nitrogenous compounds like amino acids, nitrate or ammonium salts.

Nitrogen fixation is done by two methods –

(A) Symbiotically – Some bacteria live symbiotically and do nitrogen fixation.

e.g. *Rhizobium* – In the root nodules of legumes such as alfalfa, sweet clover, sweet pea, lentils, garden pea, broad bean, clover beans.

Aerorhizobium – In the stem nodules of Sesbania

Azospirillum – Found on root surface of cereals i.e., superficial symbiosis (eg. Wheat, Rice, Maize).

Frankia - In root nodules of non leguminous plant *Casurina* and *Alnus* plants.

(B) Asymbiotically – Some bacteria occur free in soil and do nitrogen fixation.

e.g. *Clostridium, Chromatium, Azotobacter, Azospirillum, Beijernickia*
Rhodomicrobium, Rhodospirillum, Rhodopseudomonas

Note : *Azotobacter* and *Beijernickia* are aerobic *Rhodospirillum* is anaerobic bacteria. Both *Rhizobium* and *Frankia* are free living in soil, but as symbionts, can fix atmospheric nitrogen.

4. Antibiotics –

- Term antibiotic was given by *S.A. Waksman*
- First discovered antibiotic was Penicillin it was obtained from fungi *Penicillium.*
- First discovered antibiotic from bacteria was *streptomycin.*
- Many antibiotic medicines are obtained from the bacteria.
- Some substances produced by microorganism which inhibit the growth of other micro-organism are called antibiotic substances.
- These antibiotic medicine cure the disease through the **competitive inhibition**.

	Bacteria		Antibiotics
1.	Streptomyces fradiae	-	Neomycin
2.	Streptomyces venezuelae	-	Chloromycetin (chloramphenicol)
3.	Streptomyces aureofaciens	-	Aureomycin (Chlorotetracycline) & Tetracycline
4.	Bacillus subtilis	-	Subtilin & Bacitracin
5.	Streptomyces rimosus	-	Terramycin (oxytetracycline)
6.	Bacillus brevis	-	Gramicidin
7.	Bacillus licheniformis	-	Bacitracin
8.	Bacillus polymyxa	-	Polymyxin
9.	Streptomyces griseus	-	Streptomycin

5. Dairy products

Dairy products are formed with the help of bacterial fermentation.

Curd – It is made by milk.

$$\text{Milk} \xrightarrow[Lactobacillus\ lactis]{Streptococcus\ lactis \text{ or}} \text{Curd}$$

Note : Lactobacillus lactis (LAB/Lactic acid bacteria) increas vitamin B_{12} in curd LAB also help in checking the disease causing microbes in stomach.

6. Industries –

Many bacteria are used in industries

(A) Alcohol formation :-

Ethanol is formed with the help of yeast (fungi) or bacteria (**Sarcina veutriculi**) by the process of fermentation.

$$C_6H_{12}O_6 \xrightarrow{\textit{Sarcina veutriculi}} \text{Alcohol (Ethanol)}$$

(B) Vinegar formation (Acetic acid) –

$$\text{Ethanol} \xrightarrow{\textit{Acetobacter aceti}} \text{Acetic acid}$$

(C) Production of Vitamins –

- *Clostridium butylicum produces* ⟶ Riboflavin (Vit. B_2)
- *Propionibacterium and Bacillus megatherium produce* – Vit. B_{12}
- *E.coli produces* → Vit. E., Vit. K. (**E. coli** bacteria found in alimentary canal of human beings)

(D) Flavouring of tea and tobacco leaves –

e.g. Bacillus megatherium, Micrococcus condiscence

(E) Butyric acid formation -

$$C_6H_{12}O_6 \xrightarrow[\text{Fermentation}]{\textit{Clostridium acetobutylicum}} \text{Butyric acid}$$

(F) Retting of fibres –

e.g. Clostridium, Butyric acid bacteria

(G) Cleaning of hides –

e.g. Any saprotrophic

7. Decomposing bacteria – Some bacteria decompose the harmful chemicals.

- *Flavobacterium* – 2, 4 – D ⟶ Partical decomposition in long term duration
- *Acetobacter* ⟶ DDT

8. Bacteria for specific pests – Bacteria are use to kill specific pests

e.g. *Bacillus popillinae – Japaneese Beetle*

Bacillus sphaericus – Anopheles

9. Purity of Ganga water – In Gangatic water a bacteria **Bdellovibrio bacterovorus** is found, they kill the other water polluting bacteria.

10. Pollution indicating bacteria :-

Water in which *E. coli* bacteria are present known as polluted water. Quality of water depends on number of *E. coli*. If *E. coli* are very much in no. the water will be highly polluted. So the *E. coli* is known as pollution indicating bacteria.

11. Oil Clearing bacteria :-

e.g. *Pseudomonas putida*

12. Bacteria for genetic engineering –

e.g. *E. coli* and *Agrobacterium*

Some Important points

(1) Mycolic acid - *Present in all filamentous bacteria*

(2) Bacteroids - *Symbiotic bacteria which are present in root nodules of plants are known as bacteroids*

(3) Pus bacteria

- *Staphylococcus (produces yellow pus)*

- *Pseudomonas (Produces blue pus)*

(4) nif gene - "Nitrogenase Inducing factor"

- *nif gene is present in all nitrogen fixing bacteia*

(5) Bacillus thuringiensis - This bacterium is related with "Bt" toxin.

ACTINOMYCETES - FILAMENTOUS BACTERIA

(A) They were previously included in Fungi and were known as Ray fungi, because structurally they are similar to fungi.

(B) The body of fungi is known as mycelium and the structure of actinomycetes is also similar to mycelium. Therefore they were included in fungi. But fungi are eukaryotic while actinomycetes are prokaryotic. So these are now placed in kingdom Monera.

(C) Now their new name is Mycobacteria, Mycelial bacteria or Filamentous bacteria.

(D) Filamentous bacteria are found more in soil.

(E) These bacteria have economic importance because they are used to prepare many antibiotics.

Conidia

(a) Filamentous bacteria reproduce by means of conidia.

(b) Conidia are spore like structures and are formed in basipetal manner in chains at the apex of conidiophores.

(c) Each condium gives rise to a new bacterium.

(d) These conidia are called as **arthrospores** due to their prokaryotic nature.
eg. Streptomyces, Mycobacterium, Beggiatoa, Frankia

BLUE GREEN ALGAE (B.G.A)

(A) According to **Two kingdom** system B.G.A. were included in class **Cyanophyceae** or **Myxophyceae** of Algae. But now they are included in Kingdom Monera, because of their prokaryotic nature.

(B) B.G.A. is now known as **cyanobacteria**. The name cyanobacteria was suggested by **ICNB [International Code of Nomenclature for Bacteria]** in 1978.

(C) Cyanobacteria are photosynthetic prokaryotes. Some eubacteria also have photosynthesis process but there is some differences in the photosynthesis of cyanobacteria and eubacteria.

(D) Cyanobacteria were the first organisms that produced O_2 on our earth.

Cyanobacteria	Eubacteria
(1) They have membrane bound structure thylakoids for photosynthesis. Photosynthetic pigments are present on the surface of these thylakoids.	(1) Photosynthetic pigments are scattered in groups in the cytoplasm, these groups are known as chromatophore.
(2) In them, photosynthesis is oxygenic i.e. O_2 is evolved during photosynthesis.	(2) In them, photosynthesis is non- oxygenic i.e. O_2 is not evolved during photosynthesis.
(3) They have following pigments. ● Chlrophyll 'a' - green ● Carotenoids - yellow ● C - Phycocyanin - blue ● C - Phycoerythrin - red	(3) They have following pigments :- ● Bacteriochlorophyll 'a' and bacteriochlorophyll-b (In purple bacteria) ● Bacteriochlorophyll-a and bacterioviridin -

Note : Cyanobacteria are not always of blue-green colour. eg. Trichodesmium is a red coloured. The red colour of water of red sea is due to this alga.

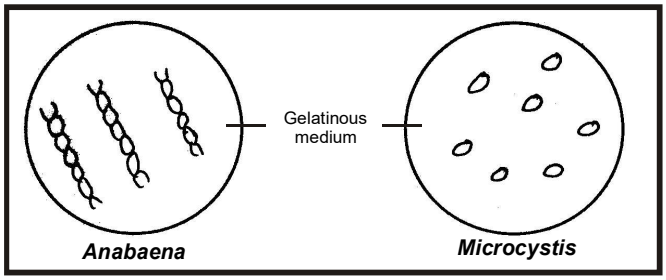
Different forms of BGA or Cyanobacteria :

(A) Unicellular :- Some B.G.A. are unicellular

eg. *Spirulina*

(B) Colonial :- Some B.G.A. are found in colony. i.e. cell colonies.

eg. *Anabaena, Microcystis*



(C) Filamentous :- Some B.G.A. are filamentous. Their are many cells arranged in a row in their body. The filament of B.G.A. is known as **trichome**.

eg. *Oscillatoria*

Note : **Spirulina** is an edible B.G.A. because it has very large amount of proteins. It can be grown artificially in water tanks. It is used as a fodder for cattle

STRUCTURE OF B.G.A. :-

(A) The structure of B.G.A. is **similar to Gram (-ve) eubacteria.**

(B) B.G.A. is surrounded by a mucilagenous sheath. This sheath is made up of mucopolysaccharides [Pecticacid]. The cell wall of B.G.A. is also bilayered. Outer wall is made up of lipopolysaccharides and the inner wall is made up of peptidoglycan.

(C) The cell membrane of B.G.A. is also made up of lipoproteins like that of eubacteria.

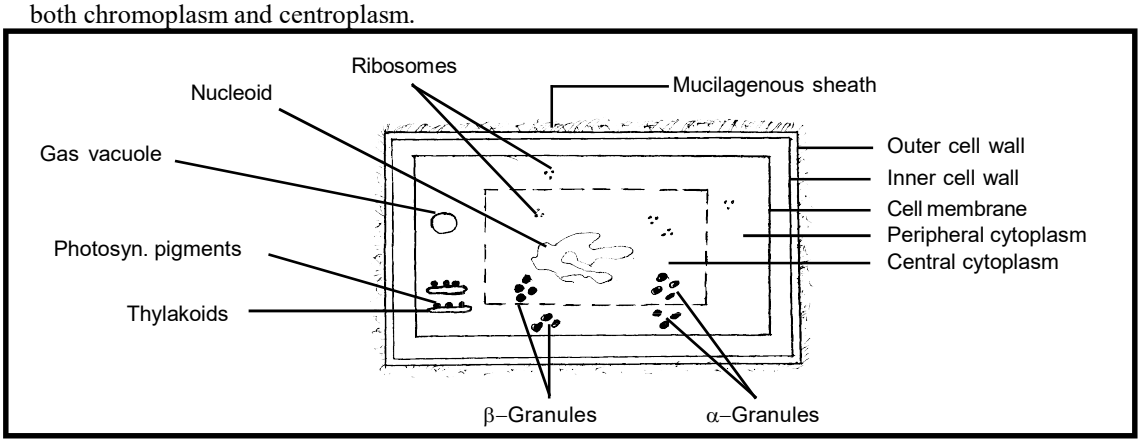
The cytoplasm of B.G.A. is divided into two parts

(a) Peripheral cytoplasm -

It is known as **chromoplasm**. In this part gas vacuoles and photosynthetic thylakoids are found. Photosynthetic pigments are present on the surface of these thylakoids.

(b) Central cytoplasm -

This is known as **centroplasm**. In this region nucleoid is present. Ribosomes are of 70s type, and are scattered in both chromoplasm and centroplasm.



Check Point :

(1) The cytoplasm of prokaryotes lacks membrane bound cell organelles but exceptionally in B.G.A. two membrane bound structure are present.
   (i) Gas vacuole – It provides the buoyancy to the B.G. algae in water.
   (ii) Thylakoids – Photosynthetic pigments are present on its surface.

(2) Exceptionally gas vacuoles are also present in purple and green photosynthetic bacteria.

Stored food

B.G.A. stores its food in the form of α-granules and β-granules.

- **α- granules** - They are made up of cyanophycean starch. It is structurally similar to glycogen.
- **β - granules** - They are made up of fat droplets.

Oscillatoria can survive in hot water springs. The temperature of this water is about 80°C. *Oscillatoria* have capacity to tolerate high temperature because of -

Homopolar bonds in proteins - Proteins are denatured at high temperature and the living beings die. But homopolar bonds are present in the proteins of cytoplasm of *Oscillatoria*, which can not break easily and the bonds are very much in number so they can tolerate high temperature.

Nitrogen fixation :-

(A) Some of the B.G.A., can perform Nitrogen fixation. They converts atmospheric nitrogen into nitrogenous compounds like amino acids, nitrates. These nitrates increases the fertility of soil. Hence B.G.A. improves the fertility of soil by nitrogen fixation.

(B) B.G.A. fix nitrogen in two forms :-

Symbiotic form and Asymbiotic or free living form

Free living form	Symbiotic form
eg. ***Anabaena, Nostoc & Aulosira*** Some B.G.A. are found free living in water and soil and perform nitrogen fixation. ***Aulosira*** $\rightarrow$ This.B.G.A. is found in plenty in paddy fields. It germinates in water. This B.G.A. performs nitrogen fixation due to which the production of rice increases. ***Oscillatoria*** = also fix N_2 in paddy fields. ***Azolla*** $\rightarrow$ If Azolla is grown with rice, than the production increases up to 50% [because ***Anabaena*** are found in the leaves of ***Azolla***]	eg. ***Anabaena*** & ***Nostoc*** These B.G.A. form symbiotic association with many plants and performs nitrogen fixation. **for eg :-** * In thallus of ***Anthoceros***. * In the leaves of ***Azolla*** * In the coralloid roots of ***Cycas*** * In stem of ***Gunnera*** * In root nodules of ***Trifolium***

Important points

1. **Nitrogenase enzyme is** necessory for nitrogen fixation. For the synthesis of this enzyme, their is a special type of gene present in BGA, which is known as nif-gene [nif = nitrogenase inducing factor]. This gene stimulates the production of nitrogenase enzyme.
   - The discovery of nitrogen fixation in BGA was done by an Indian scientist - P.K. De
   - Detailed study of N_2 - fixation - Prof. R.N. Singh (Indian)
2. Heterocysts don't perform the photosynthesis like other vegetative cells.
3. A special type of cell is found for nitrogen fixation in BGA which is known as **heterocyst**. Heterocysts is thick walled, non green cell.

Reproduction :

In BGA reproduction is done by two main processes

(1) Vegetative (2) Asexual

(1) Vegetative Reproduction :-

(i) Binary fission :- This is the most common method of reproduction in prokaryotes. By this process only unicellular prokaryotes can reproduce.

eg. *Spirulina*

(ii) Fragmentation :- Filamentous prokaryotes, reproduce by this process. At the time of reproduction, some cells become thick walled, which are known as harmocyst **(hormogonia)**. Due to the formation of hormogania, the filament gets broken and each part is grown into a new filament.

eg. *Oscillatoria, Nostoc, Anabaena*

(2) Asexual Reproduction :- It is method of protection from unfavourable conditions.

Note : In B.G.A. genetic recombination was first discovered by H.D. kumar

WATER BLOOM :

"Excessive growth of plants in water, that pollute the water"

(A) It mainly develops due to BGA

eg. *Anabaena flos-aquae, Microcystis aeruginosa, Aphanizomenon flos-aquae*

(B) BGA grow rapidly in water and secrete toxic substances. These toxic substances are known as **death factor.** Death factor is the main cause of death in aquatic animals. It also gives toxicity and bad odour to the water.

ECONOMIC IMPORTANCE OF BGA

Useful activities :-

(1) They provide fertility to soil by nitrogen fixation.

eg. *Nostoc, Anabaena*

(2) The most proteinaceous food for animals -

eg. *Spirulina*

(3) It gives fertility to sterile alkaline soil and use soil. BGA secretes an acidic chemical which decreases the alkalinity of soil

eg. *Nostoc comune , Scytonema ocellatum , Aulosira fertilissima*

(4) Some BGA are used as green manure

eg. *Anabaena, Spirulina*

(5) Some BGA secrete toxin, which inhibits the growth of mosquito larva in water

eg. *Oscillatoria, Anabaena, Aulosira*

Harmful activities :-

(1) Water bloom

(2) BGA that grow in water tanks, pollute the water

eg. *Oscillatoria*

ETOOS KEY POINTS

(i) Cyanoacteria are Gram (- ve) oxygenic photosynthesizing organisms. It is believed that origin of O_2 on earth was due to cyanobacteria.

(ii) Maximum cyanobacteria are non motile but some filamentous cyanobacteria show gliding and oscillatory movement.

eg. Oscillatoria show oscillatory movement

(iii) **Rivularia** & **Scytonema** develop slipperiness at wet places.

ARCHAEBACTERIA

"Group of ancient bacteria"

1. Evolutionary they are primitive. They were the first to be born on our planet and they are present nowdays with their primitive characters. They are the **"Oldest living fossils".**
2. They are different from eubacteria in many ways.
3. All archaebacteria are **obligate anaerobes**.
4. Their cell wall is not made up of peptidoglycan like that of eubacteria. Their cell wall is made up of complex polysaccharides and complex polypeptide.
5. *Thermococcus, Methanococcus* and *Methanobacterium* exemplify archaebateria that contain protein homologous to eukaryotic core histones.
6. Their cell membrane is not a unit membrane, while in eubacteria the cell membrane is unit membrane .

   Note : Cell membrane of archaebacteria is composed of a single layer of branched chain molecules of lipids while the lipids present in the cell membrane of eubacteria are straight chain molecules. Due to the branched chain structure, archaebacteria have more resistance ability as compared to eubacteria. i.e. Archaebacteria are not effected by high temperature, high salinity, radiations and change in pH. They are resistance to all these. So that Archaebacteria are found in highly unfavourable habitat.
7. In archaebacteria sequence of nucleotide in 16 s – r RNA is differ from other prokaryote.

Archaebacteria includes following bacteria

1. **Methanogens** :-

   "Methane producing bacteria"

   (i) These bacteria convert CO_2 of swampy areas (Marshy) into methane (CH_4).
   eg. *Methanobacterium, Methanococcus, Methanomicrobium*

   (ii) These bacteria convert the organic substance (cellulose) present in cow dung into methane by fermentation (Gobar gas fermenter).
   eg. *Methanobacterium, Methanococcus, Methanomicrobium*

   (iii) An archaebacterium is found in the rumen of cattle, where it digests the cellulose by fermentation and convert it into methane.
   eg. *Rumenococcus*
2. **Halophiles :-**

   These archaebacteria are found in highly saline areas.

   eg. *Halobacterium*
   Halococcus

   Halophiles surrounded by purple membrane. This membrane absorbs the bright light and **directly forms ATP** i.e. They cannot prepare food (carbohydrates) like eubacteria. Instead of it they directly form ATP. Therefore Halophiles are **non photosynthetic**.
3. **Thermo acidophiles :-**

   (A) These archaebacteria are found at those places where temperature is approx 80°C and medium is acidic [pH = 2]

   (B) They are found in **hot sulphur springs**. These can also survive at 100°C temperature.

   (C) Hot water sulphur springs are found in the Himalyan region.

   (D) These are chemoautotrophs.

   (E) They oxidise sulphur to H_2SO_4 and obtain energy. This is used to prepare food. Due to conversion of sulphur to H_2SO_4 the medium (water) becomes acidic in nature.

   (F) Exceptionally these archaebacteria are facultative aerobes.

   eg. Thermus , Sulpholobus , Thermoplasma

RICKETTISIA

They are gram negative obligate pleomorphic. They are intermediate between true bacteria and virus.

(A) They are also called as bacteria because they are similar to eubacteria in structure.

(B) These are Intracellular endoparasite and cell wall is like bacterial wall.

(C) These are non motile.

(D) ATP synthesis is absent but ADP is exchanged with host cell ATP.

Diseases caused by rickettsia in humans :-

(1) Typhus fever — **Rickettsia prowazekii**

(2) Rocky mountain spotted fever — **R. rickettsii**

MYXOBACTERIA

- They are gram –ve coccus like or rod shaped bacteria, having mucilage on their cell wall, so they form slimy colonies and are usually called as swarm stage or **pseudoplasmodium**.
- They multiply by transverse binary fission and also form nonmotile fruiting bodies called as cysts or microcysts or myxospores.
- They do not form flagella,pili and endospores. They are bacteriolytic and cellulolytic.
- Some myxobacteria show gliding movement
  e.g *Myxococcus, Cystobacter, Flexibacter, Stigmatella*

CHLAMYDIA

- The chlamydiae are a group of microbes classified as a type of rickettsiae.
- They also have the character of rickettisiae, like very small in size, having both DNA & RNA and a number of enzymes.
- They can be treated with some antibiotics.
- They are obligate intracellular energy parasites of animals. They form elementary body, initial body or reticulate body, during their reproductive cycle. They divide by binary fission.
- e.g. *Chlamydia trachomatis, C.psittaci.*
- Disease caused by chlamydia are (1) Trachoma (eye disease) (2) Non gonococcal urethritis (reproductive system disease) (3) Chlamydial opthalmia (4) Keratoconjuctivitis.

Check Point :

(1) Barophilic prokaryotes – Prokaryotes which grow and multiply in very deep marine sediments.

(2) Root knot disease of vegetable is caused by **Meloidogyne javanica.**