Chapter = 06

Prokaryotes

INTRODUCTION:

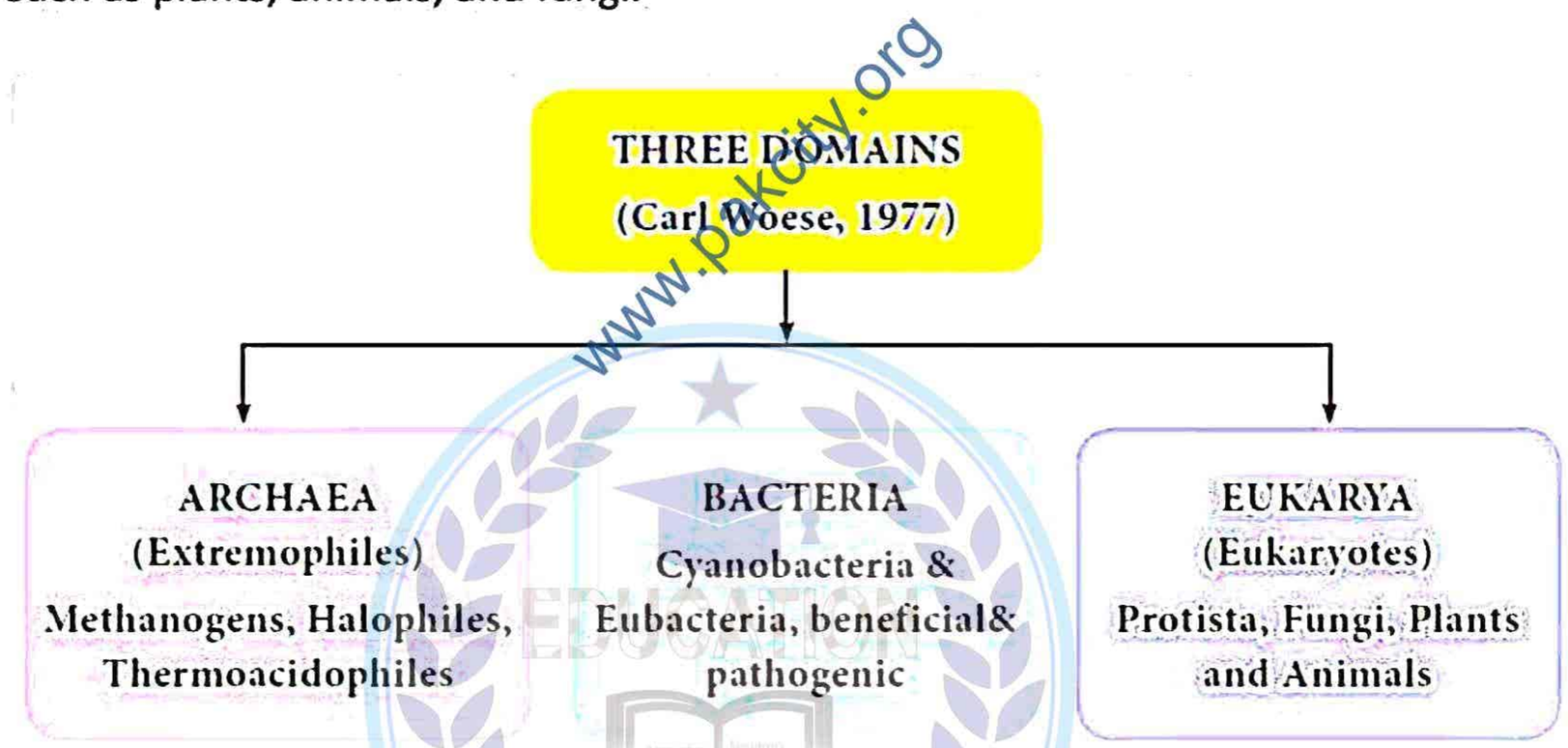
The microorganisms Archaea were previously called archaebacterial. Archaea have unique characters and are different from bacteria but,
Archaea shares some traits with bacteria and Eukarya.

PROKARYOTES:

Prokaryotes are found almost everywhere - in every ecosystem, on every surface of our homes, and inside of our bodies. Some live in environments too extreme for other organisms, such as hot vents on the ocean floor. Prokaryotes can be hard to detect, count," and classify.

TAXONOMY OF PROKARYOTES:

For a long time, all prokaryotes were classified into a single domain but however Carl Woese in 1977 divided prokaryotes into two distinct lineages that is Archaea and Bacteria. Today, these groups are considered to form two out of three domains of life. The third domain (Eukarya) includes all eukaryotes, such as plants, animals, and fungi.



CLASSIFICATION OF ORGANISMS GIVEN BY DIFFERENT SCIENTISTS IN DIFFERENT ERA:

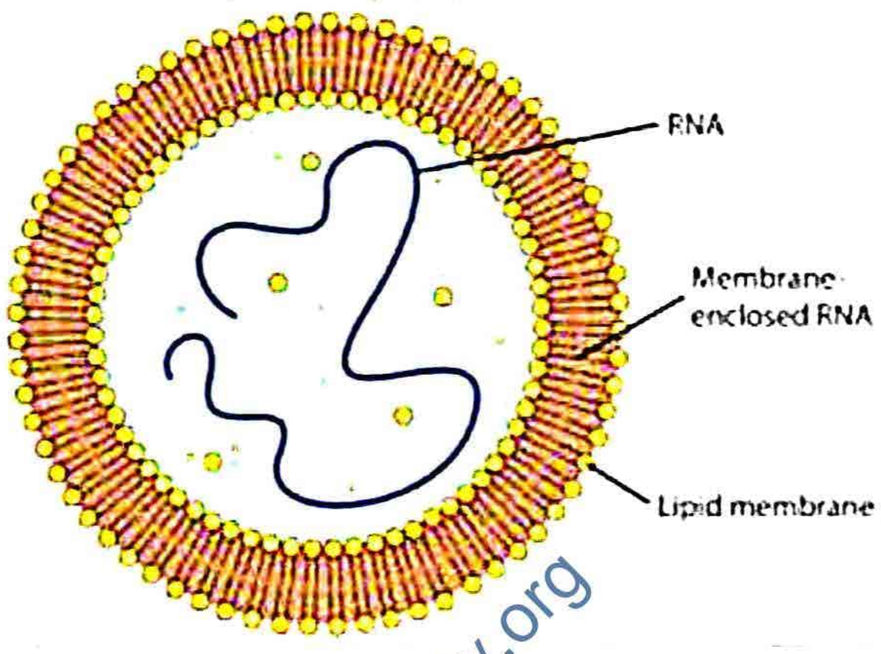
Linnaeus 1758	Haeckel 1866	Chatton 1925	Copeland 1938	Whittaker 1969	Woese et al. 1990
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	3 domains
	Protista	Prokaryota	Monera	Monera	Bacteria Archae
Plantae	Plantae	Eukaryota	Protoctista Plantae	Protista Plantae Fungi	Eukarya
Animalia	Animalia	Eukaryota	Animalia	Animalia	Eukarya

PHYLOGENY OF PROKARYOTES:

• Prokaryotes evolved from protobionts about 3.5 billion years ago. Prokaryotes after their evolution facing atmospheric radiation of this planet and also oxygen shortage.

• Protobionts are aggregation of abiotically produced organic molecules surrounded by a membrane or membrane like structures and exhibits some of the properties which are associated with life including simple reproduction, metabolism and excitability.
• Protobionts are considered as precursor of prokaryotic cells.
• The early habitat of prokaryotes was microbial mats which were few centimeters thick, moist and sticky.
• They were present in hydrothermal vents.
• Microbial mats when dried then becomes stromatolite.

Stromatolites are layered mounds, columns, and sheet-like sedimentary rocks. They were originally formed by the growth of layer upon layer of cyanobacteria.



DOMAIN ARCHAEA:

• The microorganisms Archaea were previously called archaebacterial, but now they are considered as separate domain according to domain system of classification.
• They are spherical, rod, lobed and square shaped.
• They range in size 0.1 to 15 um in diameter.
• Archaea have unique characters and are different from bacteria but,
• Archaea shares some traits with bacteria and Eukarya.

SIMILARITIES AMONG ARCHAEA AND BACTERIA:

• Prokaryotes.
• Flagella.
• Single chromosome, plasmids Carbon and nitrogen cycling.
• Chemolithotrophy.
• Hyperthermophilic growth.

SIMILARITIES AMONG ARCHAEA AND EUKARYA:

• Genes.
• DNA replication.
• RNA polymerases.
• Gene expression.

UNIFYING FEATURE OF ARCHAEA:

i. DIFFERENCE BETWEEN CELL WALL COMPOSITION:

The cell walls of Archaea do not contain peptidoglycan while bacteria contain In some archaea cell wall is composed of polysaccharide or protein or cell wall may absent.

ii. DIFFERENCE IN CELL MEMBRANE COMPOSITION:

Lipids of archaea contain glycerol linked to branched chain hydrocarbons in contrast to lipid of bacteria
that contain glycerol linked to fatty acids.

iii. METHANOGENESIS:

The ability to form methane is a type of metabolism that is performed only by some archaea.

iv. DIFFERENCE IN MODE OF NUTRITION:

Archaea use three sources of energy to prepare food is using sun light, using inorganic compounds, using organic compounds.

v. DIFFERENT IN RNA

In rRNA of archaea and eubacterja, near nucleotide 910 researcher found following to lipid difference;

Eubacteria = AAACUCAAA
Archaea = AAACUUAAA

DIFFERENCE BETWEEN BACTERIA ARCHAEA

BACTERIA	ARCHAEA
These are modern bacteria.	These are most ancient bacteria.
These bacteria can not withstand very harsh conditions.	These bacteria can withstand very harsh conditions.
Their cell wall is chiefly made up of peptidoglycan.	Their cell wall is not made up of peptidoglycan, instead made up of protein, glycoprotein and polysaccharide.
Example: E. coli, Vibrio cholera.	Example: Thermus aquaticus.

HABITAT OF ARCHAEA:

Archaea are found in different habitat such as,

- Thermophiles: live in hot spring.
- Acidophiles: live in high acidic condition.
- Methanogens: live in marshy areas and in gut environment.
- Halophiles: live in high salt conditions.

MODE OF LIFE:

Archaea do not live as parasite although it forms symbiotic relationship with other organisms such as,

- Methanogens E. coli live in intestine of human and helps in digestion.
- Cenarchium symbiosum live within sponges.

IMPORTANCE OF ARCHAEA:

- Some thermophilic archaea use in biotechnology due to their survival in high temperature.
- Archaea provide the major routes for ammonia oxidation in the environment.

DOMAINS

CHARACTERISTICS	ARCHAEA	BACTERIA	EUKARYA
Cell membrane	Ether-linked lipids, pseudopeptidoglycan	Ester-linked eudopeptidoglycanpeptid	Ester linked lipids, various structures
Gene Structure	Circular chromosomes, similar translation and transcription to Eukarya	Circular Chromosomes, unique translation and transcription	Multiple, linear chromosomes, similar translation to Archaea
Internall cell structure,	No membrane-bound organelles or nucleus	No membrane- bound oragnelles or nucleus	Membrane-bound organelles and nucleus
Metabolism	Various methanogenesis unique to archea	Various including photosynthesis, aerobic and anaerobic respiration fermentation, and autotrophy	Photosynthesis and cellular respiration
Reproduction	Asexual reproduction, horizontal gene transfer	Asexual reproduction, horizontal gene transfer	Sexual and asexual reproduction

BACTERIAL ECOLOGY AND DIVERSITY:

- Earth evolved about 4.5 billion years ago.
- Initial temperature of earth was very high.
- Volcanic activities releasing gases (CO_2, SO_2, HS) and O_2 almost unavailable on this planet.
- Life evolved about 3.5 billion years ago.
- Bacteria have been the very first organisms to live on this Earth.
- They made their appearance 3.5 billion years ago in the waters of the first oceans.
- The very first bacteria probably metabolized hydrogen sulphide and carbon monoxide.
- Eventually photosynthetic bacteria evolved and used sunlight to build sugars from carbon dioxide and water.
- These photosynthetic bacteria established a suitable atmosphere and formed the basis for aerobic life.
- After that other oxygen breathing organisms have evolved on this planet such as about 600 million years ago the first multicelled animal was evolved for example sponges.
- It was evidenced that mitochondria and chloroplast were primitive bacteria.

THEORY OF SYMBIOGENESIS OR ENDOSYMBIOTIC THEORY:

- This theory was proposed by Russian Konstantin Mereschkowski in 1905.
- It is the evolutionary theory of the origin of eukaryotic cells from prokaryotic organisms.
- According to this theory the organelles of eukaryotic cells represent formerly free living prokaryotes taken in by endosymbiosis.
- Genome of mitochondria, chloroplast and bacteria are similar. It shows similarities among them.
- Mitochondria and chloroplast have their own DNA which can produce their protein and enzymes necessary for their function.
- These both organelles are double membrane bound which shows that they are ingested by primitive host.
- Furthermore, they reproduce like bacterial cell.

BACTERIAL HABITAT:

• Bacteria are found almost everywhere in air, water, soil, deep in the earth's crust, arctic ice, glaciers, food and in the bodies of plants and animals including human being.
• They are found 48000 meter above in the atmosphere and 10,000-meter-deep in the water.
• 1 gram of soil contain 40 million bacterial cells.
• 1 milliliter of fresh water contain 1 million bacterial cells.
• The whole earth contains approximately 5 x 10^{30} bacteria.
• Some are benthic bacteria living at the sea floor where Temperature and pressure are very high. Benthic bacteria obtaining nutrition by ingesting organic and inorganic molecules such as they oxidize sulphur.

DIFFERENCE BETWEEN AEROBIC BECTERIA AND ANAEROBIC BACTERIA

AEROBIC BACTERIA	ANAEROBIC BACTERIA
Preferred aerated environment.	Preferred non-aerated environment.
Produce CO2 and H_2O.	Produce CO2, ethanol and Lactic acid.
Found in soil, water and open surfaces.	Found in intestine and marshes.
AB produce more energy.	AnB produce less energy.
Examples: Lactobacillus, Mycobacterium	Examples: Clostridium and E.coli

MAJOR GROUPS OF BACTERIA:

Bacteria have been subdivided into different groups based on their cell wall (gram positiv and gram negative), presence of endospore, metabolism, growth and nutritional and physiological characteristics.
• Proteobacteria (gram negative).
• Chlamydia (gram negative).
• Spirochete (gram negative).
• Cyanobacteria (gram negative).
• Staphylococcus (gram positive).

DIFFERENT GROUPS OF BACTERIA

Phylum	Characters	Examples
Protobacteria	Free living, symbionts, parasitic	H. pylori causes ulcer in GIT
Chlamydia	Obligate parasite, low peptidoglycan	Chlamydia cause STD
Spirochetes	Spiral shaped, flagellated, free livings, parasitic	Treponema palidum causes syphilis
Cyanobacteria	Aquatic, chlorophyllous, blue green algae	Prochlrococcus
Gram positive bacteria	Pathogenic, decomposer, cell wall thick lacking outer membrane.	Clostridium botulism Bacillus anthrax.

CYANOBACTERIA AS PHOTOSYNTHETIC BACTERIA:

• They have gram negative type of cell wall.
• They are evolved around 2.5 billion years ago.
• They are unicellular autotrophic organisms mostly occur in colony form.
• They form colony on rocks and in soil near glaciers and volcanos.
• They have ability to survive in extreme low and high temperature.
• They are mostly free living but some are found as epiphytic or symbiotic.

• Like algae and plants they utilize CO_2 and H_2O to harvest light energy and releasing O_2 to this planet during photosynthesis.
• Hence contribute to reduce the atmospheric temperature.
• They are mostly aquatic found in fresh water.
• Cyanobacteria has RUBISCO enzyme that can convert CO_2 into sugar.
• The protoplasm differentiated into an outer colored region chromoplast, which contain various pigments such as chlorophyll-a (green) and phycocyanin (blue pigment) while in some species phycoerythrin (red pigment) is also present.
• Inner colourless region of the protoplasm is known as centralism.
• About one third of cyanobacteria are able to fix atmospheric nitrogen.
• In most cases nitrogen fixation occurs in heterocyst, which are without nuclei, thick walled cell found at certain intervals in filamentous cyanobacteria.
• In Pakistan cyanobacteria e.g. Nostog and Anabaena are cultivated as fertilizers.
• Some cyanobacteria are toxic and causes gastroenteritis in human.
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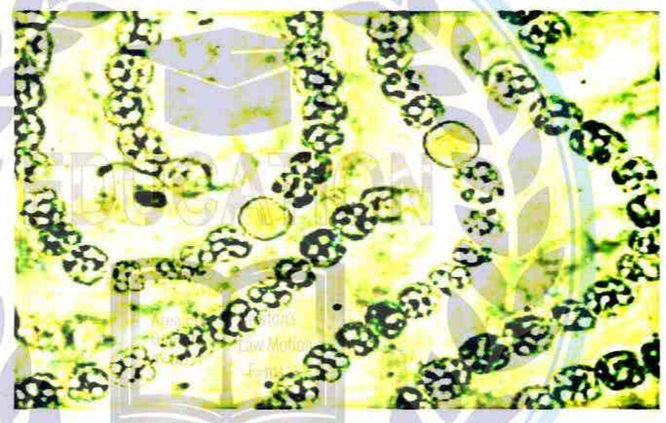
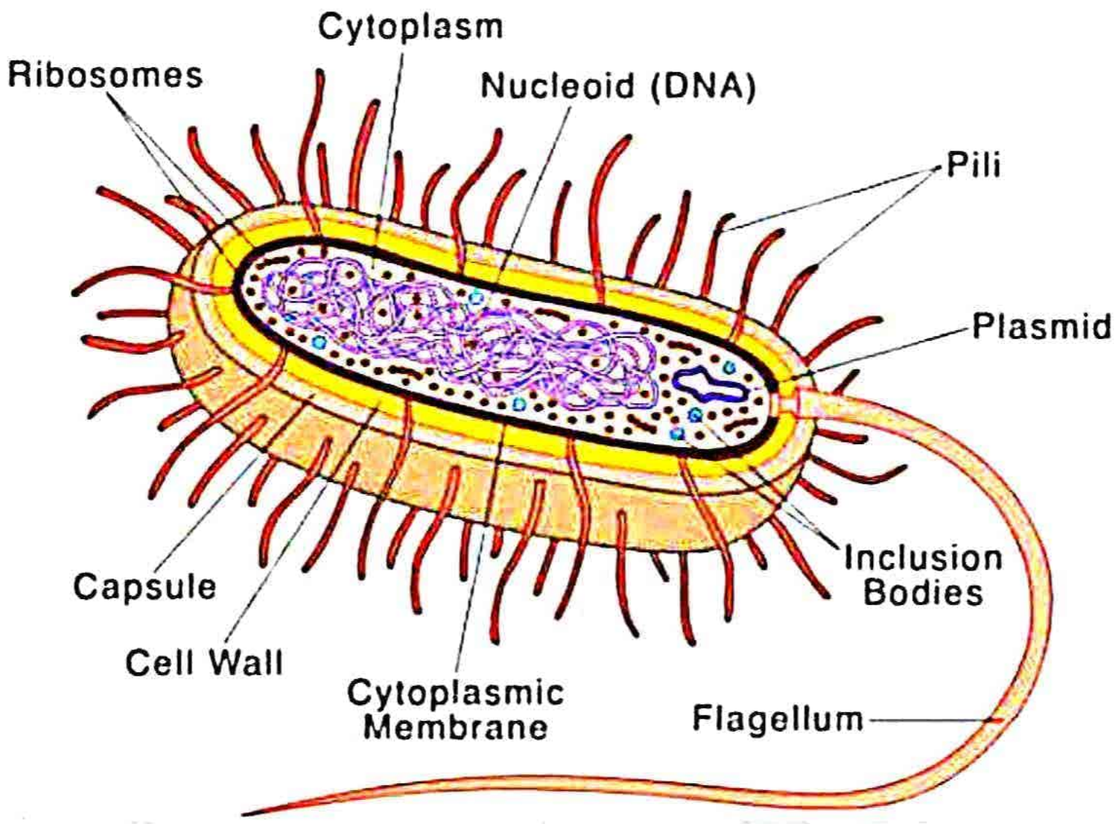
• Cyanobacteria do not have chloroplast but they have green pigments.
• They are not true photosynthetic eukaryotic organisms so require little amount of energy.
• They have higher growth rate than phytoplankton.
• They provide most of the O_2 in this planet so, life is not possible without the cyanobacteria evolution.



STRUCTURE OF BACTERIA

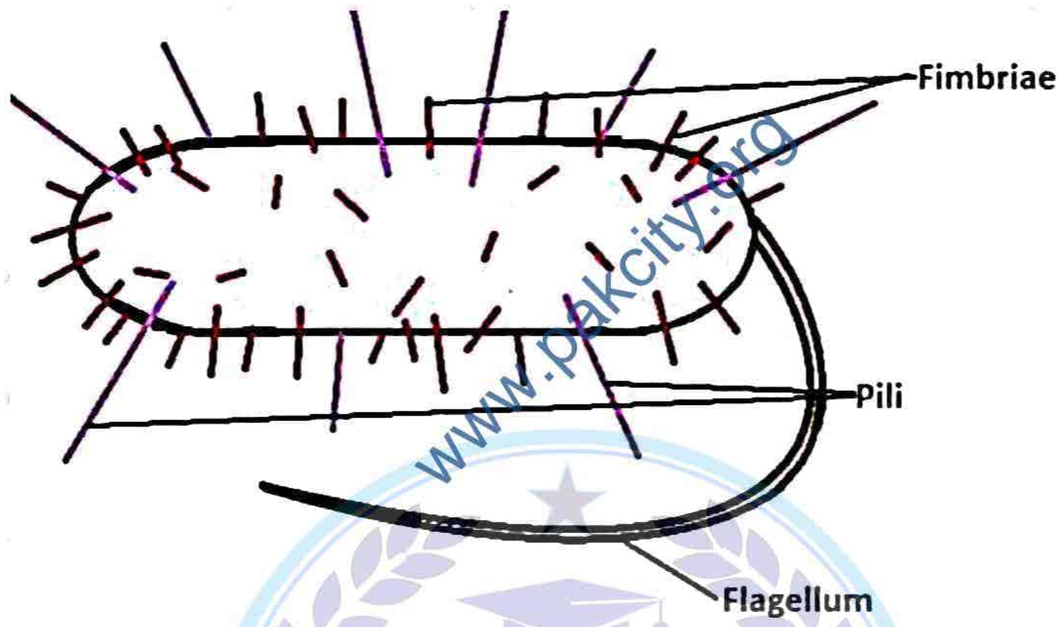
Bacteria are the smallest and simplest unicellular organism. Their size ranges in between 0.1 to 10 µm in length. A bacterial cell divided into following regions.

a. Appendages.
b. capsule.
c. cytoplasmic region.



A-APPENDAGES:

The structures that project from the surface of bacterial cell are called bacterial appendages that includes flagella and pili.



I. FLAGELLA:

- The flagellum is Latin word which means a whip.
- It is long slender thread like structure which are used for locomotion.
- Bacterial flagella are composed of Flagellin protein and lack microtubules.

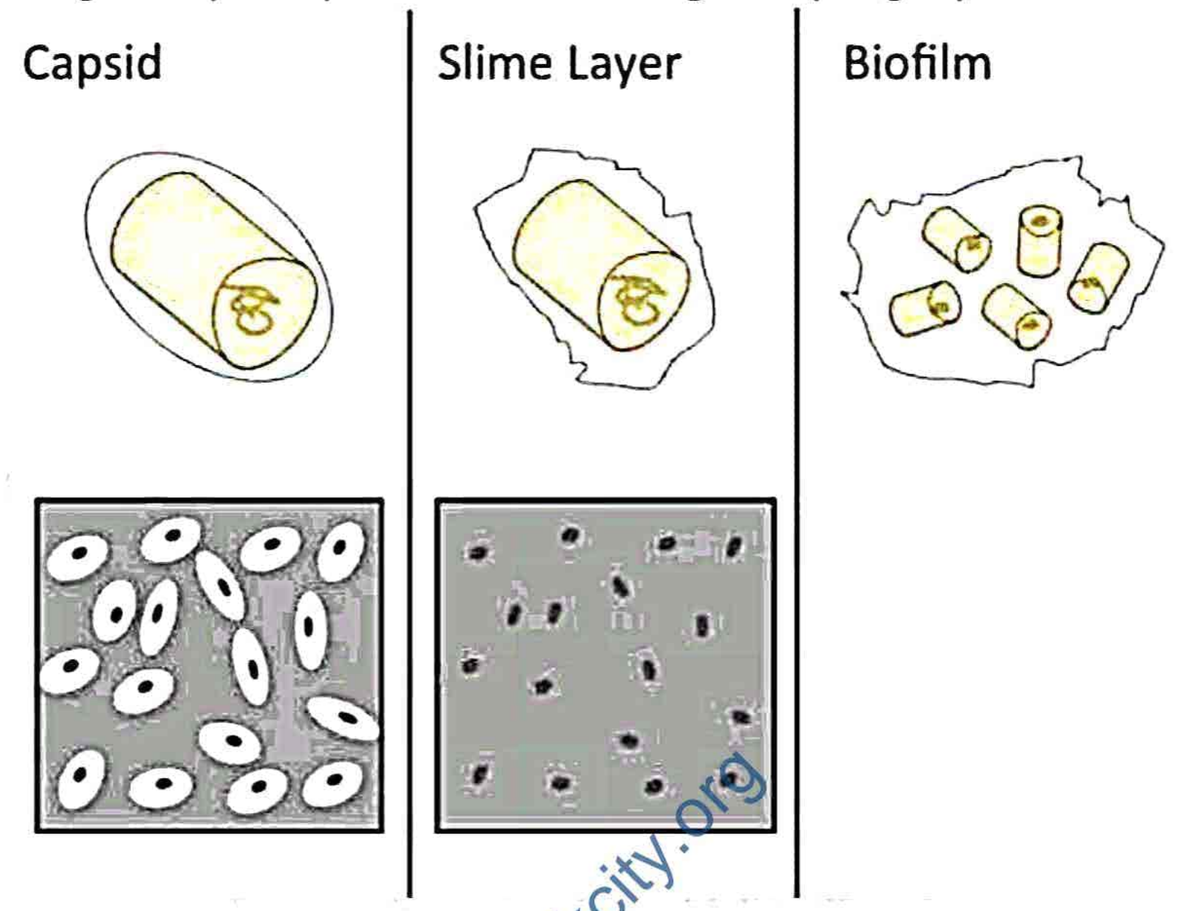
II. PILLI.

- Pilli are tubular extensions of cell membrane and project through the cell wall.
- They are composed of pillin protein and are only found on some species of gram-ve becteria.
- They help in conjugation or attachment on the surface of tissues of an infected person but not in locomotion.

B-CAPSULE:

- Usually bacteria has two protective coverings the cell wall and cell membrane.
- But some bacteria has third covering made up of glycocalyx which act as capsule.
- Glycocalyx may condensed and form capsule or slime which is sticky layer.
- Capsule is thick, rigid and tightly attached with cell wall and provide sticky or gummy nature to cell wall.
- Slime is thin and less rigid and loosely attached to cell wall and provide slimy and slippery nature to cell wall which is formed by polysaccharide, polypeptide and hyaluronic acid.

- Capsule is hydrophilic in nature and prevent desiccation.
- Capsule protect the bacteria from ingestion by WBCs.
- Glycocalyx also form biofilm by adhesion with each other due to which bacteria become more resistant and it is difficult to kill them.
- It is a protective sheath made up of polysaccharides and proteins.
- Capsule present outside the cell wall of bacterial cell.
- It provides greater pathogenicity and protects bacteria against phagocytosis.



DIFFERENCE BETWEEN GRAM POSITIVE AND GRAM NEGATIVE BACTERIA:

	GRAM POSITIVE BACTERIA	GRAM NEGATIVE BACTERIA
Cell wall	A single-layered, smooth cell wall.	A double-layered, wavy cell-wall
Peptidoglycan Layer	It is a thick layer/ also can be multilayered	It is a thin layer often single-layered.
Gram Reaction	In the gram staining procedure, retain the purple colored stain.	In the gram staiping procedure, do not retain the purple colored instead stain pink or red.
Cell wall thickness	20-80nm	8-10nm
Teichoic acid	Present	Absent
Outer membrane	Absent	Present
Mesosome	It is more prominent	It is less prominent.
Porins	Absent	Present
Rigidity and Elasticity	Rigid and less elastic	Less right and more elastic
Variety of amino acid in cell wall	Few	Several
Aromatic and sulfur containing amino acid in cell wall	Absent	Press
Lipid and Lipoprotein content	Low (acid-fast bacteria have lipids linked to peptidoglycan)	High (Because of presence of outer membrane

Cell Wall Disruption by Lysozyme	High	Low (requires pretreatment to destabilize outer membrane).

CELL WALL:

• Cell wall is present beneath the extracellular substances. It is external to cell membrane or plasma membrane.

CHEMICAL COMPOSITION OF CELL WALL:

• It is made up of peptidoglycan (Murein) which is the mixture of lipoglycan and peptidoglycan.
• Different kinds have different amount of peptidoglycan. The intact cell wall also has additional chemicals like sugar, teichoic acid, lipoprotein, lipopolysaccharides.
•These chemicals are linked with peptidoglycan.

CELL WALL OF ARCHAEBACTERIA:

• They do not have peptidoglycan but it contain protein, glycoprotein and polysaccharides.

CELL WALL OF EUBACTERIA:

•They have typical cell wall i.e. peptidoglycans present in eubacteria.

CELL WALL OF GRAM POSITIVE BACTERIA:

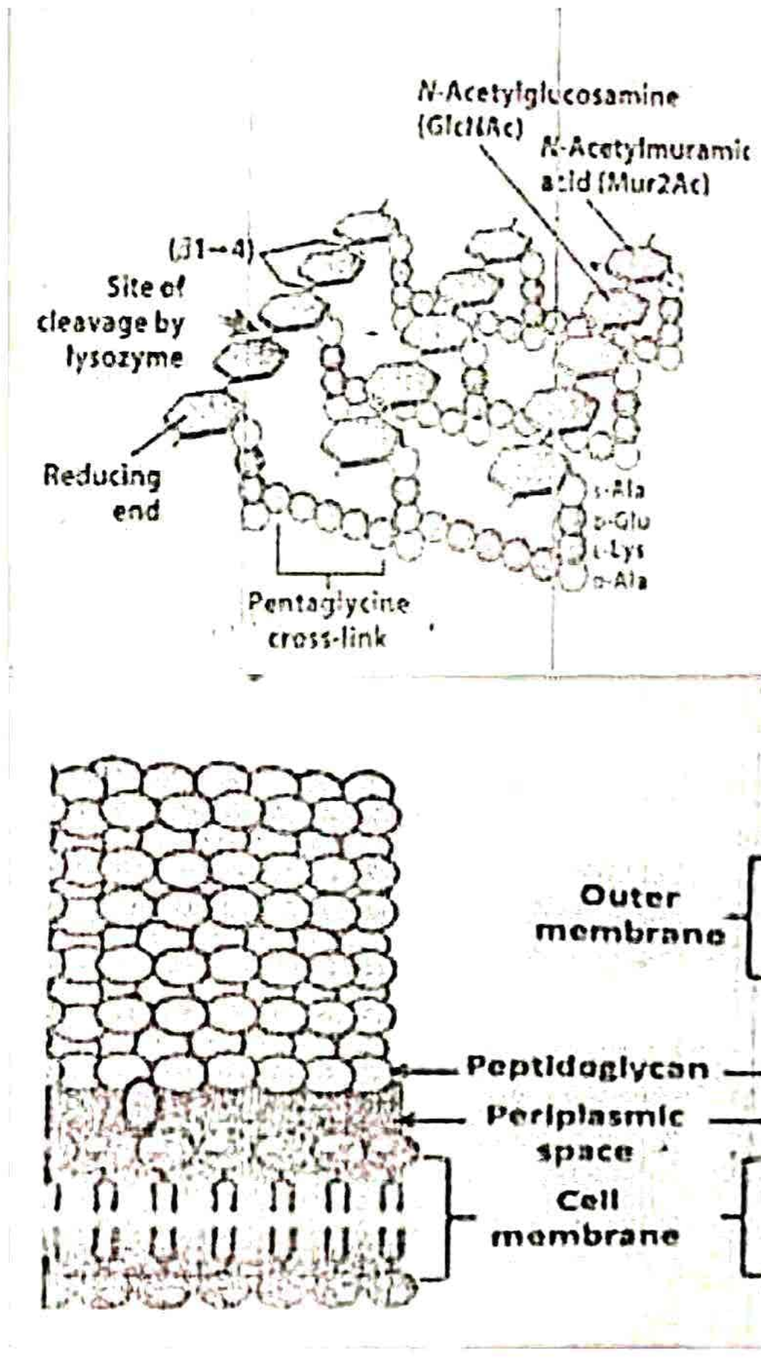
• The cell wall contain 50% peptidoglycan (of dry weight), Teichoic acid and lipoteicholic acid.
• Thickness is 20 to 80 nm.
• No outer membrane present.
• Lipids are 1-4%.
• It is more permeable.
• The cell wall of gram positive retain the primary dye..
• It retains the crystal violet stain. It is stained purple.

CELL WALL OF GRAM NEGATIVE BACTERIA

• The cell wall contains only 10% peptidoglycan.
• Lipoprotein and liposaccharides are much present.
• It is thinner than gram positive cell wall.
• The gram negative cell wall is more complex.
• Between peptidoglycan region an outer membrane is present a periplasmic region.
• It is less permeable. It retains secondary dye.

FUNCTION OF CELL WALL

• Cell wall gives definite shape to cell.
• It protect the cell.
• It provides rigidity.
• It is 20 to 30% of dry weight of the cell.
• Cell wall is absent in mycoplasmas.

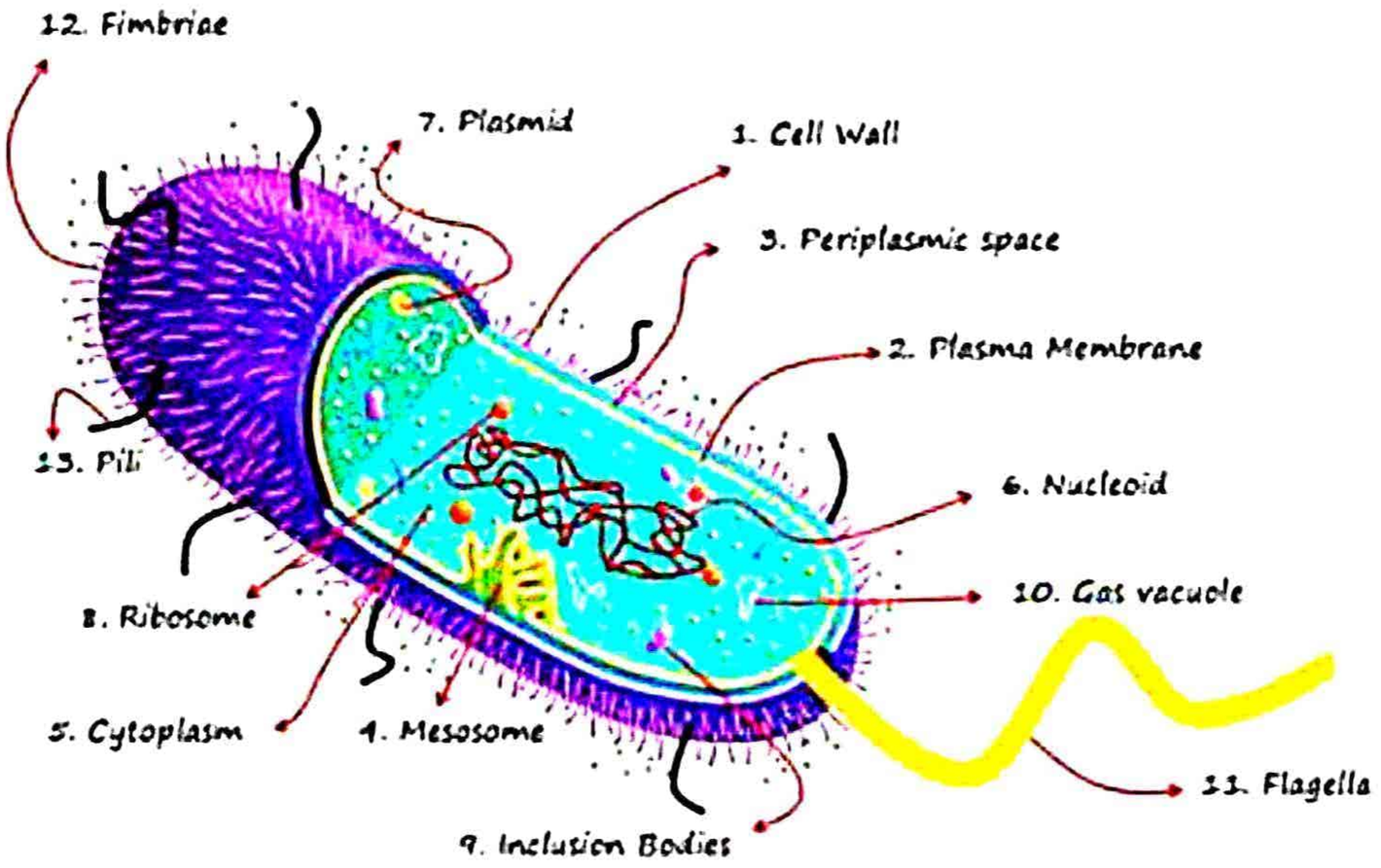


CELL MEMBRANE:

- Cell membrane lies beneath the cell wall which Jacks cholesterols in lipid bilayer unlike eukaryotic plasma membrane.
- At certain points this membrane invaginations into the cytoplasm to form infolding, these are known as mesosomes.
- It cotain many pore.
- In addition to the control of transport of materials across the cell, bacterial plasma membrane also involves in cellular respiration, photosynthesis and DNA replication.

MESOSOMES:

- These are vesicular and pocket like structures formed by the invaginations of the cell membrane into the cytoplasm.
- Structure; they are in the form of vesicles, tubules or lamella (plate).
- Function: they help in the DNA replication, cell division, respiration and export of enzyme.



C-CYTOPLASMIC REGION

- Bacterial cytoplasm is jelly like dense mass present between plasma membrane and nucleoid.
- It lacks cytoskeleton and cellular organelles except ribosomes.
- Ribosomes are large in numbers and freely disperse in cytoplasm.
- These are small 70s ribosome.
- Small granules of stored food and waste materials are also present in bacterial cytoplasm.
- Stored food include glycogen, protein, fat etc. whereas wastes may consists of alcohol, lactic acid and acetic acid etc.

INCLUSIONS:

- Furthermore, inclusion are also present in cytoplasm.
- Inclusion bodies are non-living cytoplasmic aggregates of stainable substances, usually proteins.
- They do not take part in metabolic activities.
- Inclusions include glycogen, lipid droplets, crystals and pigments.

BACTERIAL HEREDITARY MATERIAL:

- There are no nuclear membrane and nucleoli in bacterial cell.
- Discrete chromosomes are also absent but densely packed DNA present.
- Bacterial hereditary material (DNA)-is-found as concentrated structures called chromatin bodies.
- It is mostly scattered in the nucleoid region.
- Nucleoid has a single, circular and double stranded DNA molecule.
- A small fragment of extra chromosomal circular DNA, called Plasmid is also present.

CHARACTERISTICS OF PLASMID:

- These are self-replicating.
- They are not essential for bacterial growth and metabolism.
- They have drug resistant ability.
- They have heavy metals.

SHAPES AND SIZE OF BACTERIA:

(1) Cocci

• These are spherical or rounded bacteria presents in the form of Mono (single cocci), Diplo (two) or Streptococcus form (long chain of cocci), Tetrad (Four), Sarcina (eight cocci) and Staphylococcus (grape like arrangement of cocci).
• They are non-flagellated and cannot move from one place to another.

2. Bacilli:

• Bacilli are rod shaped bacteria, present in the form of Mono, Diplo or streptobacilli.
• They may be flagellated and can move from one place to another.

(3) Spirilia:

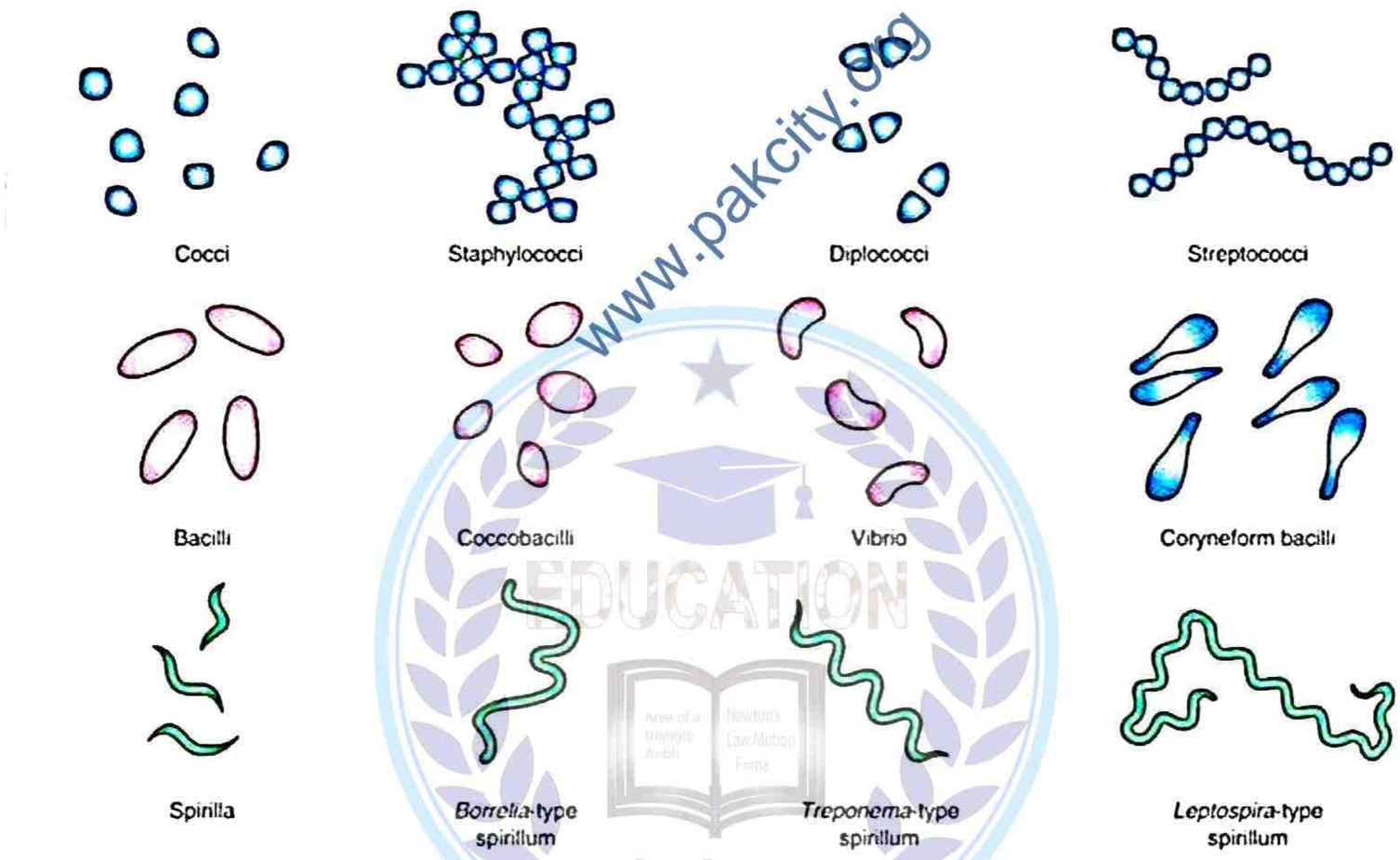
• These are flagellated, rigid and deeply curved bacteria.

(4) Spirochete:

• It is a thin, flexible spiral, cork, screw shape. e.g. spirillum minus.

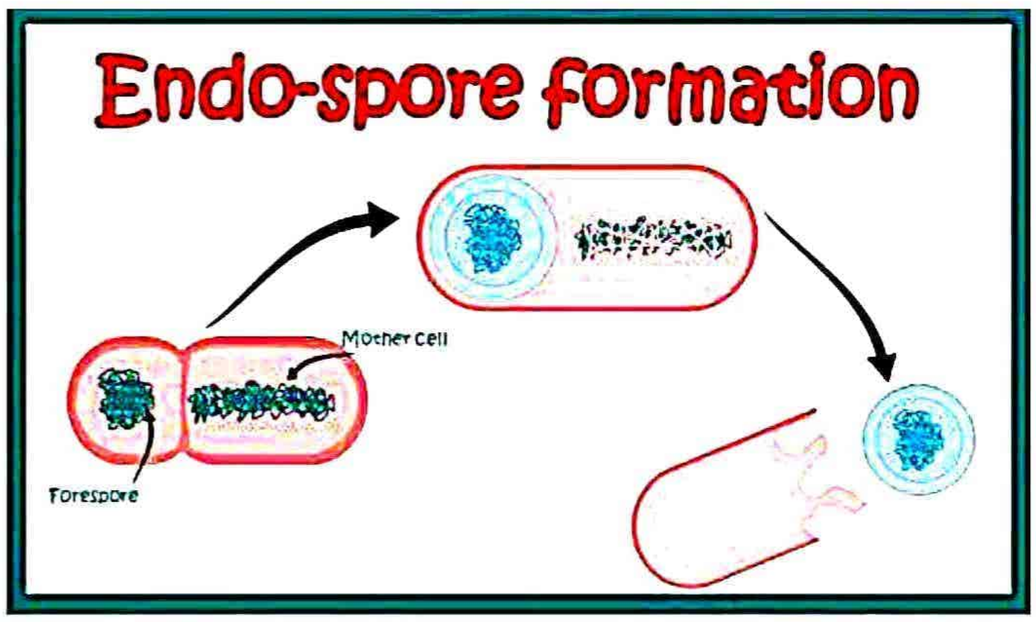
(5) Vibrio:

• It is curved or coma-shaped which are intermediate to spiral and rod shape, are called vibrio e.g. Vibrio Cholarae.

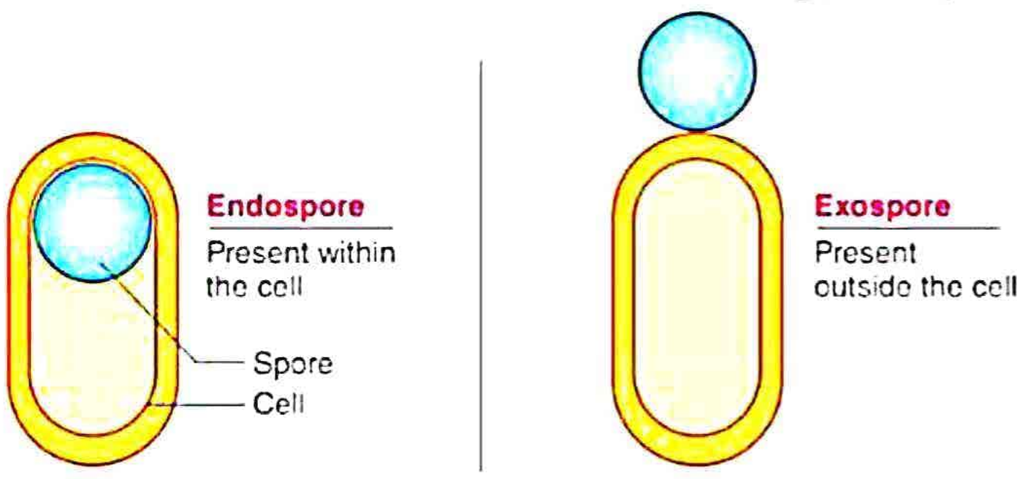


ENDOSPORE FORMATION IN BACTERIA:

• When essential nutrients are depleted in the environment and other conditions such as temperature, pH of the medium and availability of water become unfavorable certain bacteria from resistant and metabolically dormant bodies. Depending upon the type of bacteria these bodies are;



Endospore, Exospore and Cyst.



ENDOSPORE DEVELOPMENT:

- Endospore is a complex structure and resistant to high temperature that is why it is capable to survive a period more than 1000 years.
- The spore develops within the vegetative cell inside the cell wall, so it has been named endospore.
- Bacterial cell forms a copy of its chromosome and surrounds it with a tough three layered wall.
- Water is removed from the endospore.
- The metabolism inside the endospore stop.
- The rest of the original parts of cell disintegrates.
- Endospore germinate when environmental conditions become favorable by absorbing water and splitting the wall and releasing the cell inside and start functioning as bacterial cell.

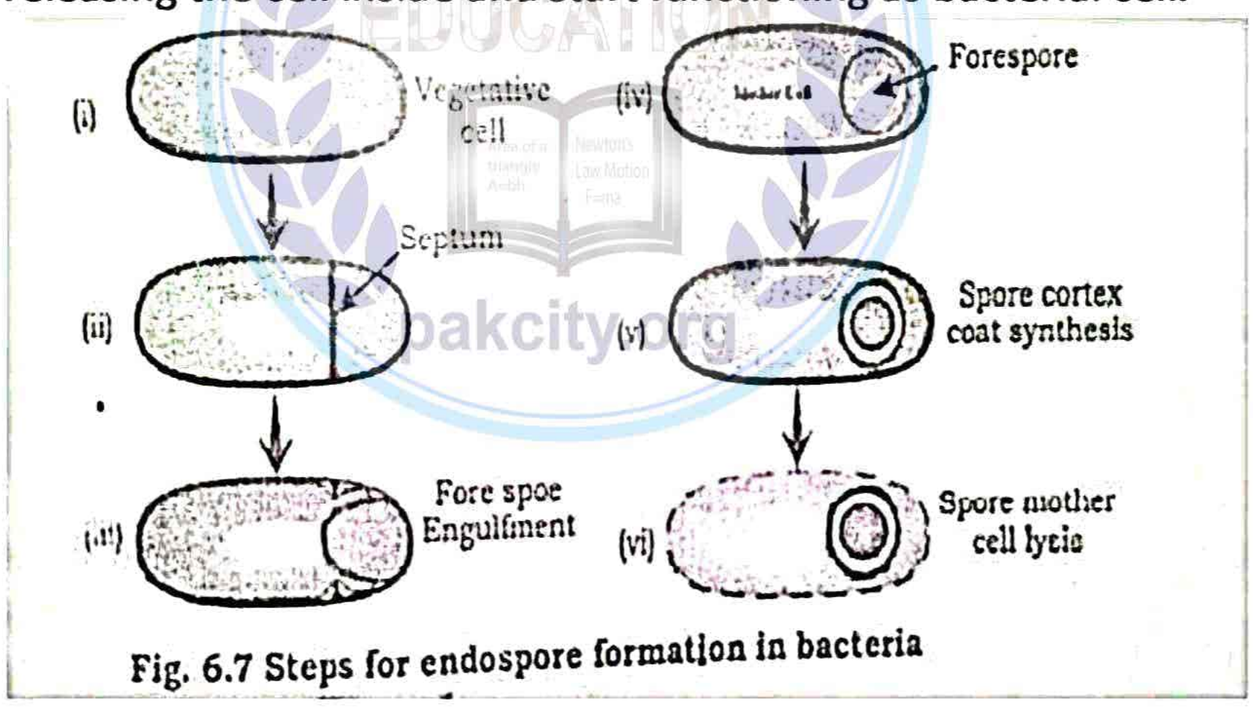
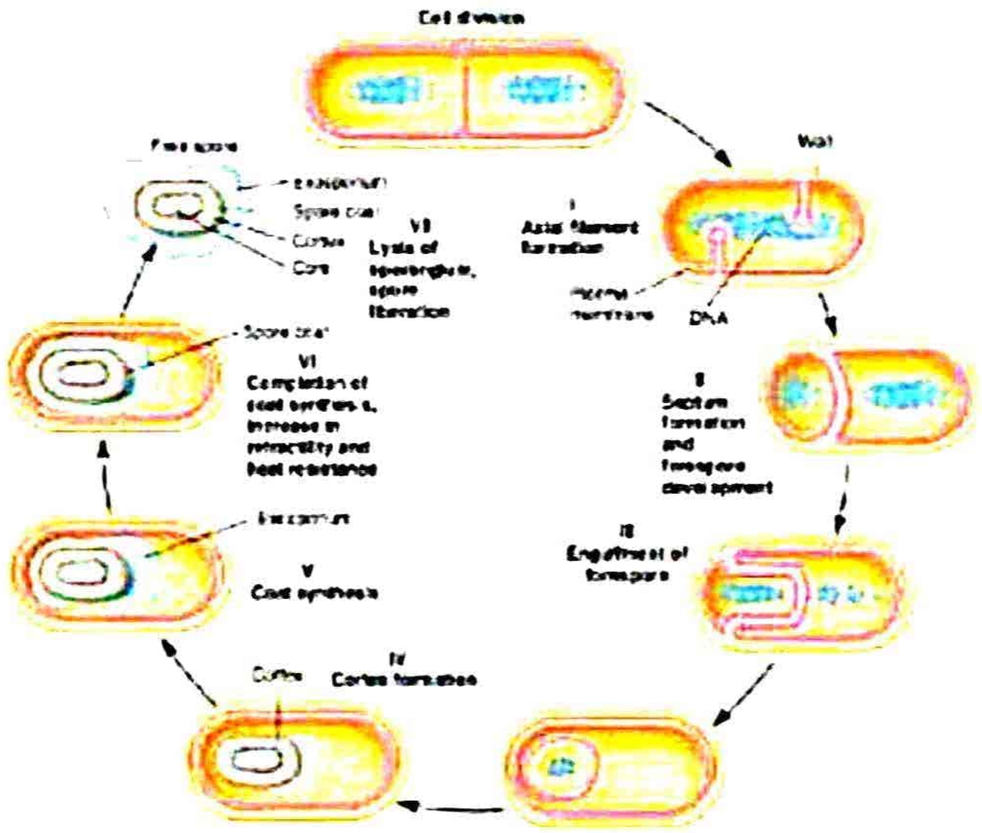


Fig. 6.7 Steps for endospore formation in bacteria

SOME OTHER SURVIVAL METHODS OF BACTERIA:

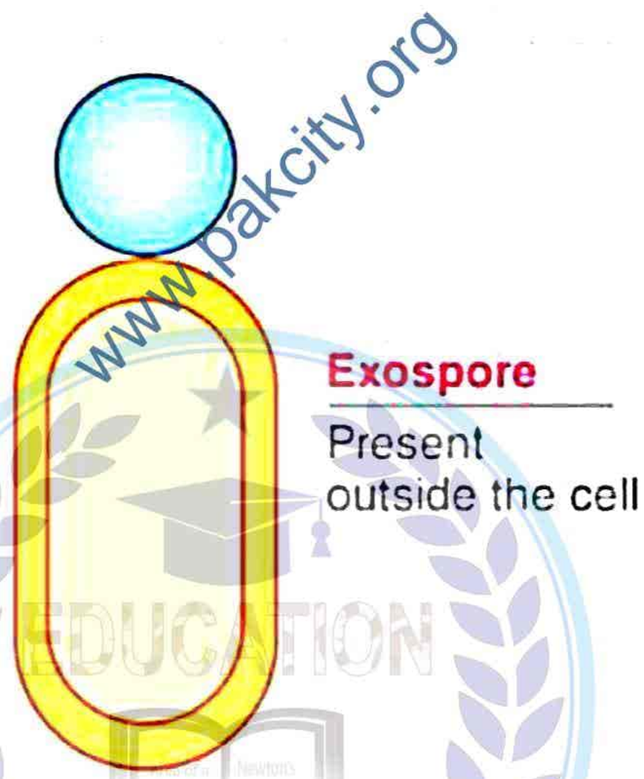
On the other hand, the Actinomycetes which are large group of spore forming Gram +ve bacteria that grow by forming long tubules called filaments.



EXOSPORE FORMATION:

• Under nutrient poor conditions these filaments differentiate into round thick walled resting structures termed as exospores.

• In contrast to endospore, these structures are part of the reproductive process and are formed outer to the cell.



CYST FORMATION:

• Azatobactor species and several others are known to form cysts, which are dormant cell with thickened cell walls.

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

MOTILITY IN BACTERIA:

• Bacteria can show movement in response to various stimuli such as magnetic field, temperature, chemicals and light by using its flagella.

Examples:

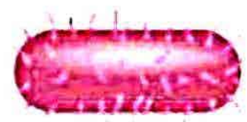
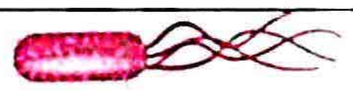
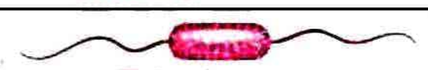
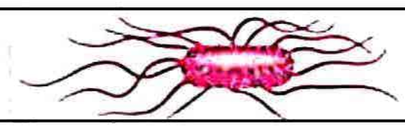
• **Chemotaxis:** movement in response to certain chemicals such as nutrients or toxic substances.

• **Phototaxis:** movement in response to light such as toward optimal light concentration or away from strong light.

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

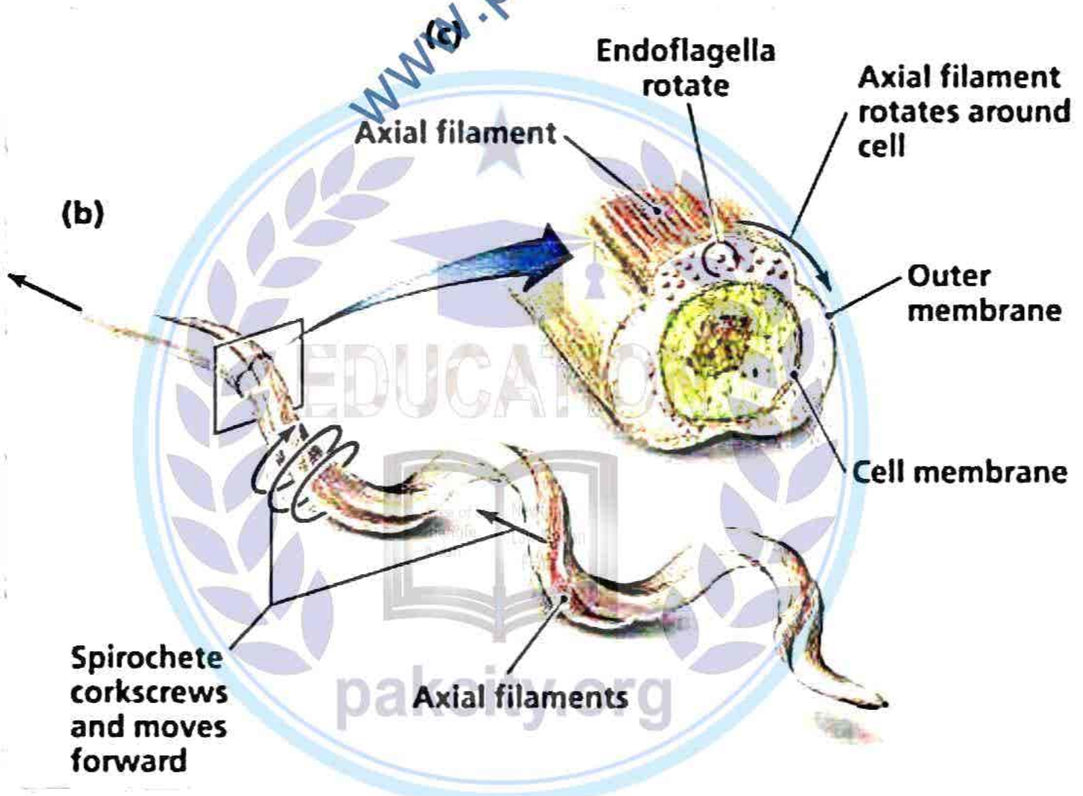
FLAGELLAR MOVEMENT:

- Most bacilli and Spiralia are motile by means of flagella; cocci are usually non motile.
- The presence of flagella, as well as their number and distribution on the cell, are important characteristics for purposes of identification and classification of bacteria.

Atrichous	bacteria without flagella	
Monotrichous	bacteria with single flagella at one pole present.	
Lophotrichous	bacteria with a tuft of flagella at one pole present	
Amphitrichous	bacteria with a tuft of flagella at each of two poles present	
Peritrichous	bacteria are surrounded by flagella	

SPIROCHAETAL MOVEMENT:

- A somewhat modified version of the bacterial flagellum is called axial filament.
- The axial filament runs length wise between the bacterial inner membrane and outer membrane of the cell wall in periplasmic space.
- Spirochetes can perform flexing, swimming, creeping or spinning type of movement with the help of axial filament.
- It is present in spirochete.



GLIDING MOTILITY:

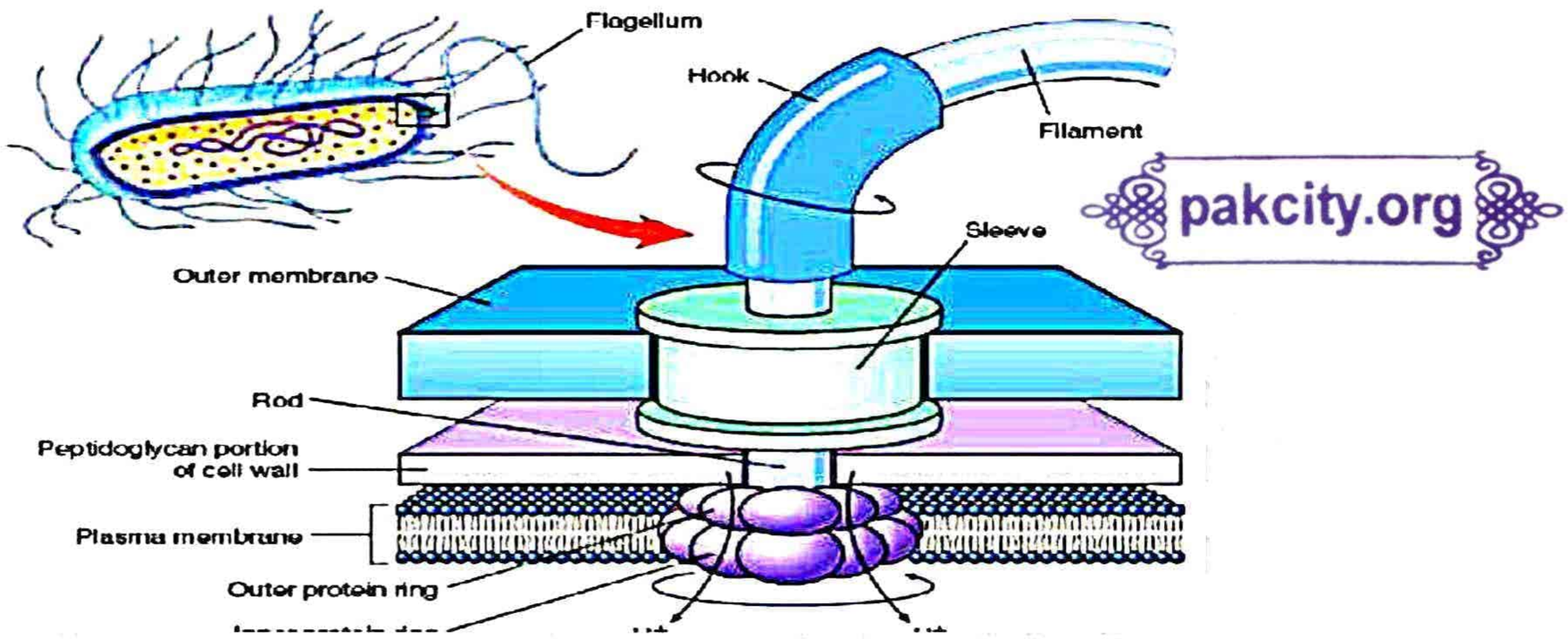
- Like spirochetal movement, the gliding motility is also represented by some genera of the cyanobacteria and myxobacteria.
- These organisms can move slowly over solid surface.
- They do not have filamentous structures either internally like axial filament of spirochetes or externally flagella of bacilli but they secrete a slimy substance like garden snails during locomotion.

STRUCTURE OF BACTERIAL FLAGELLUM:

The flagella are long, thin, whip like helical structure composed of flagellin protein about 20nm. The flagella structure is divided into three parts:

1. Basal body.

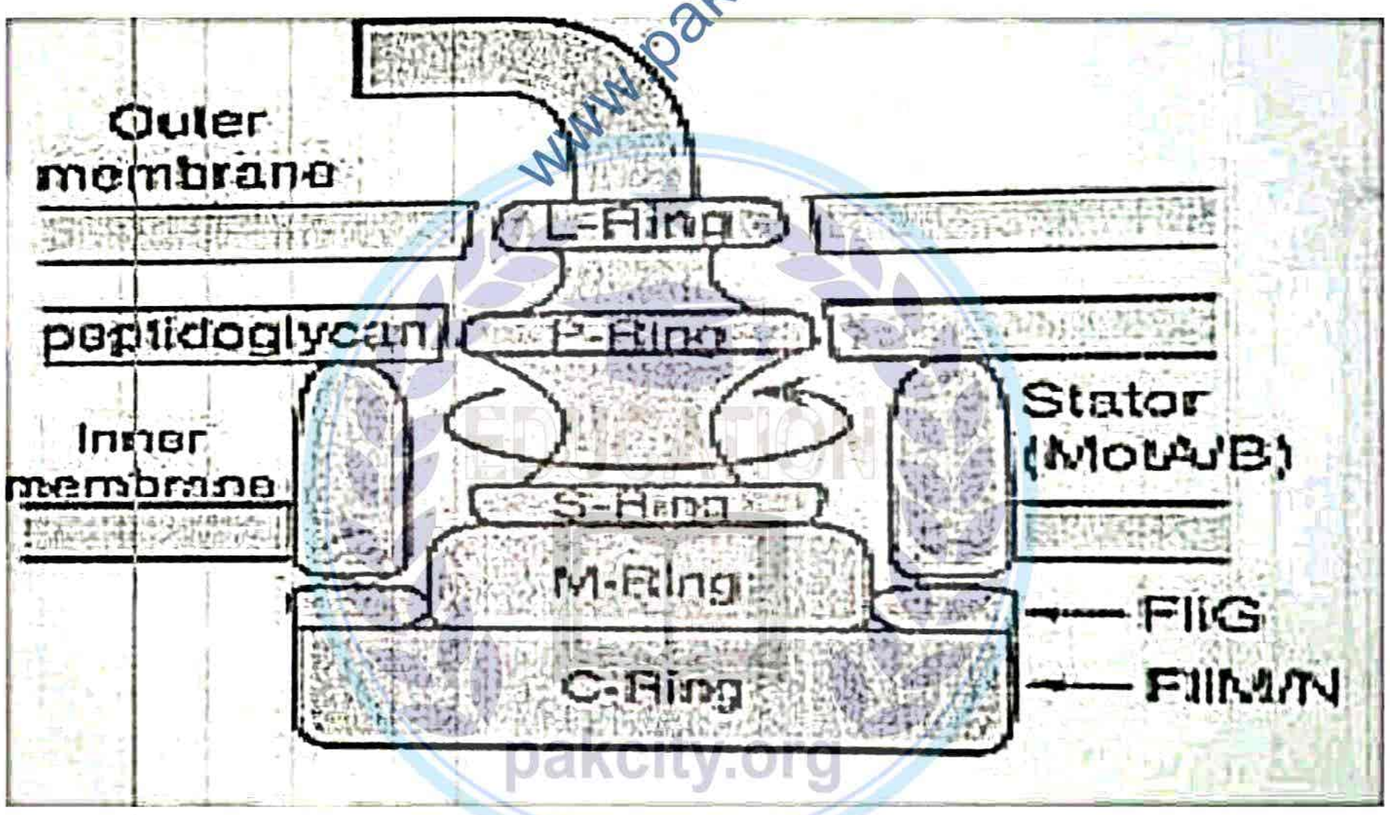
2. Hook.
3. Filament.



1. BASAL BODY:

- It is the motor portion, attached to the cell wall and cytoplasmic membrane.
- It consists of rings surrounded by a pair of proteins called motility protein B (MotB). The rings include: L-ring, P-ring, C-ring and MS-ring but we will discuss C-ring only.

C-ring: Anchored in the cytoplasm, proteinaceous, cup shaped structure and work as the rotor of the motor.



2. HOOK:

- It is a broader area present at the base of the filament.
- Connects filament to the motor protein in the base.
- The hook length is greater in gram +ve bacteria.

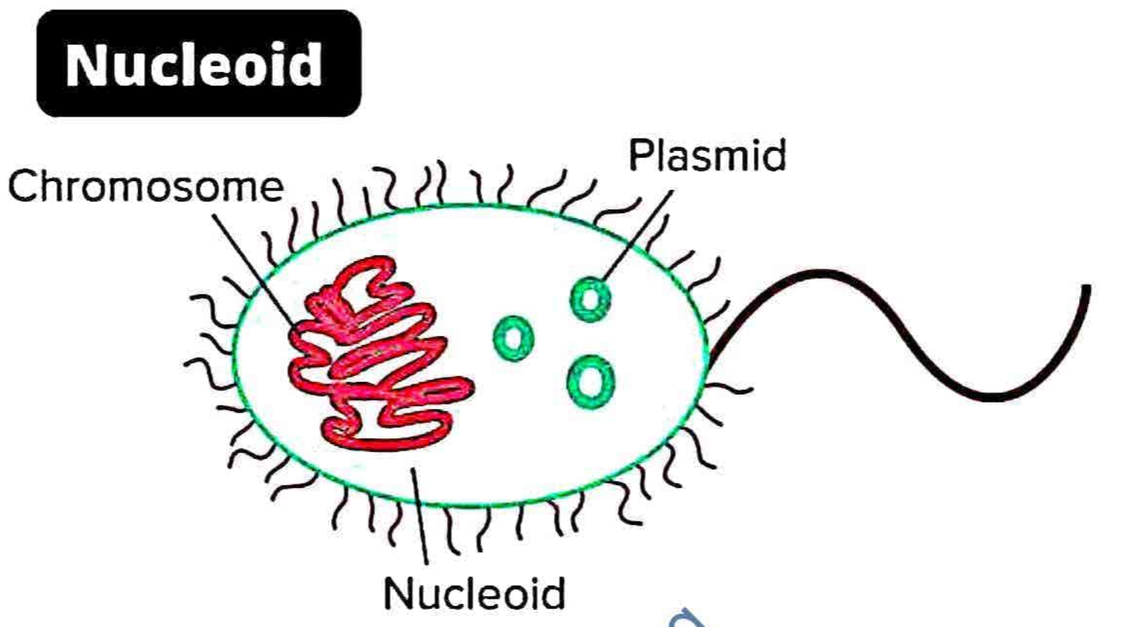
3. FILAMENT:

- Thin hair-like structure arising from the hook.

GENOMIC ORGANIZATION OF BACTERIA:

- Bacterial genome is composed of single chromosome.
- It is one long, single double helical supercoil DNA molecule.
- In most bacteria this DNA is circular.

- In bacterial DNA 3500 genes are present.
- The bacterial chromosome is not enclosed within the nuclear membrane.
- Located in the cytoplasm of the bacterial cells which is known as nucleoid.
- Nucleoid differs from the nucleus in lacking any membrane.
- A nucleoid occupies around one-third space of the entire bacterial cell.
- In many bacteria extra chromosomal circular DNA is also present known as plasmid.
- Plasmid has 5 to 100 genes.
- Plasmid does not take part in reproduction, it produces antibiotic resistance power in bacteria.
- Plasmid also use in the genetic engineering for rDNA synthesis.



MODES OF NUTRITION:

Bacteria can be divided into two types autotrophic and heterotrophic.

1. AUTOTROPHIC BACTERIA:

a. PHOTOAUTOTROPHIC BACTERIA:

- They contain chlorophyll (chlorobium) so they can pr by solar using energy.
- Photosynthesis in bacteria differs from other green plants because there is no release of oxygen instead they release sulphur.
- Such photosynthesis is called anoxygenic photosynthesis.

$$CO_2 + H_2S \longrightarrow C_6H_{12}O_6 + S$$

i. GREEN SULPHUR BACTERIA:

Green sulphur bacteria is yellow green or brown in color. They have chlorobium or bacteriochlorophyll c, d, a which is located in chlorosome-and plasma membrane. E.g. Chlorobium

ii. PURPLE SULPHUR BACTERIA:

Purple sulphur bacteria is purple or reddish brown in color. They have bacteriochlorophyll a or b which is present in chromatophore and plasma membrane. E.g. Chromatium

iii. NON-SULPHUR BACTERIA:

They are non sulphur bacteria because they don't release sulphur as a byproduct instead they release hydrogen. They also have bacteriochlorophyll. E.g. Rhodopseudomonas.

b- CHEMOAUTOTROPHIC:

These bacteria prepare their food by using chemical energy in the absence of photosynthetic pigment. This process is called chemosynthesis. It is of following types:

i. SULPHUR BACTERIA:

They oxidize Sulphur or H_2S compounds. E.g. Thiobacillus

$$2H_2S \text{ or } S_2 + O_2 \longrightarrow 2S + 2H_2O + \text{energy}$$

ii. IRON BACTERIA:

iron bacteria oxidize ferrous Fe^{2+} or Fe^{3+} compounds.

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

Example: Thiobacillus, Ferrobacillus, etc.

iii. HYDROGEN BACTERIA:

They oxidize molecular hydrogen. E.g. Hydrogenomonas, Pseudomonas

$$2H_2 + O_2 \longrightarrow 2H_2O + \text{Energy}$$

$$4H_2 + CO_2 \longrightarrow 2H_2O + CH_4 + \text{Energy}$$

iv. METHANE BACTERIA: (Methanomonas)

Methanomonas obtained their energy from the oxidation of methane. The by-products are H_2O and CO_2.

v. NITRIFYING BACTERIA:

They oxidize nitrogen compound into nitrates.

$$2NO_2 + O_2 \longrightarrow 2NO_3 + \text{Energy}$$

Example: Nitrobacter, Nitrosomonas

vi. CARBON BACTERIA:

These types of bacteria oxidize CO into CO_2

$$2CO + O_2 \longrightarrow 2CO_2 + \text{Energy}$$

Example: Bacillus oligocarbophillous

2. HETEROTROPHIC BACTERIA:

These bacteria cannot prepare their food themselves. They obtain their food or nutrition from an outside source.

It is of following types:

A. SAPROTROPHIC BACTERIA:

- These bacteria depend on the dead organic matter, excreta and dead plants for their nutrition.
- They secrete enzymes that break down complex organic compounds into simpler products.
- They are mostly present in the humus (the organic component of soil formed by the decomposition of leaves and other plants materials by the micro-organism).

Examples of these types of bacteria are Bacillus mycides, Acetobacter, etc.

B. PARASITIC BACTERIA:

- These bacteria grow inside the tissues of other living organism.
- They obtain food at the expense of their host.
- Some parasitic bacteria cause diseases, and they are called pathogenic bacteria, while others do not cause diseases but harm the host.
- These bacteria lack certain complex system of enzymes therefore they usually depend upon host cell.
- Example: Vibrio cholerae, Diplococcus pneumoniae, Mycobacterium tuberculosis, Salmonella typhi etc.

C. SYMBIOTIC BACTERIA:

- These bacteria are found in mutual association with other living organism.
- They obtain their food from the host without harming it.
- Symbiotic bacteria fix free atmospheric nitrogen into nitrogenous,compounds which are utilized by the plants, and in return, the plant gives nutrients and protection to the bacteria.
- Rizobium redicicola symbionts in the root nodules of pea family plants.

DIFFERENCE BETWEEN CYANOBACTERIA AND OTHER BACTERIA PHOTOSYNTHESIS:

Character	Bacteria	Cyanobacteria
Nutrition	Maybe autotrophic or heterotrophic.	Usually autotrophic
Photosynthetc Pigments	bacteriochlorophyll	chlorophyll a
Accessory pigments	Absent	Present (phycocyanin and phycoerythrin)
Reserve food	Glycogen	Cyanophycean starch
Hydrogen donor	During photosynthesis H^+ donor is not H_2O, as a result, oxygen is not evolved and photosynthesis is anoxygenic.	The H^+ donor is H_2O, oxygen is released. The process is oxygenic.

GROWTH AND REPRODUCTION:

Bacterial growth can be divided into four main phases, which are as follows;

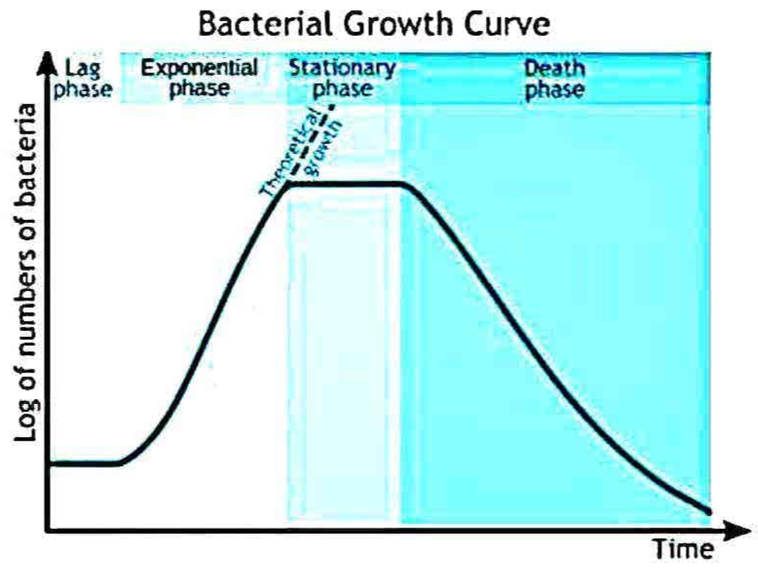
i. Lag Phase (no growth): It is inactive phase during which bacteria prepare them for division.

ii. Log Phase (rapid growth): In this phase bacteria grow and multiply very rapidly.

iii. Stationary Phase (equal death and birth): In this phase bacterial multiplication is equal to bacteria death rate.

iv. Decline (extra death): In this phase death is more rapid then multiplication rate.

• There is no typical sexual reproduction and mitosis in bacteria. In some bacteria, the genetic material is transferred from one bacterium to another through genetic recombination.



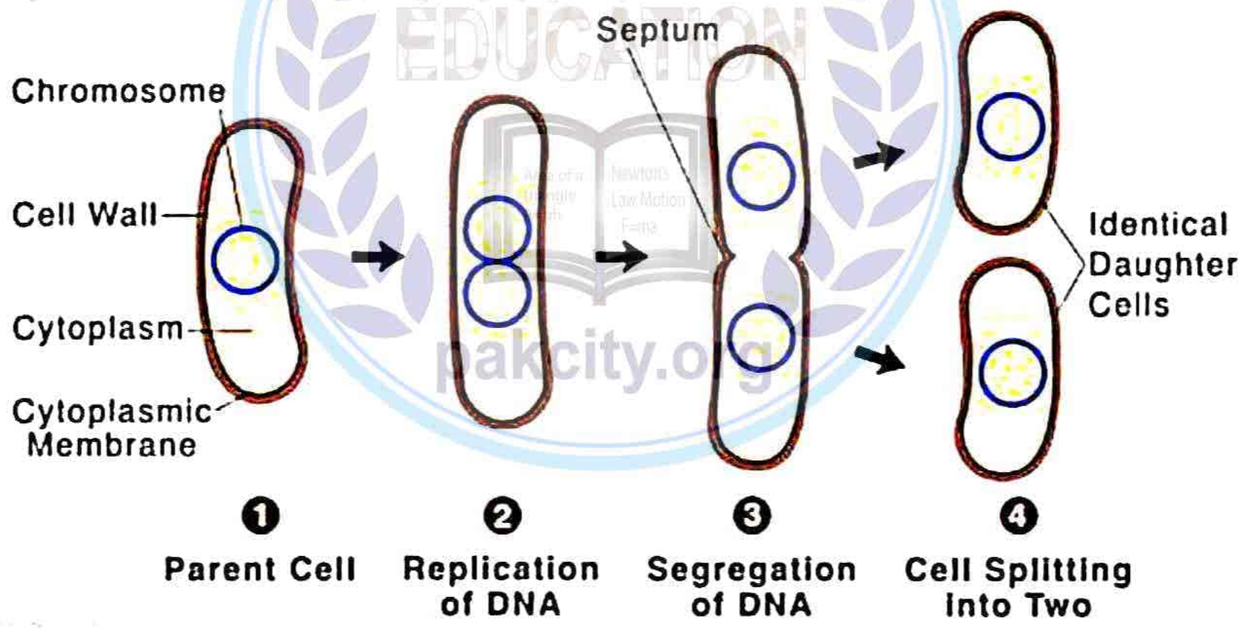
REPRODUCTION IN BACTERIA:

• Growth means increase in number of cells and increase of volume.
• While in case of bacterial cell, it is increased in number of bacteria.
• It is considered as reproduction in bacteria.
• In favorable conditions bacteria can grow very rapidly.
• The common type of asexual reproduction is binary fission.

ASEXUAL REPRODUCTION:

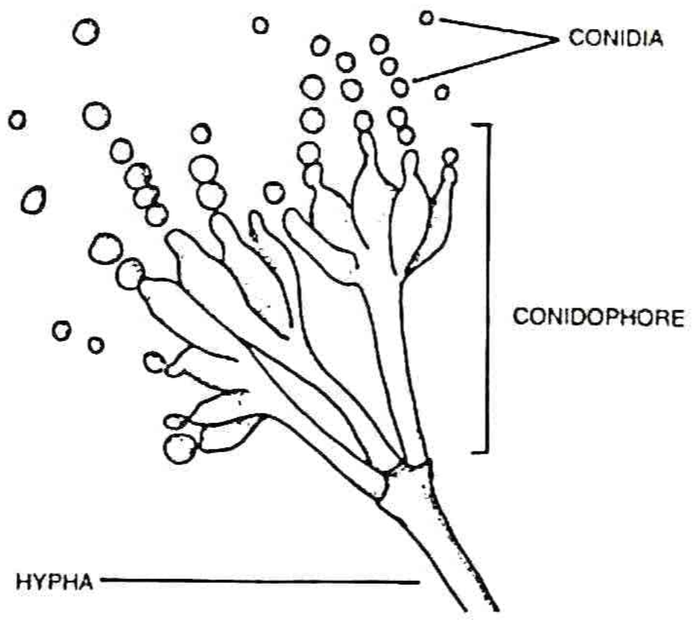
FISSION:

• Binary fission is the fastest mode of bacterial asexual reproduction.
• It usually takes place in favorable conditions.
• Hereditary material DNA in the form of chromatin body replicates. After the replication of hereditary material, a constriction appears in the middle of the cell, which later splits it into two parts.
• Newly form bacterial cells grow in size and form mature bacterial cells.
• The single fission takes place in 20-30 minutes.



CONIDIA FORMATION:

• It is another method of asexual reproduction in which a small spore (conidia) is formed in filamentous bacteria such as Streptomyces.
• Conidia is formed on the conidiophore filament.
• It is on maturity separated from the parent cell and start germination and develop into new bacterium.



BUDDING:

- A small outgrowth develops on the cell surface of cyanobacteria which gradually increase in size.
- This outgrowth is known as bud.
- After separation from the parent body it develops into new bacterium.

E.g. Hyphomicrobium vulgare, Rhodomicrobium vannielia.

MUTATION AND GENETIC RECOMBINATION IN BACTERIA:

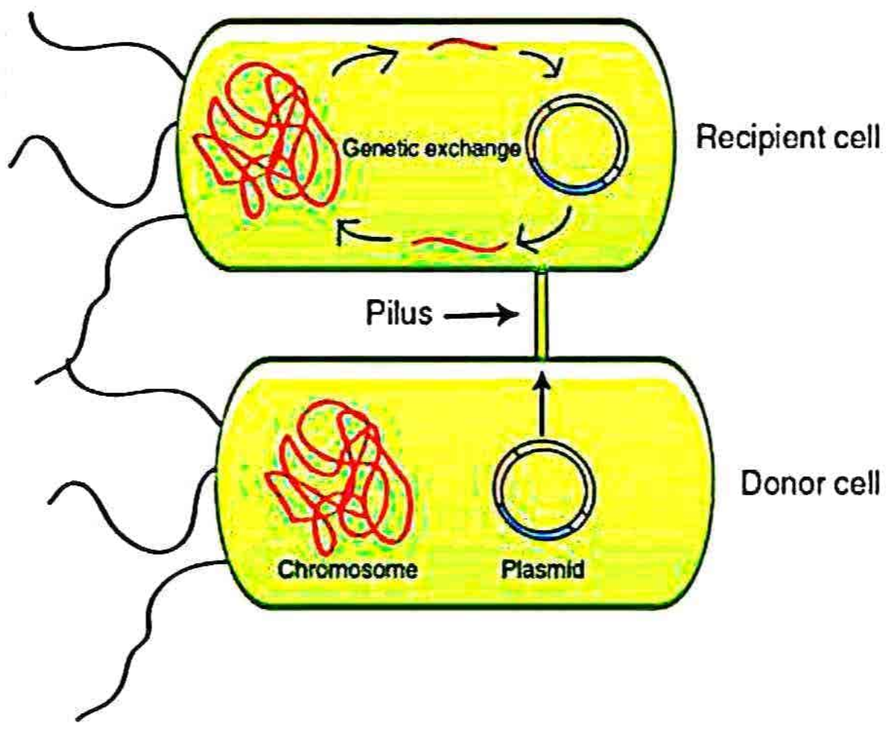
- The joining together genetic material is known as genetic recombination.
- Genetic recombination results in genetic changes with the help of which bacteria adopt new characteristics such as drugs resistance pathogenic ability.

THREE TYPES OF GENETIC RECOMBINATION:

i. CONJUGATION:

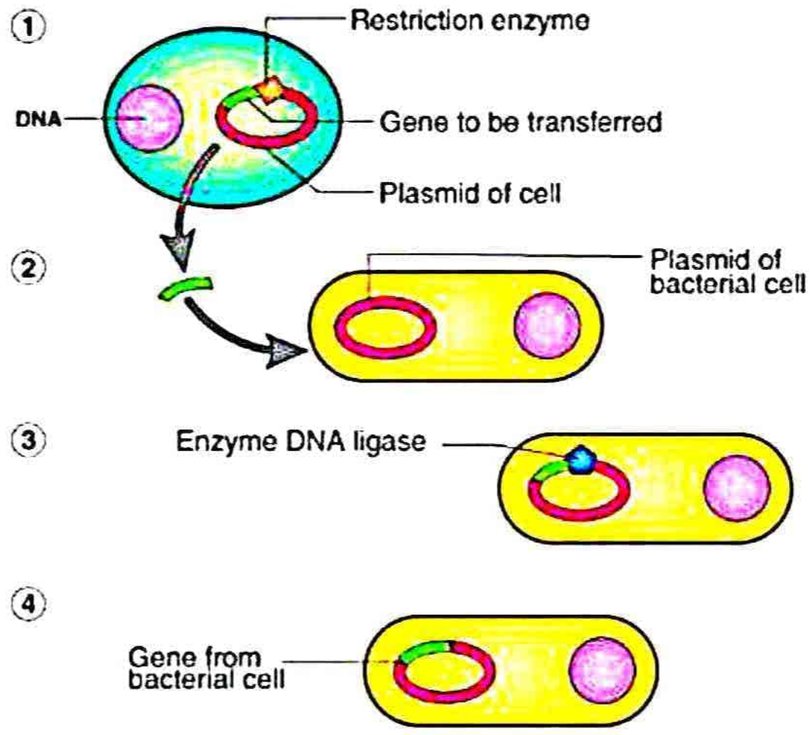
Simple process of genetic recombination in which genetic material is transferred from one bacterium to another through a conjugating tube or cytoplasmic bridge. Conjugation in bacteria was discovered by Joshua Lederburg and Edward L.Tatum in 1946".

Conjugation



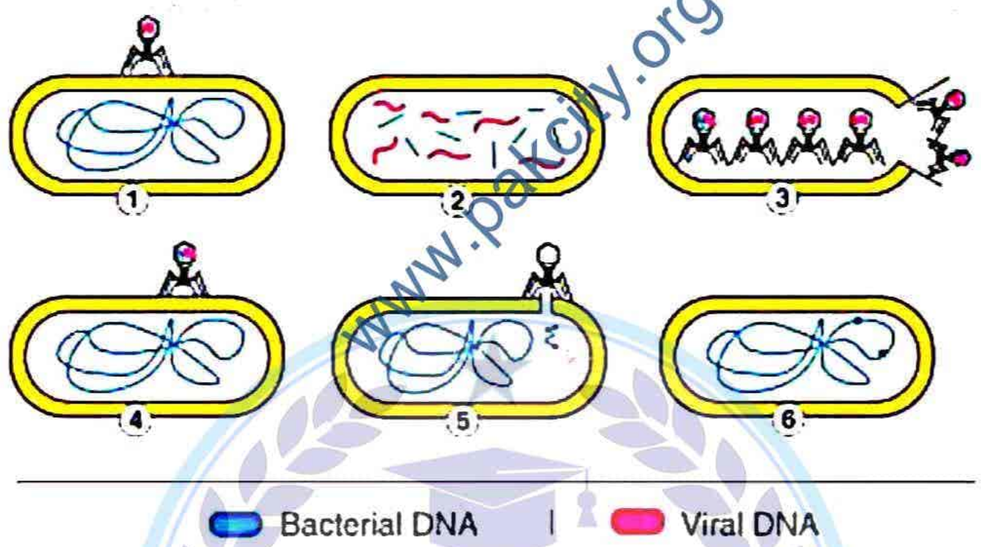
ii. TRANSFORMATION:

In this process, genetic information transfers from one bacterium to another by producing a change in it. This type of genetic recombination was first proved by Fred Griffith in 1928.



iii. TRANSDUCTION:

It is the mode of genetic recombination in which genetic material is transferred from one bacterium to another by a third party, which is usually bacteriophage. This process was experimentally carried out by Lederberg and Zinder in 1952.



IMPORTANCE OF BACTERIA:

A. USEFUL BACTERIA:

1) DECOMPOSER:

- Bacteria decompose various dead organic compounds into simple forms such as nitrates, sulphates, phosphates etc.
- These decomposed compounds again utilized by plants hence bacteria recycling compounds or chemicals.
- Nitrifying bacteria present in soil converts proteins of the dead bodies into nitrates so they increase the fertility of soil.

NH4+ ammonium N

↓

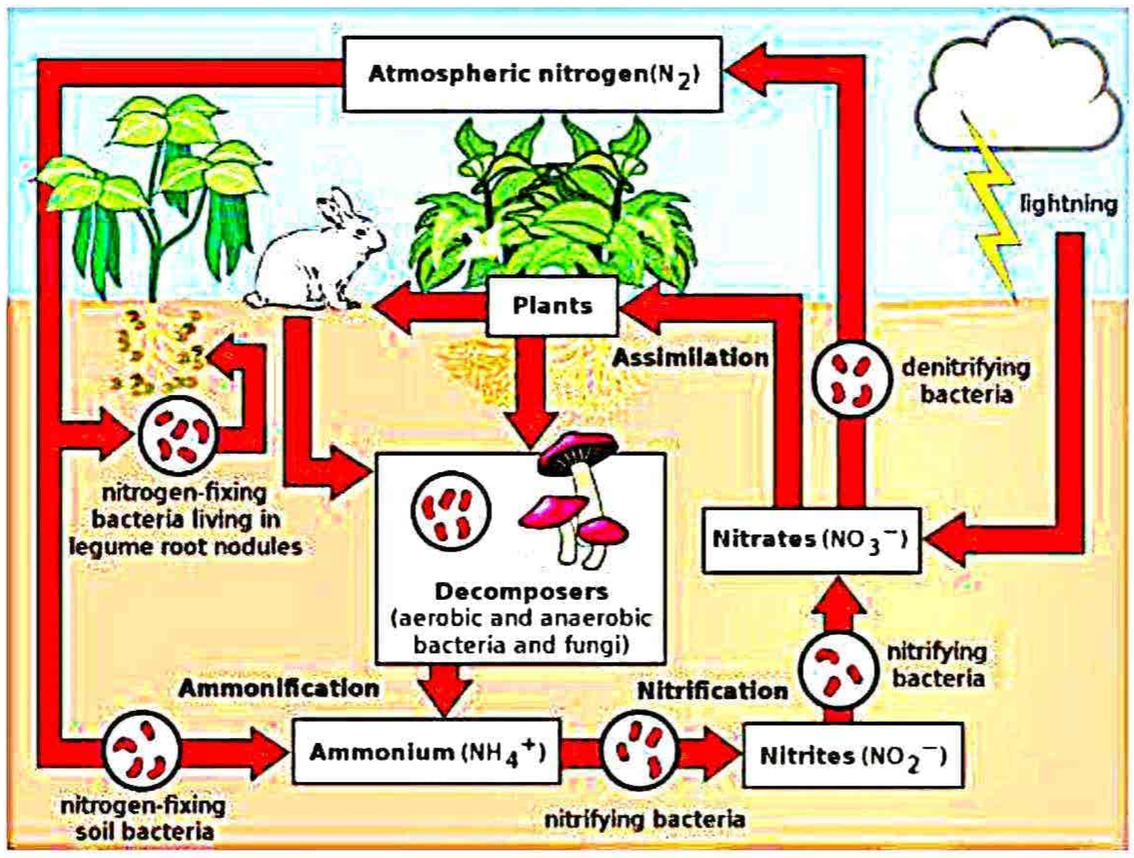
Nitrosomon

NO_2-(nitrite)

↓

Nitrobacter

NO3-(nitrate)



2) ALIMENTARY CANAL BACTERIA:

These bacteria contain Cellulase enzyme which digest the cellulose in herbivorous animals.

3) INDUSTRIAL BACTERIA:

Symbiotic bacteria are used in industries for,

- Ripening of tobacco leaves.
- Ripening of cheese.
- Fermentation of sugar into alcohol (chemical break down of substance by bacteria) Curdling of milk.
- Retting of fibers (softening).

Conversion of hides (tough skin of animals) into leather.

4) PHARMACEUTICAL BACTERIA:

Some drugs are obtained from bacteria such as,

- Tyrothricin is an antibiotic mixture which was isolated from Bacillus brevis.
- Subtilisin is a protease initially obtained from Bacillus subtilis.
- Riboflavin vitamin produce by Clostridium.

5) GENETICALLY ENGINEERED BACTERIA:

Genetically modified E. coli use for Growth hormone and insulin synthesis.

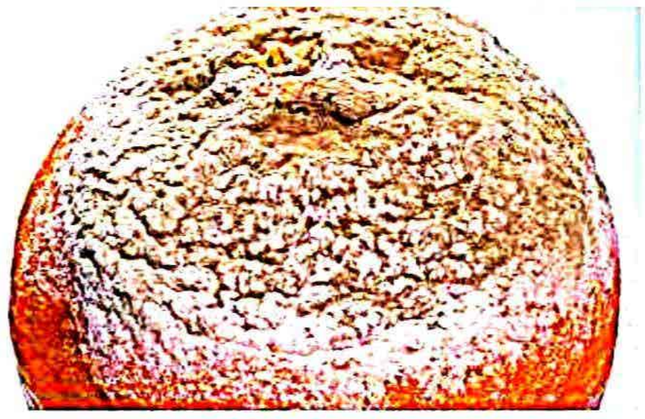
HARMFUL BACTERIA:

1) PATHOGENIC BACTERIA:

Pathogenic bacteria cause various diseases in human such as Botulism caused by clostridium botulinum and in plants such as black rot of cabbage.

2) FOOD SPOILAGE:

Bacteria spoil food by decomposition and fermentation.



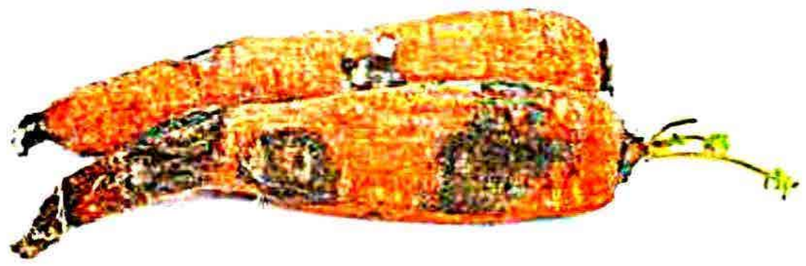
BACTERIAL DISEASES IN HUMAN:

DISEASE	CAUSES	SIGNS AND SYMPTOMS	TREATMENT AND PREVENTION
Cholera	Vibrio cholera	Vomiting, diarrhea, sleepiness, lethargy, dehydration, cramps, electrolyte imbalance, dry skin	hydration, antibiotics
Typhoid	Salmonella typhi	Fever, skin rash, weakness, abdominal pain, constipation, headache	Hands wash, drink clear water, cook well food, use antibiotics
Tuberculosis	Mycobacterium tuberculosis	fever, cough with phlegm chill, night sweats, loss appetite, and weight loss	Follow safety measures and use antibiotics such rifampin
Pneumonia	Klebsiella pneumonia	fever, chest pain, cough with blood and mucus, night chills, sweating, chest pain, fatigue, loss of appetite, vomiting, Headache	Hands wash, drink clear water, cook well food, vaccine and antibiotics

BACTERIAL DISEASES IN PLANTS:

Disease	Causes	Signs and symptoms	Treatment and prevention
Leaf Spot	Pseudomonas and Xanthomonas	Necrosis, black marks on leaf, shoot, bud and flower	Spray bacteriocide, use of pathogen free seeds

Soft Rot	**Erwinia carotovora**	**Maceration of plants tissues**	**Use germs free seeds, weeds control, protect plant from bruising**



Wilt disease	Erwinia tracheiphila	Wilting, plants die due to vessels blockage	Insecticides, beetle control

ACTERIAL FLORA OF HUMAN BODY:

Flora is collective term for bacteria or other organisms found in human body. About 100 trillion bacteria are found in human that form the normal flora.

NORMAL FLORA:

- The mixture of microorganisms (bacteria, fungi and protists) that not cause any disease in animals and human are known as normal flora.
- These are mostly found on surface tissues such as skin and mucus membrane.

SIGNIFICANCE OF THE NORMAL FLORA:

Antagonize: Normal flora prevents other pathogens to invade human body.

Immunostimulant: Normal flora behaves as antigen in human body hence stimulate antibodies production.

Nutrients: Some normal flora produces vitamins such as vitamin K and B12 by E col.

CONTROL OF HARMFUL BACTERIA:

A-CHEMICAL METHOD TO CONTROL HARMFUL BACTERIA:

The growth of bacteria may be controlled by the treatment of different chemicals. These chemicals may be used to inhibit the growth of bacteria on dead materials and living materials, in other words to kill saprophytes and parasites. There are three types of treatment, antiseptic, antibiotics, disinfectant and antimicrobial chemicals.

1. Sterilization:

Sterilization describes a process that destroys or eliminates all forms of microbial life.

2. Disinfectant:

Disinfection is the elimination of microorganisms from inanimate objects or surfaces. Following types of disinfectant used;

a. Phenol: phenolic compounds act primarily against Gram-positive and to a lesser extent on Gram-negative. It is effective at concentrations of 0.1%-1%. E.g. flavonoids.
b. Halogens: These include bleach, chlorine, and iodine.

Heavy metals:

IODINE:
- Iodine is widely used as a skin disinfectant (antiseptic).
- It is active against bacteria, fungi and viruses etc. For Example: Betadine.

CHLORINE:
- Chlorine is used as disinfectants in microbiology laborites, hospital water sup swimming pools etc.
- Chlorine is commonly used as hypoclorites.
- Chlorine hypoclorites are markedly bactericidal.

They have a wide spectrum of action against viruses.

c. HEAVY METALS:
- Include copper, selenium, mercury, silver, and zinc.
- Very tiny amounts are effective.

SILVER:
- 1% silver nitrate used to protect infects against gonorrhoeal eye infections, now has been replaced by erythromycin.

MERCURY:
- Organic mercury compounds like merthiolate and mercurochrome are used to disinfect skin wounds.

COPPER:
- Copper sulfate is used to kill algae in pools and fish tanks.

d. SOAPS AND DETERGENTS:
- Soap and detergent remove the bacteria from the surfaces of our hands and cloths by decreasing the surface tension.

e. ALDEHYDES:
- Include some of the most effective antimicrobials.
- Inactivate proteins by forming covalent crosslinks with several functional groups.

FORMALDEHYDE:
- Excellent disinfectant, 2% aqueous solution.
- Commonly used as formalin, a 37% aqueous solution.
- Formalin was used extensivelyto preserve biological specimens and inactive viruses and bacteria in vaccines.
- Irritates mucous membranes, strong odor.

GLUTARALDEHYDE:

- Less irritating and more effective than formaldehyde.

f. ETHYLENE OXIDE:

- Kills all microbes and endospores, but requires exposure of 4 to 18 hours.
- 4 Commonly used to disinfect hospital instruments.

g. OXIDIZING AGENTS:

- Oxidizing agents such as hydrogen peroxide kill microorganisms by releasing large amounts of oxygen, which contributes to the alternation of microbial enzymes.

h. FOOD PRESERVATIVE:

- Foods can be preserved by using a number of organic acids to maintain a low microbial population. Benzoic acid, Sorbic acid etc.

THE USE OF ANTIBIOTICS:

Antibiotics are compound that are mostly derived from biosynthesis of other microorganisms, Streptomyces and penicillium are two organisms which have given us antiobiotics Antiobiotics act in different ways to kill microorganisms like.

- Antibiotics that inhibit cell wall synthesis.
- Antibiotics that inhibit protein synthesis.
- Antibiotics that inhibit nucleic Acid Synthesis or DNA replication.
- Antibiotics that interfere with Metabolic Pathways.

B. PHYSICAL METHOD TO CONTROL HARMFUL BACTERIA:

BOILING: On boiling at 100°C bacterial protein and all membrane denatures ultimately destroy bacteria.

DRY HEAT OVEN: Heating bacteria at 170°C for 2 hours in oven denature bacterial protein and cell membrane.

FUEINERATION: Destroying bacteria by burning.

AUTO CLAVE: Killing bacteria by heating at 121°C for 15-40 minutes.

PASTEURIZATION: Killing bacteria at ultra high temperature heating at 72°C for 15 records and similarly at 138°C
for 2 seconds destroy bacteria in milk, apple Juice, honey.

REFRIGERATION: Keeping temperature b/w 0-7°C inhibit the growth and metabolism of bacteria.

FREEZING: Temperature bellow O°C or at -2°C inhibit the metabolism of bacteria at freezing temperature bacteria destroy.

HIGH PRESSURE PROCESSING: In this process food is exposed to high pressure i.e. 100-800 Mpa, at this pressure bacteria denature.

HYPER BACTERIA OXYGEN THERAPY: In this process patient is exposed to pure oxygen at 1-3 pressure for several house. It is helpful for killing anaerobic bacteria. Ex: gas gangrene

SIMPLE DESICATION: Removing water from food staff helpful in stopping the metabolism of micro organisms and resulted in the lysims of cell.

LYSOPHILIZATION: Is low temperature dehydration process. In this technique freezing product and lowering pressure, which inhibit the metabolism of bacteria.

IONIZING RADIATION: X-rays or gamma rays are ionizing radiation used in bacterial conduct. X-rays altered the DNA strands and molecular structure of bacteria and resulted in the killing of bacteria.

MEMBRAME FILTERATION: This process used for heart sensitive solutions like vitamins. In this process a filtering membrane of 0.2 um used for removing bacteria.

NO IONIZING RADIATIONS: Ultraviolet rays from rm used for removing bacteria.

DIFFERENCE BETWEEN LYSOSOME AND MESOSOME:

LYSOSOME	MESOSOME
It is found in eukaryotes only	It is found in prokaryotes only.
It is a vesicle evolved from Golgi complex involved in digestion and defence etc.	It is membrane like structure evolved from cell membrane involved in cell respiration and division.

DIFFERENCE BETWEEN AUTOTROPY AND HETEROTROPY

AUTOTROPY	HETEROTROPY
Mechanism in which organisms prepare their own food by themselves using simple molecules.	Mechanism in which organisms depend upon other organisms for their food.
Photosynthesis and chemosynthesis bacteria.	Saprotrophic and parasitic bacteria.

DIFFERENCE BETWEEN PHOTOSYNTHESIS BACTERIA AND CHEMOSYNTHETIC BACTERIA:

PHOTOSYNTHESIS BACTERIA	CHEMOSYNTHETIC BACTERIA
These bacteria synthesis their food by the process of photosynthesis.	These bacteria can oxidize inorganic compounds like ammonia, nitrate, nitrite, sulphur or ferrous iron. As a result energy is released which is used for their synthetic reactions.
Green sulphur bacteria, purple sulphur bacteria and purple non-sulphur bacteria photosynthesis bacteria.	Nitrifying bacteria are Chemosynthetic

DIFFERENCE BETWEEN PROKARYOTES AND EUKARYOTES:

PROKARYOTES	EUKARYOTES
These cells have no membrane bounded nucleus e.g. bacteria.	These cells have membrane bounded nucleus e.g. animal, plant cells

These cells do not have double membranous structures e.g. Golgi complex, mitochondria etc.	These cells have double membranous structures e.g. Golgi complex, mitochondria etc.

DIFFERENCE BETWEEN CHEMOTAXIS AND PHOTOTAXIS:

CHEMOTAXIS	PHOTOTAXIS
They also help to detect and move in response to chemical signals (stimulus) like food, wastes, poisons etc. This type of behaviour is called as chemotaxis.	Sometime bacteria show movement toward optimal light concentration or away from strong light. This type of behaviour to light stimuli is called phototaxis.

DIFFERENCE BETWEEN CYANOBACTERIA AND PLANTS:

CYANOBACTERIA	PLANTS
Oxygenic photosynthesis.	Oxygenic photosynthesis.
Chlorophyll A present.	Chlorophyll A present.
Photosynthetic pigments and electron transport chain components are located in thylakoid.	Photosynthetic pigments and electron transport chain components are located in thylakoid membranes.
Photosystem II is present only.	Photosystem I and II both are present.
Cyanobacteria use phycobilin as accessory pigments.	Plants use carotenoids, xanthophylls etc as accessory pigments.

DIFFERENCE BETWEEN SPORE AND CYST:

SPORE	CYST
The metabolically dormant (inactive) bodies with thick wall are called spores.	Cyst are domant, thick-walled and desiccating resistant structure.
They are produced at later stages of growth.	They develop during differentiation of vegetative cells.
Spores are resistance to adverse environmental conditions like light, hight temperature, desiccation, pH and chemical agent.	They are not heat resistant.
They grow under favourable conditions and form new vegetative cells.	Such cells germinate only under suitable conditions.

DIFFERENCE BETWEEN FLAGELLA AND PILLI:

FLAGELLA	PILLI
Flagella are larger than flagella.	Pili are smaller than flagella.
It is a structure just beneath the cell membrane in the cytoplasm. The flagella originate from basal body.	These are hollow, nonhelical, filamentous appendages.
Flagella are made up of protein Flagellin.	They are made up of special protein called pillin.
Most of bacilli and spiral shaped bacteria have flagella, Cocci very rarely have flagella.	True pili are only present on gram-negative bacteria.

Primary function of flagella is to help in motility They also help to detect and move in response to chemical signals (stimulus). It is a type of behavior called as chemotaxis.	Pili are not involved in motility. They are involved in mating process called conjugation some pili are used for attachment of bacteria to various surfaces.

DIFFERENCE BETWEEN NUCLEOID, PLASMID AND NUCLEUS:

NUCLEOID	PLASMID	NUCLEUS
Nuclear material or DNA of bacteria aggregates to form irregular shaped dense body called Nucleoid.	Bacteria have many self replicative, semiautonomous DNA rings.	It is membranous bound organelle present in eukaryotes.
Nuclear membrane absent.	Nuclear membrane absent.	Nuclear membrane is present.
Nucleoid has very long molecule of DNA. This DNA is tightly folded and fit inside cell components and controls cell metabolic activities.	They are not essential for bacterial growth and metabolism. They contain drug resistant, heavy metals, disease and insect resistant genes. In the modern genetic engineering techniques plasmids are important vectors.	DNA is also present. DNA forms many chromosomes that control all cellular functions.
Its nuclear material is composed of single, circular and double stranded	It is extra-chromosomal, many circular-and double stranded DNA molecule.	No circular DNA.

DIFFERENCE BETWEEN CAPSULE AND SLIME:

CAPSULE	SLIME
Some bacteria produce capsule.	It is present in some bacteria.
It is tightly bound to the cell.	It is a loose, soluble cover of macromolecules called slime.
It has a thicker, gummy nature that gives sticky characters to the colonies of encapsulated bacteria.	Slime provides greater pathogenicity to bacteria and protects them against phagocytosis.
Capsule is made up of repeating polysaccharide unis, or of protein, or of both.	It is made up of lipids and protein usually.