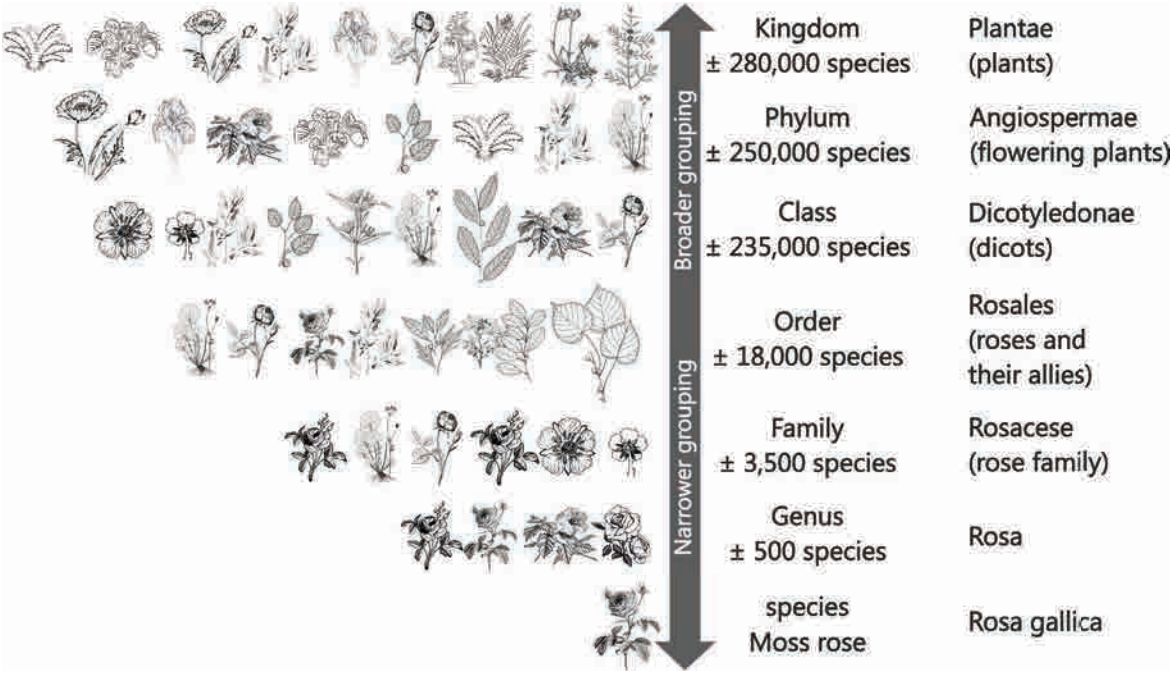
CHAPTER 2

BIOLOGICAL CLASSIFICATION - PART 1

Topics Discussed

1. Introduction

The scientist than realized the importance and purpose of the classification. Though there were many approaches for classification all were in vain and no results came out. The reason being that the basis for classification was random and not universal without linking it to the scientific logic. Aristotle was the initiator for scientific classification of organisms. The criteria he chose for classification were morphological characters for plants and blood colour for animals.



Objective for this Chapter

At the end of this chapter, you will be able to:

- Describe the reasons for classification.
- Relate earlier taxonomy to present taxonomy methods.
- Realize the emergence of the present classification system.
- Evaluate the work of major scientist with respect to their classification systems.
- Evaluate the organisms as per their characters.
- Categorise various organisms under Monera Kingdom.
- Model several features of classified organisms easily.

2. Systems of Classification

Earlier at the dawn of the classification systems, the basis for classification was only the habitat and external morphological characters of the organisms. However later with development in science, taxonomist used various other basis of classification like natural affinity, and even phylogeny (evolutionary tendencies).

The systems were divided into three major categories. They are as follows:

2.1 Artificial System of Classification

The classification system used one / few external or morphological characters of the organisms for differentiating with few exceptions in classification by using even habitats of the organisms.

Artificial classification system use habitat as the basis e.g., Theophrastus system for classification.

Mechanical systems for classification are dependent on selected characters that are morphological type e.g. Linnaeus system.

Practical classification are the ones involving both plants and animals on the basis of their importance and use in man's life.

Setback points

- The characters of organisms considered here were limited and led to few divisions for classification.
- Classification system failed to consider the phylogenetic relationships between the organisms.
- The genetic traits used here were not the constant, but the variable one that changed according to the environment.

KNOWLEDGE BUILDER

- Pliny and Elder classified animals as flighted and non flighted ones giving first ever artificial classification system.
- Manu used the same basis for plants.
- Theophrastus used habitat, form and texture as the basis to classify 480 plant species into four group herbs, undershrub, shrubs and trees.
- Aristotle classified animals as anaima (vertebrates having no RBC) and enaima (vertebrates having RBC).
- Linnaeus classified another artificial system of classification that was called as sexual system of classification and divided plants into 24 classes.

2.2 Natural Systems for Classification

These classification systems were based on the taxonomic characters and on natural affinities of the organisms. The usual characters used for classification of organisms are reproductive, morphological and anatomical in nature. The branch dealing with the classification based on the biochemicals in the cell of an organism for taxonomy is called as chemotaxonomy. This system reveals the origin of the organism and their evolutionary relationship.

Artificial and natural system of classification were dependent on fixed number of organisms and no new species were included. Thus, they are the static classification systems with no change in them.

2.3 Phylogenetic Systems for Classification

The system classifies organisms on evolutionary and genetic relationship between them. The system here changes with time and thus, is called as dynamic system for classification.

- Endlicher and Eichler were botanist who first proposed a phylogenetic classification system.
- Engler and Prantl modified their work and published in a book which was first fully developed phylogenetic system.

The phylogeny system is the most important one for classification that is used by many scientist.

2.4 Phenetic System for Classification

Recently, few additional criteria and methodologies are used efficiently in classifying organisms. This ensures that the difficulties are avoided in establishing evolutionary relationships that are difficult and controversial, particularly when the fossil evidences are not in place.

2.4.1 Numerical Taxonomy or Phonetics

- The numerical technique for evolution that included both similarities and differences between the species are the basis.
- Calculators and computers are used for this technique. All possible characters known are used for comparison.
- All characters have equal importance and weightage for the analysis purpose.
- Here data for many characteristics are defined statistically and objectively, then taken into consideration.
- Then codes are assigned to each data on computers, then denoted with plus (+) and minus (-) or data not available (θ).

2.4.2 Cladistic (Phylogenetic) Taxonomy

- It classifies living being into evolutionary historical order in which the branches of organism arose.
- Here the taxonomy affinity for the organisms is based on evolutionary as well as genetic relationships among them apart from their morphology.
- From this system, origin of new systematics (Sir Julian Huxley 1940) or biosystematics occurred.
- Similar characters in the organisms that arose from common ancestor of an entire group or species are called as the ancestral characters.
- The similar character that arose from different group are termed as derived characters.
- In Cladistic method only shared derived characters are considered for the study.

2.4.3 Cytotaxonomy

- It provides cytological information of cell, the chromosome number, the structure etc. It also involves the behaviour and expression of chromosomes during classification.

- Very few species have constant number of chromosomes. Man has the diploid 46 chromosome number and potato has 48 chromosome.
- Size of different chromosome in different herbaceous plants have been found to be larger than woody plants.
- Relationship among different species has become clear with the help of the method of pairing of chromosomes during meiosis.

2.4.4 Chemotaxonomy

- This type of taxonomy utilizes the chemical constituents of plants.
- Such characters like fragrance and taste are stable i.e.do not change easily.
- Other characters of taxonomic value that have importance are presence of calcium oxalate crystals (raphides) and sulphur containing compounds in organisms of family Cruciferae.
- Many similarities and relationships among organisms have been put forth by studies and research on DNA sequencing and chemical nature of proteins.
- Study of chemical characters have greatly further helped the taxonomists in gathering possible relationships and statistical evolution of taxonomic value.

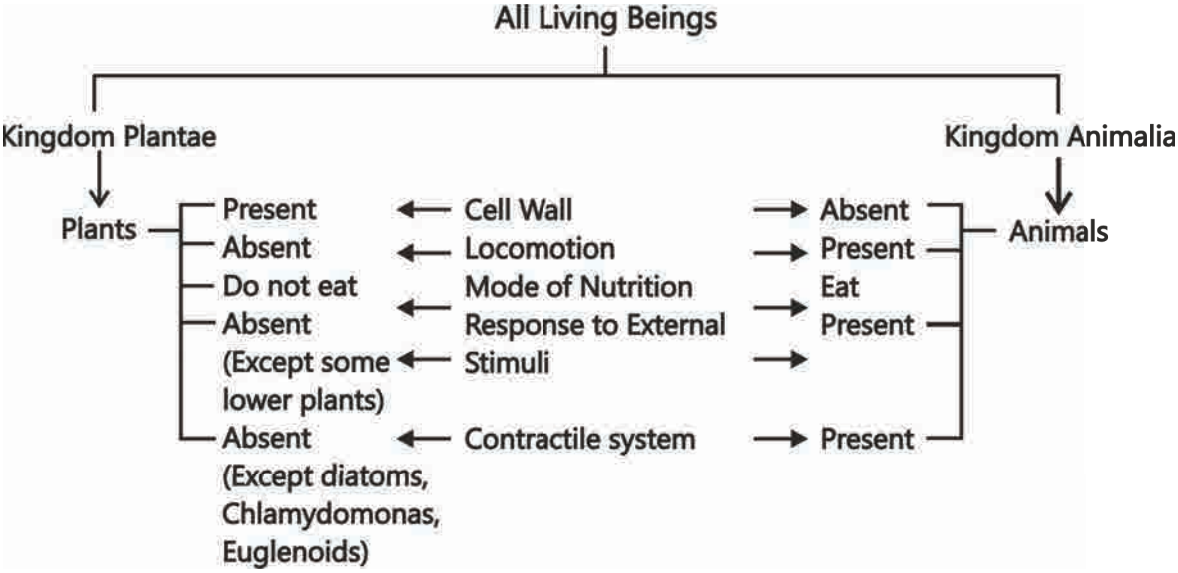
3. Kingdom Systems of Classification

3.1 Two Kingdom Classification

There was a huge list of organisms present without any grouping. Linnaeus was the first naturalist to classify organisms on the basis of their cell structure. The major difference in the organisms was presence and absence of cell wall in the cell. Thus all the organisms of the world were divided into two main kingdoms-the animal kingdom (Animalia) and the plant kingdom (Plantae). Other basis for classification were presence or absence of locomotion, mode of nutrition, response to external stimuli etc. in the organisms.

Drawbacks: This was the first classification that gave many naturalist a hint for further classification of organisms. The problems associated with the two-kingdom system of classification were that:

- Two-kingdom system of classification failed to distinguish between the eukaryotes and prokaryotes, unicellular and multicellular organisms and photosynthetic and non-photosynthetic organisms which made them all come into one single kingdom.
- There are few microorganisms like *Chlamydomonas*, *Euglena* and the slime moulds which belong to both zoology and botany world (organisms which share characteristics of both animals and plants).
- There are few set of organisms that are neither plants nor animals, which made scientist to propose a new kingdom that will include such organisms and their characters.



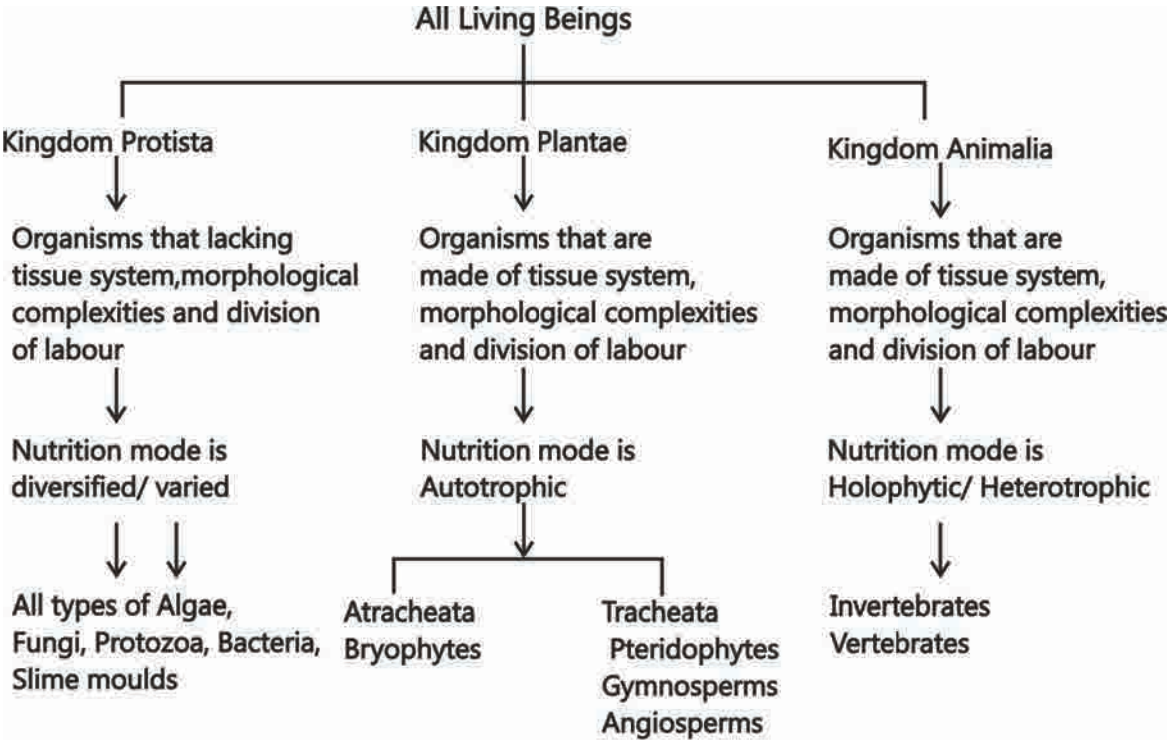
Flowchart 2.1: Two Kingdom classification

3.2 Three Kingdom Classification

To overcome the two kingdom classification problems, Heackel, a German zoologist (1866), suggested that a third kingdom Protista should be created. This kingdom will include all unicellular microorganisms separating multicellular and unicellular organisms.

Drawbacks: The problems faced by three kingdom classification were:

- The organisms with both the characters of animals and plants were in same kingdom.
- The organisms with prokaryotic and eukaryotic nature were in the same kingdom.
- Then also the organisms that were plants and animals but had few different characteristics from the traditional characteristics of plants and animals were placed in same kingdom.



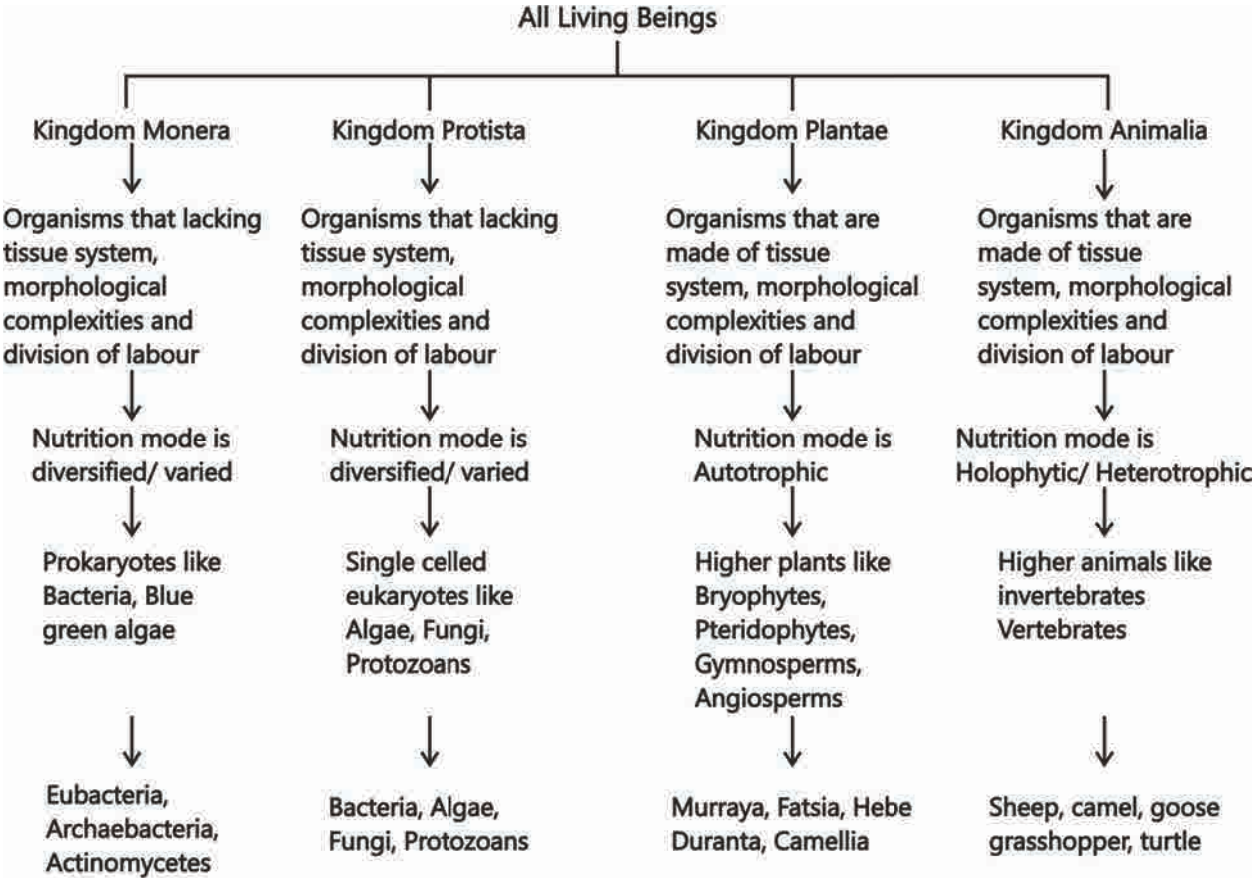
Flowchart 2.2: Three Kingdom classification

3.3 Four Kingdom Classification

Copeland (1956) gave four kingdom of classification to answer all the questions raised from the three kingdom. He included Monera as fourth kingdom that included all the prokaryotes. The kingdom was originally named 'Mychota' then called as 'Monera' by Daugherty and Allen.

Problems faced by Copeland after publishing his classification were:

Though he distinguished the cells on their nature type, there were organisms still as exceptions to the usual organism characters in that particular kingdom. The organisms thus had to be given a separate kingdom.



Flowchart 2.3: Four Kingdom classification

3.4 Five Kingdom Classification

A new concept for classification proposed by R. H. Whittaker (1969), the organisms were divided on the basis of several distinguishing characters. The organisms were divided into five kingdoms namely Monera, Protista, Fungi, Plantae, and Animalia.

The basis of classification for the organisms as per Whittaker are:

- Complexity and organisation of cell structure: prokaryotic and eukaryotic cells.
- Complexity of body organisation of the organism: unicellular and multicellular - simple multicellular forms and complex multicellular forms.
- Mode of nutrition for all the organisms: Autotrophic and heterotrophic (parasitic or saprobic or ingestive organisms). It was the major criteria of this classification system.
- Reproduction type: asexual and sexual.
- Phylogenetic or evolutionary interrelations between the organisms.

Drawbacks: This system of classification had overcome all the problems faced by the two, three and four classification systems.

- The only problem that exists is the bacteria species in Monera kingdom. The bacteria have various types and classes different from each other that were grouped in single kingdom. Hence microbiologist insisted to place them separately.
- There was no kingdom or even class for viruses in the system.
- Algae was separated into plantae, Protista and Monera kingdoms.

Kingdom Characters	Monera	Protista	Fungi	Plantae	Animalia
1. Cell type	Prokaryote	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
2. Complexity of body	Unicellular or multicellular	Unicellular	Unicellular to multicellular	multicellular	Multicellular
3. Nucleus	Incipient	Well organised	Well organised	Well organised	Well organised
4. Chloroplast	present	May or may not be present	Absent	Present	Absent
5. Cell wall	Non-cellulosic and contain poly-saccharides and amino acids	May or may not be present	Fungus cellulose	cellulose	Absent
6. Motility	May or may not be present Flagella 2+9 organisation is not present	Flagella 2+9 is present	Flagella 2+9 May or may not be present	Flagella 2+9 May or may not be present	Flagella 2+9 is present
7. True tissue system	Absent	Absent	Absent	present	present
8. Nutrition Mode	Auto or heterotrophic	Auto or heterotrophic	Heterotrophic (absorptive)	Autotrophic (photosynthetic)	Heterotrophic (ingestive)
9. Ecological Role	Producers/ decomposers	producers/ decomposers/ consumers	Decomposers	Producers	Consumers
10. Reproduction	Asexual Involving meiosis and mitosis.	sexual Meiosis gametic or zygotic.	Sexual Meiosis is zygotic.	Sexual Sporic or zygotic.	Sexual Gametic

Flowchart 2.4: Five Kingdom classification

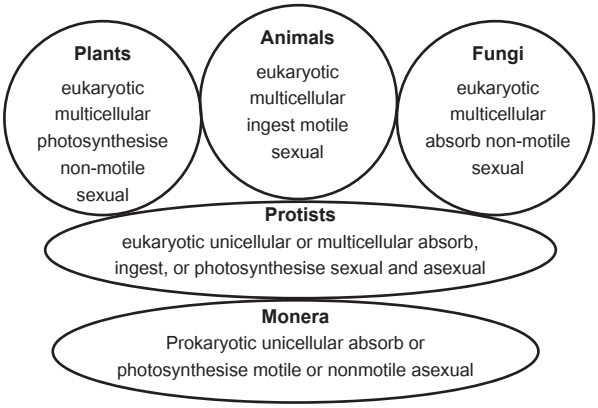


Figure 2.1: Five Kingdom classification with their major differences

3.5 Six Kingdom Classification

Gray and Doolite proposed six kingdom for classification of organisms. These six kingdoms included kingdom-Archaebacteria, Kingdom-Eubacteria, Kingdom-Protista, Kingdom-fungi, Kingdom-Plantae and kingdom-Animalia. The classification was based on the gene sequences of the organisms. The major change from Whittaker classification to this classification was that Gray and Doolite separated the archaebacteria from eubacteria. The separation of bacteria was on the basis of absence of peptidoglycan in the cell walls of the archaea and the presence of branched chain lipids (a monolayer instead of a phospholipid bilayer) in its membrane.

Did You Know

There was a new proposal of classification based on the genetic sequencing of the organisms. Carl Woese specifically studied the sequences of 16S ribosomal RNA genes, and he found that the six kingdoms naturally cluster into three main categories. He called these categories as domains of life. These domains are Bacteria, Archaea and Eukarya. He believed that the organisms in the domains have originated from common ancestor called progenote.

Tips to Memorize the Classification Sequence

- Keep Pots Clean Or Father Gets Sick
- Kids Put Cats On Fine Grass Soil
- The Kingdom of Phylum attended a Class of the Order of Families that had last name of Genus to protect and respect the Species.
- King Phillip Came Over For Great Spaghetti

Try It Yourself

1. Two Kingdom Classification was given by

(A) Linnaeus (B) John Ray (C) Copeland (D) Whittaker

2. Which kingdom was introduced in four kingdom classification and who proposed it?

(A) Protista and Copeland (B) Plantae and Linnaeus

(C) Monera and Whittaker (D) Monera and Copeland

3. Five kingdom classification is based on

(A) Complexity of cell structure (B) Mode of nutrition

(C) Complexity of body organization (D) Ecological role

4. Kingdom: Monera

The Kingdom Monera includes all prokaryotic organisms. Monerans as a whole represent the most primitive forms of life on earth during evolution. These organisms originated from more ancient living stock or a unit called as progenote present in the oceans. The kingdom Monera includes eubacteria and archaebacteria. Eubacteria includes Cyanobacteria, Actinomycetes, Mycoplasma, Rickettsiae, Chlamydiae and Spirochaetes etc.

4.1 Classification of Monerans

- 4 kingdom system had a new kingdom made that included all prokaryotic organisms i.e., eubacteria and archaebacteria together.
- However, archaebacteria are not similar to eubacteria where eubacteria are similar to eukaryotes in few ways and archaebacteria similar to prokaryotes.
- Carl Woese hence separated the archaebacteria from eubacteria on the basis of absence of cell wall and presence of lipid branched chains in archaebacteria.
- 6 kingdoms proposed by Carl Woese are

  Kingdom-1 - Archaebacteria

  Kingdom-2 - Eubacteria

  Kingdom-3 - Protista

  Kingdom-4 - Fungi

  Kingdom-5 - Plantae

  Kingdom-6 - Animalia

KNOWLEDGE BUILDER

- Anton von Leeuwenhoek discovered bacteria in stagnant rain water and tartar scrapped from human teeth.
- A.V. Leeuwenhoek called these microorganisms as dierkens that was then termed as animalcules by the Royal society. Se' dillot termed these animalcules as microbes, later termed as microorganisms by Pasteur.
- Ehrenberg was the first microbiologist to introduce the word 'bacteria'
- Louis Pasteur is called as the 'father of modern microbiology'. He also introduced the term aerobic and anaerobic i.e. presence or absence of oxygen respectively for the type of organisms habitat.
- Robert Koch, a German doctor had studied anthrax disease of sheep and concluded the causative agent to be a bacteria. Koch followed four experimental steps (Koch's postulates) for the research that helped to reveal the relationship between a microorganism and a disease.
- Smallest bacteria: *Dialister penumosintes.*
- Largest filamentous bacterium: *Beggiatoa mirabilis*

Kingdom Monera has the Following Special Factors

- Unicellular, colony forming, multicellular prokaryotic organisms lacking eukaryotic nucleus and having nucleoid instead.
- Nucleoid or genophore or incipient nucleus or prochromosome is composed of naked DNA, RNA and non-histone proteins.
- Cell wall consists of peptidoglycan (exceptions are Archaebacteria and Mycoplasma).
- Lack membrane bound organelles.
- Cyclosis is absent in the cells and ribosomes have 70 S molecular structure.
- Respiratory enzymes are present in the cell in association with plasma membrane.
- Mode of reproduction is asexual.
- Cell division is not by mitosis and has no spindle fibres formed.

After having a detailed reasoning of the classification we will move on the description of the organisms in the Kingdom.

4.2 Eubacteria

Bacteria are omnipresent that is found almost in every habitat whether it is living or dead organic matter.

4.2.1 Shapes of Bacteria

As the types of bacteria changes so does its shape changes. Bacteria are found in four basic forms or shapes. They are – spherical (Cocci), rod (Bacilli), *Vibrio* (comma) and Spiral (spring). Though most bacterial species are made of shapes that are constant and characteristic feature of that particular cell, some species have pleomorphic cell type (i.e., these can exhibit a variety of shapes), e.g., *Rhizobium leguminosarum.*

The types of cell shapes are described below:

(i) Coccus

Spherical or nearly spherical, aflagellate. They are sub-divided into six groups on the basis of cell arrangement:

- Monococcus: Only single cell represents the bacterium, e.g., *Micrococcus luteus, M. roseus.*
- Diplococcus: Cocci divide in one plane and remain attached in pairs, e.g., *Meningococcus, Gonococcus, Diplococcus pneumonia.*
- Streptococcus: Cocci remain attached to form chains of different lengths, e.g., *Streptococcus lactis.*
- Tetracoccus: Cocci divide in two planes at right angles to one another and form groups of four, e.g., *Tetracoccus, Neisseria.*
- Staphylococcus: Cocci divide in several planes resulting in formation of irregular bunches of cells, sometimes resembling a cluster of grapes, e.g., *Staphylococcus aureus.*
- Sarcinae: Cocci divide in 3 planes at right angles to one another and resemble cubical packets of 8 or more cells forming three dimensional geometrical figures, e.g., *Sarcina lutae.*

(ii) Bacillus

Rod-like forms, either singly or may be arranged differently. They are generally flagellate. It is the most common of all the shapes. They are of following types:

- Monobacillus –The bacteria occur singly, e.g., *Bacillus anthracis, Lactobacillus.*
- Diplobacillus –Bacteria are arranged in pairs.
- Streptobacillus –Bacteria form a chain of rods, e.g., *Streptobacillus.*
- Palisade-like –If the cells are lined side by side like match sticks and at angles to one another. E.g., *Corynebacterium diphtheriae.*

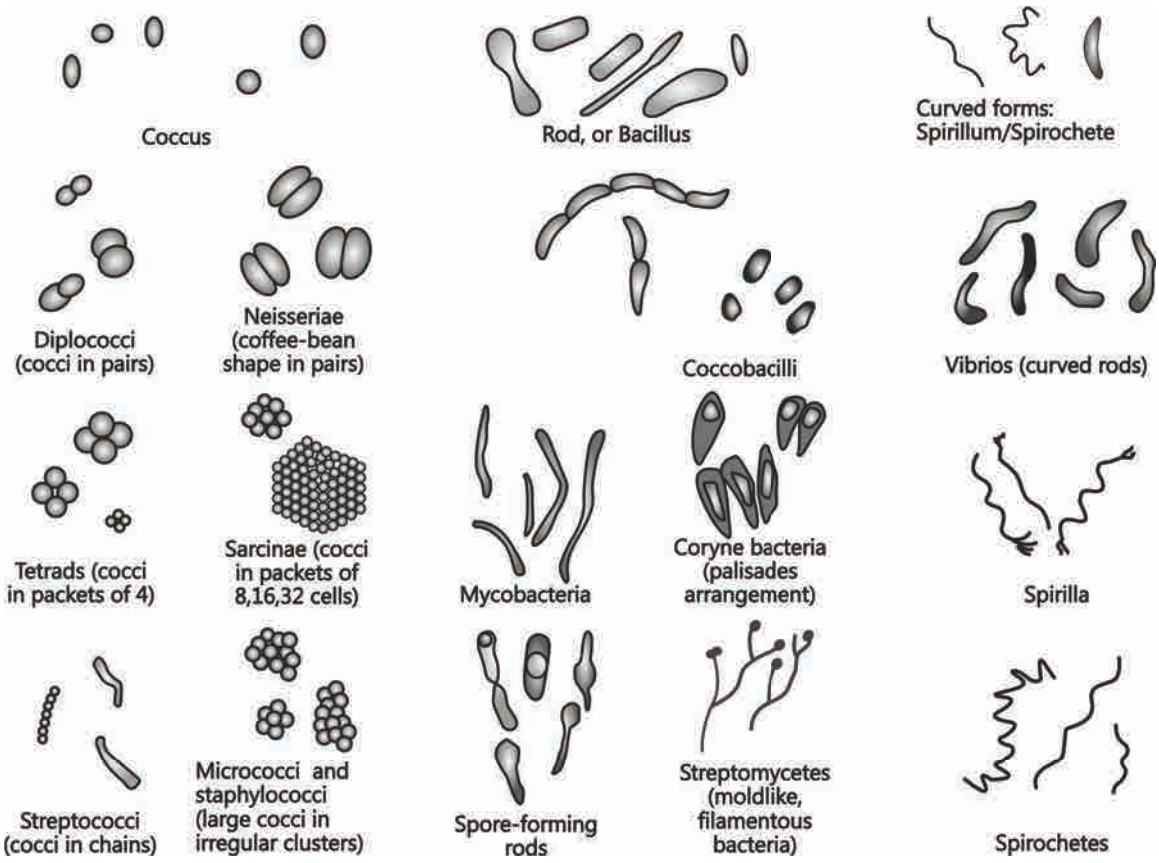


Figure 2.2: Diagram showing various types of Bacterial shapes

(iii) Spiral bacteria

Coiled forms of bacteria exhibiting twists with one or more turns are called spirillum, e.g., *Spirillum volutans.*

(iv) Stalked bacteria

The body of bacterium possesses a stalk, e.g., *Caulobacter.*

(v) Budding bacteria

The body is swollen at places, e.g., *Rhodomicrobium.*

4.2.2 Bacterial Cell Structure

Bacteria has prokaryotic origin in nature with the addition of very complex functions. Their cell structure exhibits the most expanded and extensive metabolic diversity in the cell organisation. Electron microscope is the instrument that reveals the detailed structure of a bacterial cell.

The cell includes following structures:

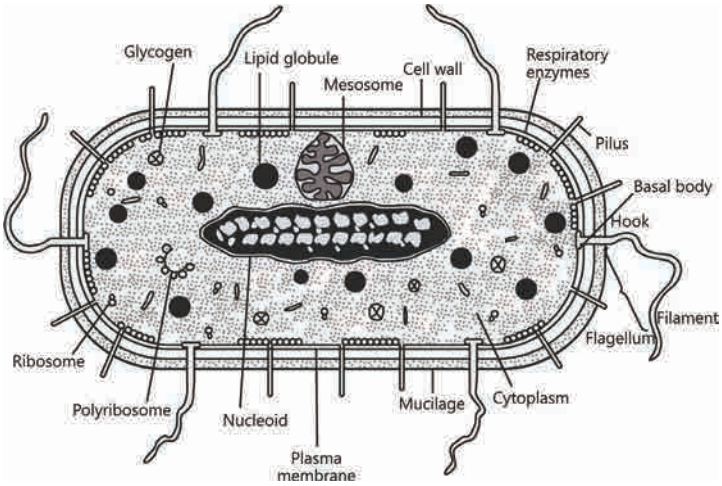


Figure 2.3: Diagrammatic image of a Bacterial cell or Prokaryotic cell

(i) Surface Appendages

Flagella and fimbriae (or pili) are the organelles that are present on the surface extending outwards of bacteria.

(a) Flagella are long, thin, filamentous appendages made of globular protein protruding out of the cell through the cell wall. These appendages are present to take care of the bacterial motility. These are thinner than the eukaryotic flagella or cilia.

Structure of Flagella: The flagella consists of three distinct regions: a basal body, the hook and filament.

- Basal body: This is the most complex portion of flagella that is present in the cell wall of the bacteria. Flagellum has four rings (L, P, S and M), out of which S and M rings are present in gram positive bacteria whereas all the four rings are found in the gram negative bacteria. L and P rings in cell wall constitute the distal set, while S and M rings formthe proximal set and are present in plasma membrane of the cell.

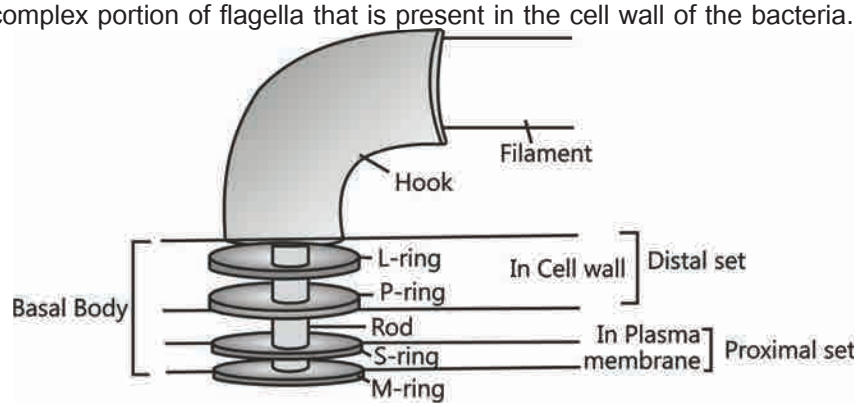


Figure 2.4: A sectional view of a bacterial cell showing the detailed structure of the flagellum and attachment of flagellum to the bacterial cell.

- Hook: It consists of different protein subunits making the attachment area for the filament.
- Filament: These contain identical spherical subunits of a protein called as flagellin which are molecular chains that run longitudinally across each other to form a wavy helical or rope-like structure. A cross-section of the flagellum clearly shows the number of flagellin molecules around a central space present in the filament.

(b) Pili and fimbriae are small plasma extending structures that are hollow, non-helical, filamentous appendages. These are projection from the cell walls of Gram-negative bacteria. These are shorter, thinner and higher in number than the flagella in the cell. These are made up of specific protein molecules called pilin.

There are different types of pili which serve different functions. One type, known as type I pili, (somatic pili) play a major role in infection by facilitating the attachment of bacterial cell to the host cell. Another type. Termed sex pili, serve as portals of genetic material from donor to recipient cell during conjugation.

Knowledge Builder

Flagella may or may not be present in the cell, and if present its number and position changes in every bacterial cell. Bacteria with or without flagella are divided as follows:

- Atrichous: Bacteria lacking flagella, e.g., *Pasteurella*, *Lactobacillus*.
- Monotrichous: Bacteria with only one flagellum that is attached at one pole of the cell, e.g., *Thiobacillus*, *Vibrio*.
- Amphitrichous: Bacteria having two flagella attached at both the ends, e.g., *Nitrosomonas*.
- Cephalotrichous: Bacteria whose cell has two or more flagella present at one end only, e.g., *Pseudomonas fluorescence*.
- Lophotrichous: Bacteria with two or more flagella present at both the ends of the cell, e.g., *Spirillum volutans*.
- Peritrichous: Bacteria have flagella present all over the surface of the cell, e.g., *Escherichia coli*, *Clostridium tetani*.

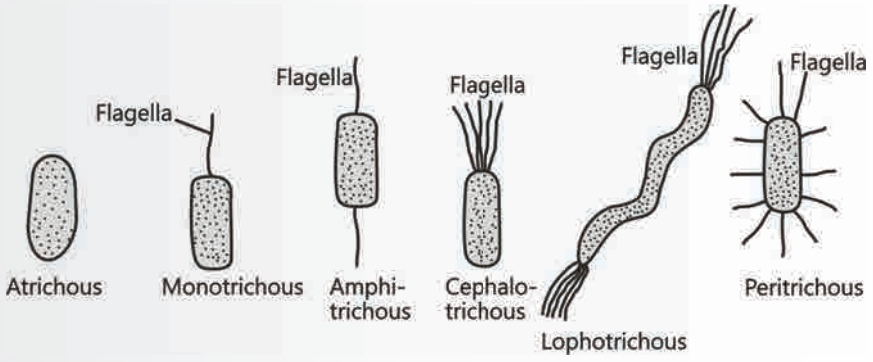


Figure 2.5: Diagrammatic image of some Bacterial cells having flagella in various positions

(ii) Glycocalyx

The outermost part of cell structure forming an envelope made of three layers: Glycocalyx, cell wall, plasma membrane present from outer most part to the inner part of a cell.

The main function of the glycocalyx is to protect the cell from external world and help the bacteria to adhere to the surface. Glycocalyx is made of either slime layer or capsule.

(a) Slime layer is made from dextran, dextrin and levan sugars and the main function is to protect the cell against desiccation and loss of nutritients.

(b) Capsule is made up of polysaccharides and D-glutamic acid. The main funtion is to provide gummy or sticky character and add virulent property to the bacterial cell.

(iii) Cell wall

The outer covering of the cell membrane is cell wall that is a rigid in nature.

Functions

- This rigidity protects the cells internal structures
- Provides shape to the cell.
- However, the main function remains to prevent the cell from expanding too much to burst. This bursting of cell may loose the cell organelles as most bacteria are in hypotonic habitat, that forces bacteria to take in much more water to eventually burst itself.

Structure: The cell walls are made up of peptidogylycan which is also called as murein or mucopeptide,are common to all the eubacteria (true bacteria) of prokaryotic nature.

- The peptidoglycan is a combination of two components- a peptide portion made up of amino acids connected by peptide linkage, and a glycan or sugar portion.

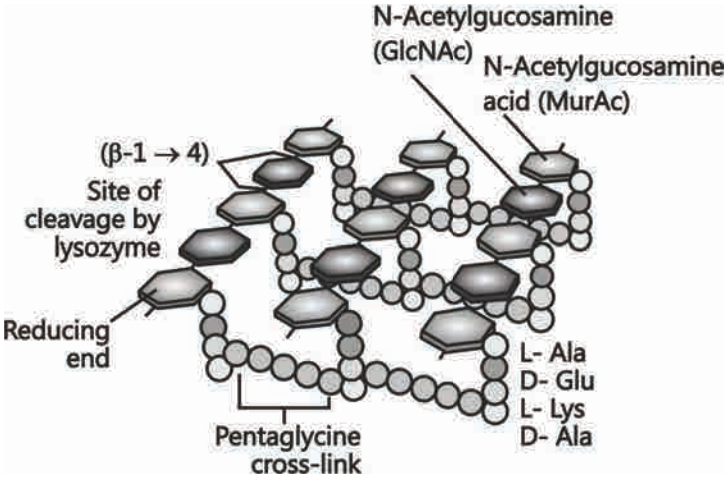


Figure 2.6: Molecular arrangement of biomolecules in a cell membrane

- The glycan portion is the backbone of peptidoglycan. It consists the alternating units of amino sugars N-acetyl-glucosamine (NAG) and N-acetylmuramic acid (NAM) joined together by β -1, 4 linkage.

- The peptidoglycan chains are linked laterally by short chains of four amino acids which are attached to N-acetylmuramic acid residues.
- The four amino acids of this tetrapeptide are D-alanine, L-alanine, D-Glumatic acid and L-lysine (in Gram positive bacteria) or diaminopimelic acid (in Gram negative bacteria).
- The tetrapeptide chains are also connected by a peptide bridge that is in between the caboxyl group of an amino acid in one tetrapeptide chain and amino group of an amino acid in another tetrapeptide chain. As a result, peptidoglycan forms a rigid, multilayered sheet.

Bacteria have separate cell wall structures depending on the thickness of peptidoglycan layer.

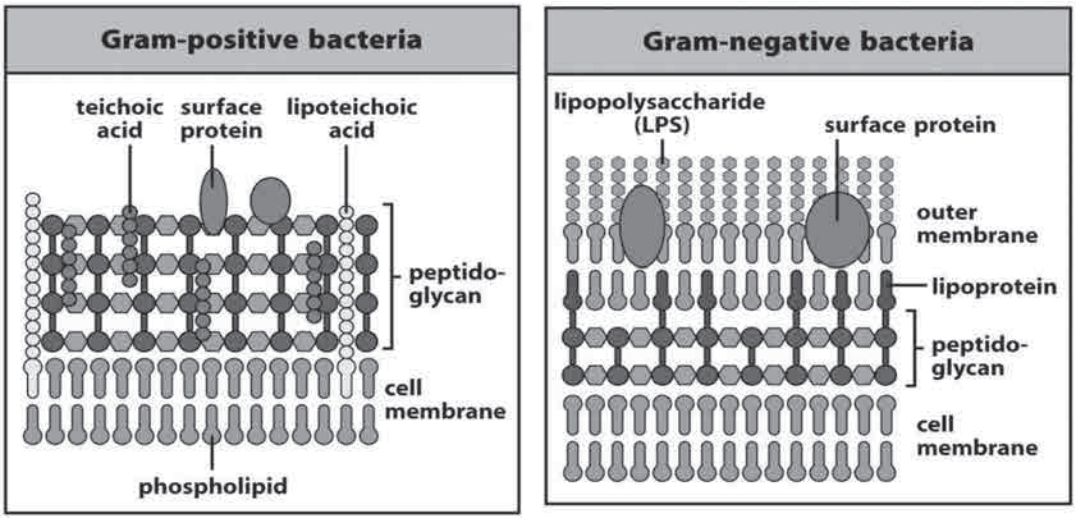


Figure 2.7: Molecular arrangement of lipids and proteins in a cell membrane

- Teichoic acid, another component which is an acidic polymer containing a carbohydrate (e.g., glucose), phosphate and an alcohol.
- It is found in cell walls of **Gram positive bacteria**.
- Teichoic acid has several roles to play in a cell like acting as receptor sites for some viruses, binding metals and maintaining cells pH in order to prevent its degradation by self-produced enzymes.
- The walls **Gram positive bacteria** contain very little amount of lipids.
- The Gram negative bacteria have cell walls that are more complex than gram positivie bacteria.
- The peptidoglycan layer is very thin constituting only 10% or less of the total cell wall. There exists an outer membrane that covers the thin underlying layer of peptidoglycan.
- The outer membrane consists of phospholipid bilayer structure made chiefly of phospholipids, proteins and lipopolysaccharides (LPS).
- The outer membrane serves as a gate to preserve the important enzymes from leaving the periplasmic space between the cytoplasmic membrane and the outer membrane.
- It also monitors the entry of various chemicals that are harmful in nature to the cell.

- It gives the bacteria its main surface antigenin the cell wall. However, outer membrane is permeable to the external nutrients which is regulated by proteins called as porins. These porins form channels across the membrane through which substances are able to enter the cell.

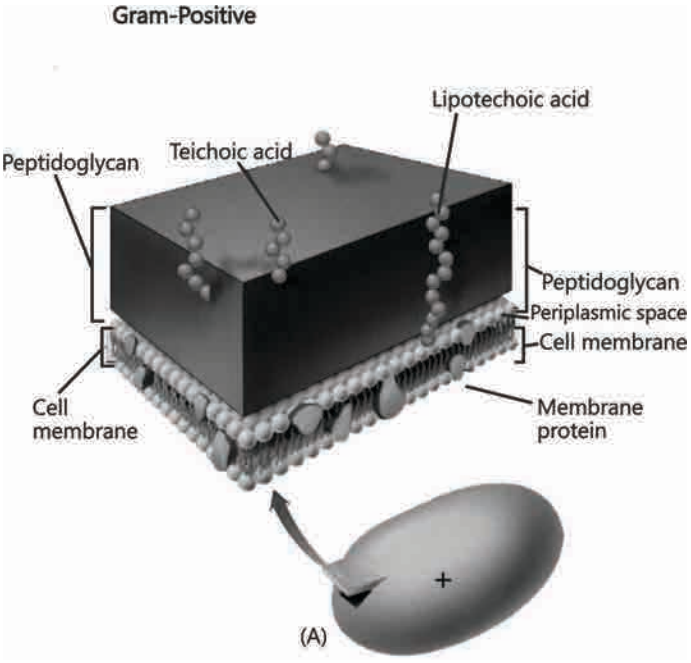


Figure 2.8: Molecular arrangement of lipids and proteins in a cell membrane of a gram positive cell

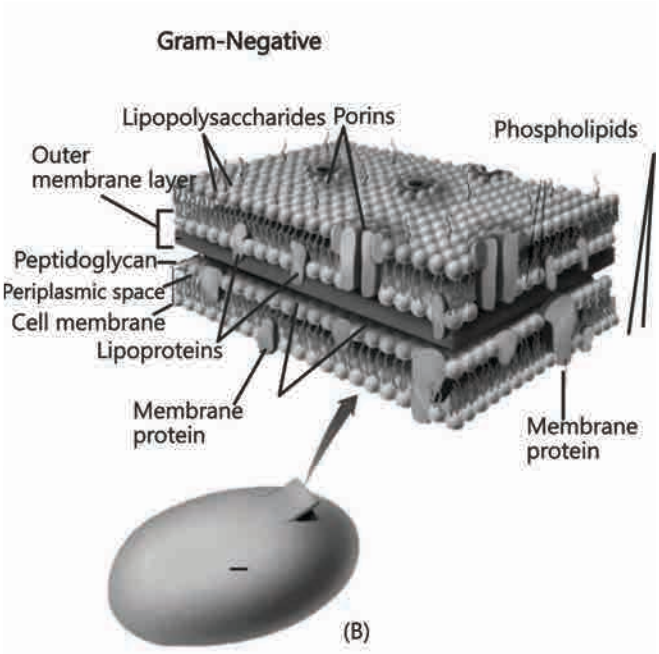
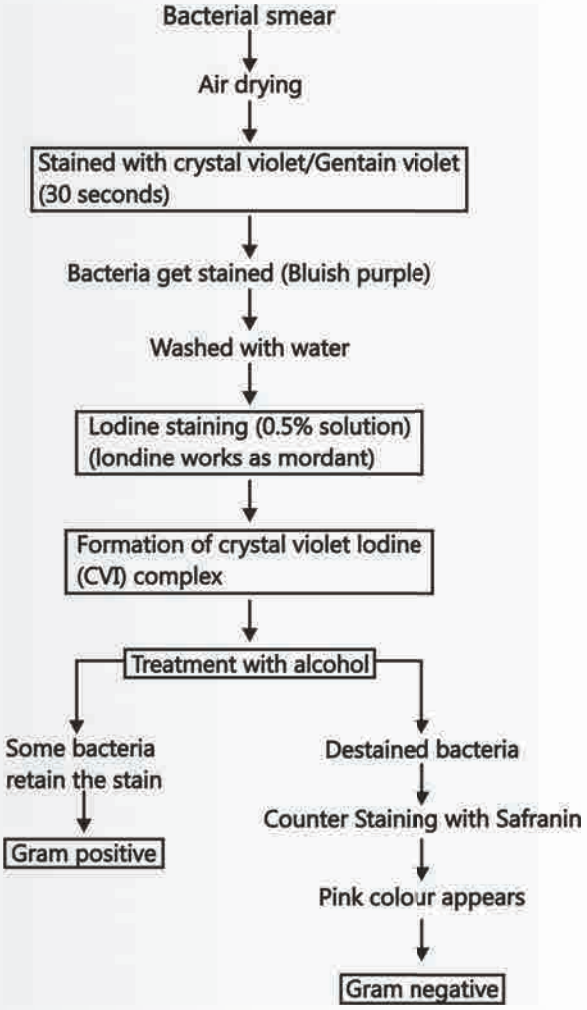


Figure 2.9: Molecular arrangement of lipids and proteins in a cell membrane of a gram negative cell

KNOWLEDGE BUILDER

Christian Gram (1884) a microbiologist, developed a staining technique for bacteria, using Gram stain (crystal violet). The basis of Gram Stain was that the bacteria are classified into two groups; Gram positive and Gram negative.



Flowchart 2.5: Gram staining technique for bacteria.

Knowledge Builder

Table 2.1: Difference between Gram positive and Gram negative Bacteria

Gram Positive Bacteria	Gram Negative Bacteria
They take the blue colour of Gram stain even after destaining with alcohol.	They get the colour blue with Gram stain initially, however lose it after destaining with alcohol.
Cell wall	
The cell wall has 150-200 Å thickness. The cell wall lacks the cover lipopolysaccharide layer and has a single layer.	Cell wall has 75-120 Å thickness consisting a layer of lipopolysaccharide, which is a double layer.
Cell wall is more rigid due to high percentage (80%) of peptidoglycan.	Cell wall is less rigid due to low percentage (3-12%) of peptidoglycan.
Muramic acid content is 70-95%.	Muramic acid content is 5-20%.
Lipid content is low (2-4%).	Lipid content is high (20-30%).
Phospholipid is absent in cell wall.	Phospholipid is present in cell wall.
Teichoic acid is present.	Teichoic acid is absent.
Fewer types of amino acids are present in cell wall.	Several types of amino acids are present in cell wall
Diaminopimelic acid (DAPA) is absent in the cell wall and L-lysine is present.	DAPA present in cell wall in the place of L-lysine.
Bacteria is more sensitive to antibiotics such as penicillin.	Bacteria is resistant to antibiotics like penicillin
Cell is resistant to alkalis and insoluble in 1% KOH solution.	Cell is sensitive to alkalis and soluble in 1% KOH solution.
Mostly cells are non-capsulated.	Mostly cells are capsulated.
Protoplast is produced by the reaction with lysozyme.	Sphaeroplast is formed by the reaction with lysozyme (LPS remains unaffected).
Other Structures	
Mesosomes are very common in the cell.	Mesosomes are rarely present in the cell.
Pili are usually absent.	Pili are very common
Flagella are less common.	Flagella are very common.
Basal body of flagellum has 2 rings (S, M) only.	It has four rings (L, P, S and M).
Only few forms are pathogenic and may produce exotoxins	More forms are pathogenic and may produce endotoxins
e.g. Bacillus, Clostridium, Lactobacillus, Streptococcus, Leuconostoc, Staphylococcus, Corynebacterium	e.g. *E coli, Salmonella, Acetobacter, Azotobacter, Vibrio, Agrobacterium, Shigella, Xanthomonas*

(iv) Protoplast: Cell wall contains the protoplast which is the living matter in the cell. It includes cell membrane, cytoplasm and nucleoid and may or may not have plasmid and episome.

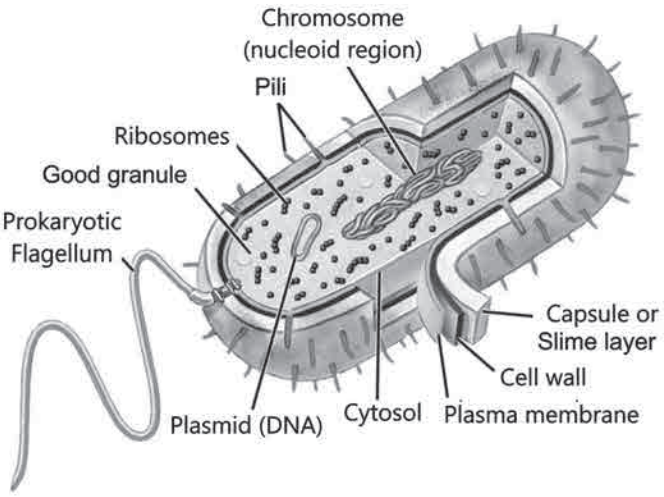


Figure 2.10: Bacterial cell with all its internal molecules

(a) Cell membrane: The layer inner to the cell wall that is the outermost layer of the protoplast. It is the living part semipermeable in nature that controls the movements of manyaqueous substances in and out of the cells. Functionally, the cell membrane of bacteria acts as respiratory ETS enzymes and succinate dehydrogenase (Krebs cycle) found in the cell membrane. These are similar to the mitochondria of eukaryotic cells. The cell membrane gets folded inwards to form a structure called mesosome (chondroid) present in some Gram positive bacteria. These structures may be in centre or periphery of the cell. They have a function in the replication of DNA when the cell divides, as these are often attached to the nuclear body. Besides, these mesosomes increase the surface area of absorption by the cell and help in septa formation during binary fission.

(b) Cytoplasm: It is jelly like homogeneous mass containing carbohydrates, fats, proteins, lipid, nucleic acids, minerals and water. It lacks streaming movements, sap vacuoles and gas vacuoles with few exceptions. Typical membrane bound organelles of eukaryotic cells are absent. The cytoplasm contains 70S ribosomes due to which it appears granular. Ribosomes are scattered all over in the cytoplasm and sometimes may form a small chain of 4-6 ribosomes attached to mRNA making polyribosome or polysome. Various non-living inclusions like glycogen particles, fats, volutin granules (poly metaphosphate – source of energy) and lipid molecules lie freely in the cytoplasm. The cytoplasm is typically colourless. However, the photosynthetic bacteria have pigments like bacteriochlorophyll and bacterioviridin giving the cell green colour in the cytoplasm. The pigments may be dispersed in the cytoplasm or be membrane bound spherical vesicles that are called as chromatophores.

(c) Nucleoid (Pro chromosome, Genophore, incipient nucleus): Bacterial cell lacks a membrane bound well-organized nucleus. It consists of a long double standard DNA molecule supercoiled to form a sphere. DNA does not has free ends and associated histone proteins which is termed as bacterial chromosome.

Plasmid (Mini chromosome): Lederberg and Hays coined the term plasmid. These are small, extra chromosomal, non-essential, circular, and double stranded, free naked DNA molecules. The genes present on them incorporate extra characters in the bacteria. These replicate autonomously. When plasmids temporarily integrate in the bacterial chromosome, then they are called as episomes.

KNOWLEDGE BUILDER

Type of Plasmids:

F-Plasmid: It is responsible for process of conjugation or fertility factor transfer by forming sex pilus.

R-Plasmid: These plasmids incorporate resistance in the bacteria (Resistance Transfer Factor, RTF) for antibiotics like penicillin, tetracycline.

Col-Plasmid: Genes of this plasmid help in the production of colicins (bacteriocin) that kill other bacteria.

Ti Plasmid: *Agrobacterium tumefaciens*, has the plasmid that is used in genetic engineering.

Degradative plasmid:*Pseudomonas putida* (superbag) has the plasmid that decomposes hydrocarbons of petroleum in oil spills.

4.2.3 Bacterial Life Processes

Bacterial life processes will deal with the prominent metabolic activities like respiration and nutrition.

(i) Respiration: On the type of respiration, all the bacteria are divided into two main groups i.e., aerobes and anaerobes. Each group is further divided into two types i.e. strict or obligate and facultative.

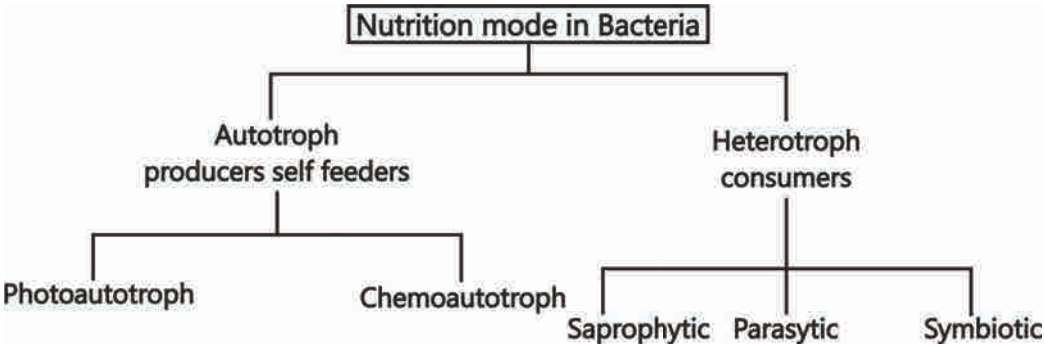
Table 2.2: Different types of Aerobes and Anaerobes

Types of Aerobes	Types of Anaerobes
Obligate or strict aerobes: These bacteria survive only in presence of oxygen as they have the enzyme system for aerobic respiration only. In the absence of oxygen, they fail to respire and thus, die, e.g., *Bacillus subtilis*.	Obligate or strict anaerobes: These bacteria always respire anaerobically. This respiration liberates much less amount of energy as compared to aerobic respiration. They lack enzymes thatcarry out aerobic respiration e.g., *Clostridium botulinum*.
Facultative aerobes: They normally respire anaerobically, howeverin presence of oxygen are capable of respiring aerobically as well. Most of the photosynthetic bacteria are facultative aerobes e.g., photosynthetic bacteria *Chlorobium*.	Facultative anaerobes: They normally respire aerobically. But are capable of switching over to anaerobic mode in order to survive, during insufficient oxygen e.g., *Pseudomonas*.

Did You Know

- Aerotolerant anaerobes: There are bacteria that perform anaerobic respiration even when the oxygen is available to them are called Aerotolerant anaerobes, e.g., Lactic acid bacteria.
- Anaerotolerant aerobes: The aerobic bacteria that continue to perform aerobic respiration whenfree oxygen is absent by using oxygen from oxidised salts are called Anaerotolerant aerobes, e.g., Denitrifying bacteria.

(ii) Nutrition in Bacteria

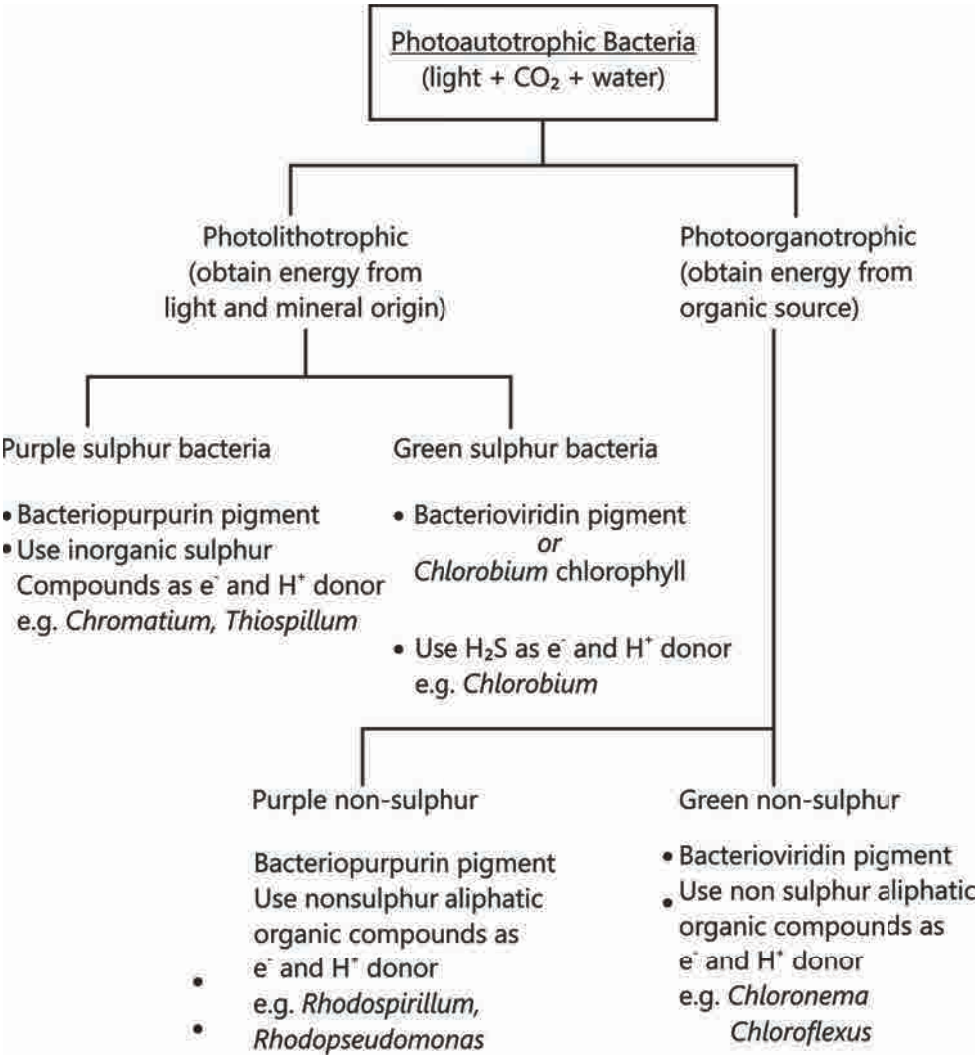


Flow Chart 2.6: Nutrition ways of various organisms

(a) Autotrophic Bacteria

Photoautotrophic or autotrophic bacteria: are capable of entrapping solar energy and utilizing it for the synthesis of complex food materials due to presence of pigments like bacteriochlorophyll (bacteriopurpurin) and bacterioviridin.

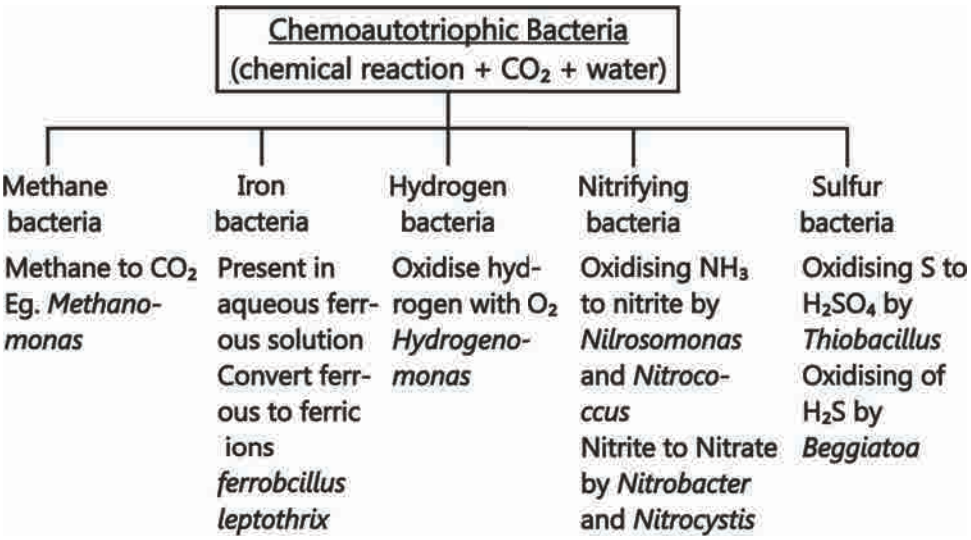
Most of the photosynthesis bacteria are anaerobes (facultative aerobes)



Flow Chart 2.7: Autotrophic bacteria showing various types of photosynthetic bacteria

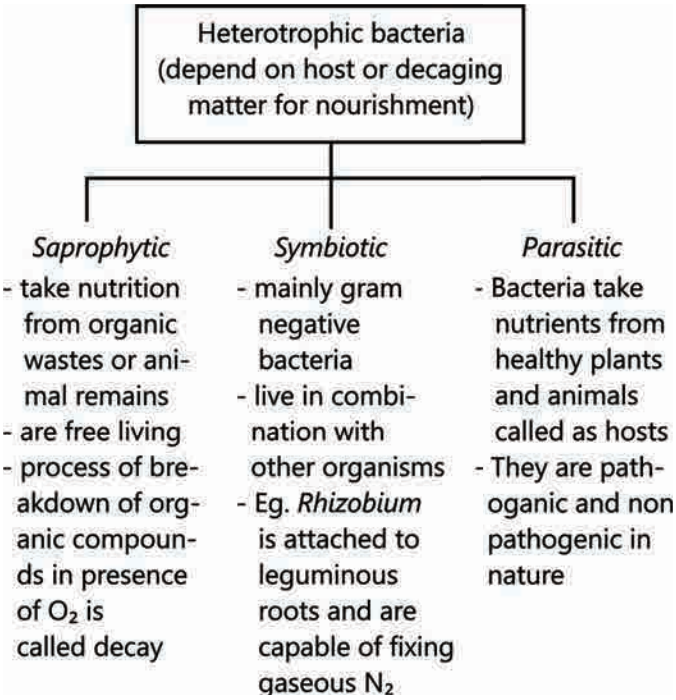
(b) Chemoautotrophic Bacteria

Bacteria belonging to this category obtain energy for the synthesis of food oxidising certain inorganic substances like ammonia, nitrates, ferrous ions etc. Thus, they do not utilise light as energy source. The chemical energy thus obtained, is trapped in ATP molecules. This energy is then used in carbon assimilation with the help of hydrogen from some source other than water, e.g., hydrogen bacteria, nitrifying bacteria, sulphur bacteria, etc. They play a great role in recycling nutrients like hydrogen, phosphorus, iron, sulphur.



Flow Chart 2.8: Autotrophic methods of food production without light as energy. It shows various types of this class of bacteria

(c) Heterotrophic bacteria



Flow Chart 2.9: Heterotrophic bacteria showing various methods of food consumption

4.2.4 Reproduction in Bacteria

Bacteria as a whole reproduce by asexual method while some bacteria also show sexual reproduction (True sexual reproduction is absent).

(i) Asexual Reproduction

Bacteria reproduce with the help of several types of asexual spores such as sporangiospores, oidia, conidia and endospores. The most common mode of asexual reproduction is binary fission.

(a) Binary Fission: This process of cell division is **amitotic type i.e., not involving the spindle formation**.

Since at one stage, the replicating chromosome appears like the Greek letter θ, this mode of replication is called theta model.

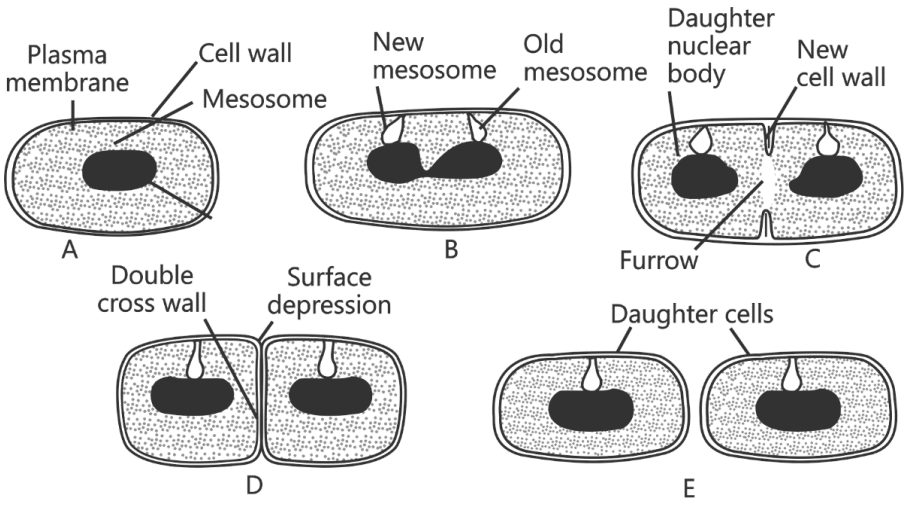


Figure 2.11: Various stages (A - E) of cell division in a Bacteria

(b) Endospores: Cells of certain bacteria, e.g., *Bacillus*, *Clostridium* etc. from thick-walled, highly resistant bodies within the cell, called endospores. One bacterial cell normally produces only a single endospore. The endospores may be spherical or oval in shape and are terminal or central in position. Anticoagulant nature of endospore is due to the presence of Ca-dipicolinic acid in cortex layer of wall.

Knowledge Builder

Structure of Endospore: The endospore consists of a central core made up of nuclear material and spore cytoplasm. The central core is surrounded by a delicate membrane called core wall. Around the core wall is another layer, which is much thicker and is of relatively low density. The cortex, it turn, is enclosed in spore coat which may be smooth, grooved, or raised into ridges.

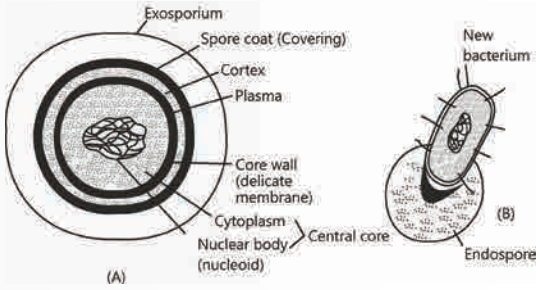


Figure 2.12: Endospores: (A) Structure of an endospore, (B) Germination of endospore

The endospores are formed when nutrients get exhausted (unfavourable conditions). During endospore formation, a part of the protoplast containing nuclear body undergoes dehydration, stores food material and gets separated from rest of the protoplast to form endospore. The endospores have tough layering that can withstand temperature ranging from 100^0 C to- 100^0 C, thus remain unharmed in pasteurisation. The remarkable resistance shown by endospores is due to: thick and impermeable spore coat, low water content, low metabolic activity and Ca-DPA complex.

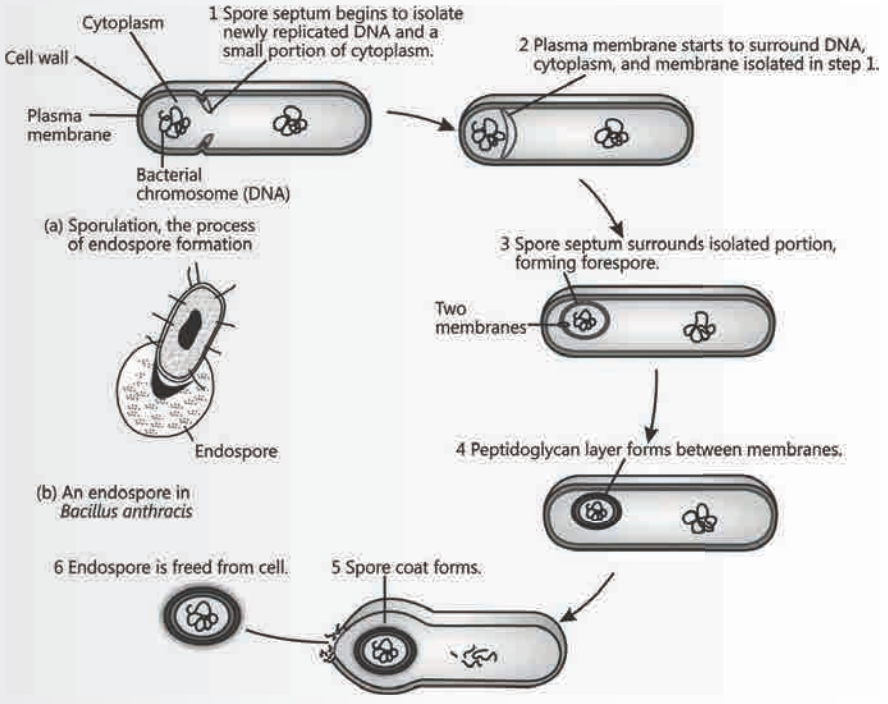


Figure 2.13: Various steps involved in an endospore formation in a cell is shown

When these endospores come under favourable conditions. Endospores are the perennation and not reproduction cells as only one endospore is formed per cell.

Try It Yourself

1. Outermost part of bacterial cell envelope is _____, which is made of ____, _____ and ____ sugars. It protect the cell against ___ and loss of nutrient.
2. Give one word for bacteria which are able to synthesis their food using light energy and organic compound as the source of electron and proton.
3. Bacterial ____ is very simple, but they are very complex in _____.
4. Which substance give anticoagulant nature to endospore?
5. Most common mode of bacterial reproduction is by _____.

(ii) Sexual Recombination (Genetic Recombination):

The bacteria exhibit a primitive form a sexual reproduction which differs from eukaryotic sexual reproduction because there is no gamete formation and fusion. However, the essential feature of sexual reproduction, i.e., exchange of genetic material does take place and is called genetic recombination. Three methods are known by which genetic recombination is achieved by bacteria. In the order of their bacteria, these are transformation, conjugation and transduction.

(a) Transformation

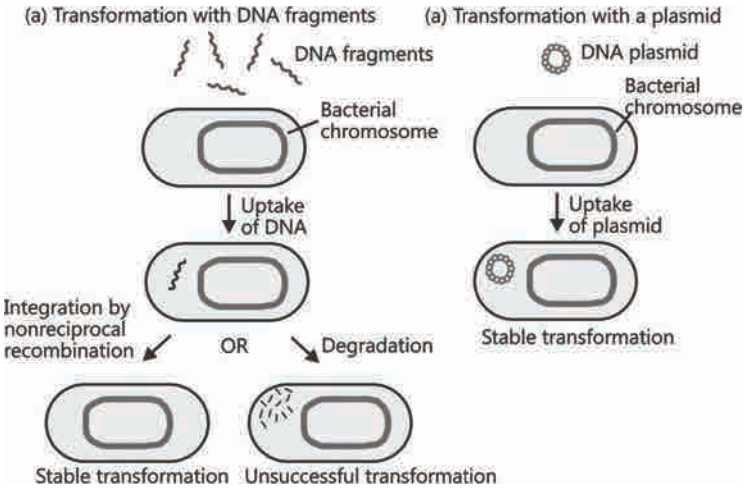


Figure 2.14: DNA intake through transformation in a bacteria

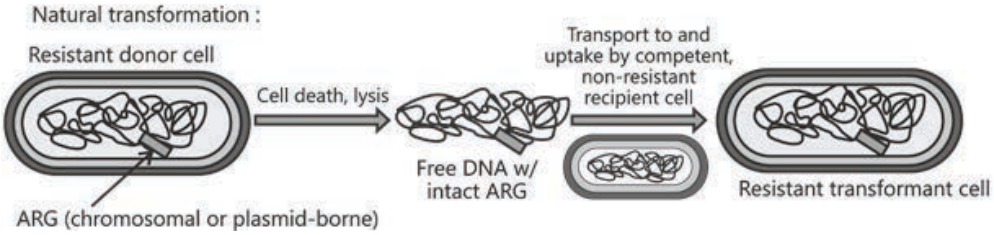


Figure 2.15: DNA intake through natural transformation process in a bacteria

Did You Know

Griffith (1928) worked on the effect of *Diplococcus* or *Streptococcus pneumonia* bacteria on mice and discovered the process of transformation.

In transformation, the donor and recipient do not come in contact. The donor cell releases a piece of DNA which is actively taken up by the recipient cell from the solution. The ability to pick up DNA from the solution is called competence.

Two strains of D. pneumonia are:

Capsulated or S-III (Virulent strain) and Non-capsulated or R-II (non-virulent strain).

Griffith concluded that something passed from heat killed S-III to R-II bacteria, so that non virulent strain changed or transformed into virulent bacterial strain.

Avery, MacLeod and McCarty (1948) repeated this experiment using various enzymes and proved that the transformation principle is DNA of heat killed S-III strain. They proved that DNA is a genetic material.

(b) Conjugation

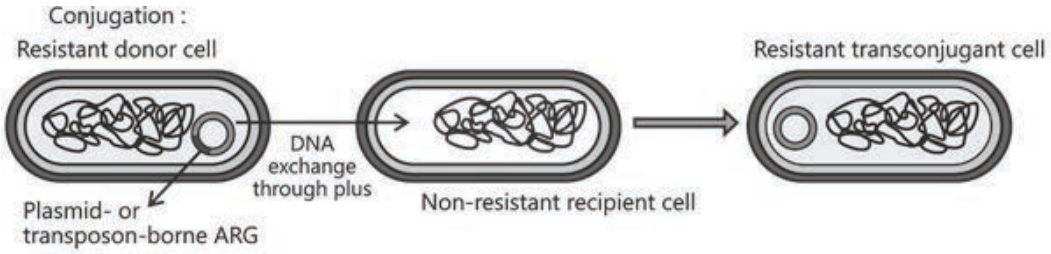


Figure 2.16: Schematic diagram of the conjugation experiment of Lederberg showing conjugation between F+ and F- cells

Did You Know

Lederberg and Tatum (1946) demonstrated in *E. coli* that during conjugation, one cell containing F^- plasmid acts as donor (F^+ or male) cell and the other lacking F^- plasmid as recipient (F^- or female) cell. The plasmid contains fertility factor or F gene which produces protrusions termed sex pili. These help the donor F^+ cell in attaching to the recipient cell. The plasmid replicates and a replica is transferred to recipient cell, changing it into F^+. Often the plasmid integrates with bacterial chromosome, converting it into *Hfr* (High frequency of recombination) cell or super male and a part or whole of bacterial chromosome is transferred to recipient cell through conjugation tube. Such association of episome with the endogenote increases the efficiency of genetic transfer. The number of genes transferred depends upon the time for which the two remain joined together. When F- conjugates with super male, the frequency of recombination increases by 1000 times, that is why it is called as *Hfr* (super male)

Schematic diagram of the conjugation experiment of Lederberg showing conjugation between F^+ and F^- cells

(c) Transduction

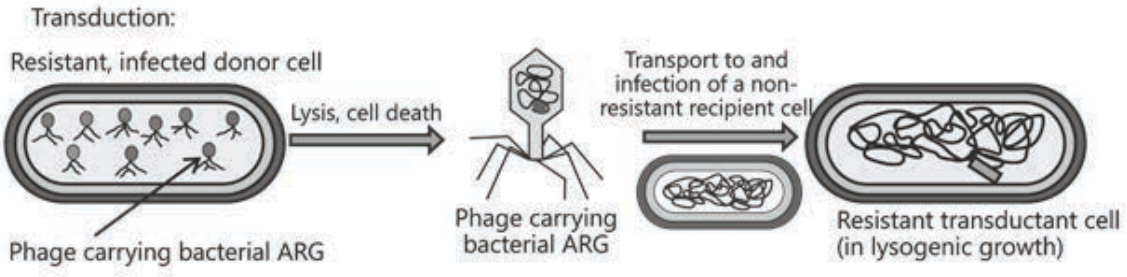


Figure 2.17: Recombination of cells through transduction

4.2.5 Economic Importance of Bacteria

Bacteria play significant role in day to day activities of human beings.

(i) Beneficial activities

(a) Role in agriculture

- Decay and decomposition of organic matter: They cause decay and decomposition of dead plants and animals, which is important for mineral cycling.
- Sewage disposal: The bacteria decomposes the sewage organic matter, converting into simpler inorganic substances that pass out through filter. This liquid is useful for irrigation purposes, e.g., *Clostridium*, *E. coli.*
- Nitrogen cycle: The proteins in the dead bodies of living organisms are converted into amino acids then into ammonia by ammonifying bacteria (*Bacillus vulgaris, B. ramosus*). Further Nitrifying bacteria convertit first into nitrates (*Nitrosomonas, Nitrococcus*) which are finally converted into nitrates (*Nitrobacter*). In presence of denitrifying bacteria (*Pseudomonas denitrificans*), nitrates and nitrites in soil are converted to gaseous nitrogen.
- Nitrogen fixation: The biological process of nitrogen gas getting converted into nitrogenous compounds in presence of nitrogen fixing bacteria is called as nitrogen fixing bacteria. For e.g., free living bacteria are *Azotobacter* and *Beijerinckia* (aerobic) and *Clostridium* (anaerobic).Common symbiotic bacteria are *Rhizobium leguminosarum* and *Xanthomonas*.
- Manure preparation: Saprophytic bacteria prepare farmyard manure by converting farm wastes, dung and other organic wastes into humus.

(b) Role in Industry

- Man has utilized the metabolic activities of bacteria in various industrial products like:
- Butter milk and sour cream

- Yoghurt
- Cheese
- Vinegar
- Retting of fibres: Retting is process where a microbial population decompose fibers in order to separate them. The tissues are dipped in water tanks full of anaerobic butyric acid bacteria that dissolve the pectin of cells, thus, separating the fibres. *Clostridium perfringens* and *Pseudomonas fluorescence are bacteria* used.
- Curing of leaves: The tastes and flavour in tea is improved using *Micrococcus candidans* and in tobacco leaves by *Bacillus megatherium.*
- Single cell proteins (SCP): These are protein supplements used for treatment. Examples: *Methylophilus methylotropus* and *Rhodopseudomonas capsulate.*

(c) Role in Medicine

Bacteria have a major role in preparation of medicinal products like antibiotics, vaccines, serums and vitamins.

- Antibiotics: The organic substances produced by microorganisms that does not allow other organisms (mostly pathogens) to grow are called antibiotics. Some antibiotics produced by bacteria are:

Bacitracin	*Bacillus lichenifomis*
Polymixin	*Bacillus polymyxa*
Gramicidin	*B. brevis*
Subtilin	*B. subtilis*

- Vaccine production: Vaccine and serums are prepared from the whole or part of bacteria or their toxins. They are against typhoid, cholera TB, pertussis, tetanus and diphtheria e.g., DPT (against diphtheria, pertussis and tetanus), TT (against tetanus), BCG (Bacille of Calmette-Gurein against TB), DT (against diphtheria and tetanus).
- Vitamins: Several bacteria are used in industrial production of a various vitamins.

Riboflavin	*Clostridium butylicum*
Cobalamine (B_{12})	*Bacillus magnatherium and Pseudomonas denitrificans*
B-complex vitamins and vitamin K	*Escherichia coli* from the human intestine

Pollution control: *Pseudomonas putida* degrades petroleum wastes. Flavobacterium can decompose 2, 4-D.DDT can be decomposed by *Acetobacter aerogens*. Gange's water contains *Bdellovibrio bacteriovorus* that maintains purity of its water.

Poly-hydroxybutyrate is used to produce biodegradable plastic.

Did You Know

Antibiotics: The term antibiotic was given by Waksman, who discovered streptomycin. The first commercial antibiotic penicillin was discovered by Flemming (1959) from a fungus called *Penicillium*.

Vaccine: BCG was the first vaccine prepared that used whole bacteria after destroying its pathogenicity. It is the first vaccine given to the infant.

Table 2.3: Organisms causing Human Diseases

Name of casual organism	Name of the human disease
Shigella dysenteriae , S. sonnei, S. boydis	Bacillary dysentery
Chlostridium botulinum	Botulism
Vibrio cholerae	Cholera
Leptotrichia buccalis	Dental plaque
Corynebacterium diptheriae	Diptheria
Salmonella typhimurium	Typhoid
Staphylococcus aureus	Food poisoning
Clostridium perfringens	Gangrene
Escherichia coli, Salmonella	Gastroenteritis
Neisseria gonorrhoeae or Salmonella schottmulleri	Gonorrhoea
Mycobacterium leprae (Hensen's bacillus)	Leprosy
Neisseria meningitides	Meningitis
Heliobacter pylori	Peptic ulcer
Staphylococcus aureus	Pimples
Yersinia pestis	Plague
Diplococcus pneumonia	Pneumonia
Streponema pallidum	Rheumatic fever
Treponema pallidum	Syphilis
Clostridium pallidum	Tetanus
Streptococcus pyrogenes	Tonsilitis
Mycobacterium tuberculosis	Tuberculosis
Salmonella typhosa / typhi	Typhoid
Gardinerella vaginalis	Vaginitis
Bordetella pertussis / Hemophilous pertussis	Whooping cough
Salmonella typhimurium	Enteric fever (paratyphoid)
Mycoplasma hominis	Male sterility and female abortion in humans

Table 2.4: Organisms causing Animal Diseases

Name of casual organism	Name of the animal disease
Brucella sui	Brucellosis
Clostridium chanvei	Black leg
Bacillis anthracis	Anthrax
Salmonella abortusovis	Abortion

Table 2.5: Organisms causing Plant Diseases

Name of casual organism	Name of the animal disease
Pseudomonas solanaecearum	Potato wilt
Xanthomonas citri	Citrus canker
Agrobacterium tumefaciens	Crown gall
Erwinia amylovora	Fire blight of apple
Xanthomonas oryzae	Bacterial blight of apple
Xanthomonas malvacearum	Angular leaf spot of Gossypium
Xanthomonas phaseoli	Bean blight of Phaseolus
Pseudomonas rubrilineans	Red stripe of sugarcane
Erwinia cartovora	Soft rot of carrot
Corynebacterium tritci	Tundu (bacterial rot) of wheat
Corynebacterium campestris	Back rot of cannage
Streptomyces scabies	Potato scab
Pseudomonas tobaci	Wild fire of tobacco

4.3 Cyanobacteria

Cyanobacteria are the only moneran Gram negative photosynthetic bacteria that have prokaryotic cell structure. These are the most primitive organisms that have the ability of oxygenic photosynthesis. They played major role in adding oxygen to the atmosphere, which made the existence of aerobic forms of living organisms. They are also called as BGA (Blue green algae) and are classified as cyanophyceae or myxophyceae.

4.3.1 Occurrence

- They are mainly fresh water forms, and a few are marine habit. Red sea has abundant population of a cyanobacterium *Trichodesemium erythodesmium*, which gives red colour to water.
- They occur in symbiosis with several group of eukaryotes i.e. green algae, fungi, bryophytes like mosses and Anthoceros, ferns, gymnosperms, angiosperms, sponge, shrimps, mammals etc.
- *Anabaena azollae* is associated with *Azolla*, which is an aquatic fern. *Anabaena cycadeae* is associated with coralloid roots of *Cycas*.
- In many lichens which are symbiotic association of algae and fungi, where in the algae may be a cyanobacterium. When they live endozoically in protozoans they are called cyanelle.

4.3.2 Structural Organization

These are unicellular or multicellular forms in filamentous or colonial type. Filamentous form consists of one or more cellular strands that is called as trichomes and is surrounded by mucilaginous sheath. Cyanobacteria are lacking flagellum throughout life cycle.

(i) Cell Structure

- The cell structure in cyanobacteria is typically prokaryotic.
- The cell does not have a well-defined nucleus instead have centrally located chromatin material similar to that of the bacterial chromosome.
- The cell wall has 4 layers with the cover mucilaginous sheath made from the mucopeptides.
- Protoplasm is distinctly divided into two parts: the centroplasm and chromoplasm.
- The chromatin material is present in the central colourless centroplasm.
- The peripheral protoplasm contains thylakoids that imparts colour or pigment to the cell is called as chromoplasm.
- The thylakoids contain pigments chlorophyll *a* and phycobilins i.e. phycocyanin (blue coloured), phycoerythrin (red coloured) and allophycocyanin (light blue coloured).
- The protoplastis prokaryotic and thus does not have membrane-bound organelles like endoplasmic reticulum, Golgi bodies, mitochondria, lysosomes, plastids and contains 70S ribosomes.
- The cyanobacterial cell produces distinct reserve food material in the forms of granules that store biomolecules.

KNOWLEDGE BUILDER

Gaidukov's phenomenon: Cyanobacteria or blue green algae have the special ability of adaptively changing their colour depending on the wavelengths of light falling on them, e.g., *Trichodesmium erythraeum* changes from usual green to red colour and thus is also known as "red sea" causing alga. This phenomenon is also called as or Complementary Chromatic adaption.

Q.41 In bacteria, the respiratory enzymes are situated

(A) Cytoplasm (B) Cell membrane

(C) Ribosomes (D) Mitochondria

Q.42 Cell wall in Gram positive bacteria is composed of

(A) Lipid and protein (B) Murein

(C) Proteins only (D) Cellulose and pectin

Q.43 One of the following is a filamentous bacteria

(A) *Pseudomonas* (B) *Clostridium*

(C) *Actinomyces* (D) *Azotobacter*

Q.44 Pili represent

(A) Extra chromosomal genetic elements (B) Protoplasmic outgrowths of donor cells

(C) Small flagella (D) Special bacterial cilia

Q.45 Plasmids represent

(A) A group of monerans (B) Small parasitic organisms

(C) Genetic elements (D) Extra chromosomal elements

Q.46 The resting spores produced by bacteria in unfavourable conditions are called

(A) Oidia (B) Endospores (C) Exospores (D) Chlmydospores

Q.47 Conjugation in bacteria was discovered by

(A) Beadle and Tatum (B) Zinder and Lederberg

(C) Griffith (D) Lederberg and Tatum

Q.48 Genophore is the name of

(A) DNA of eukaryotes (B) DNA of bacteria

(C) Genes of Drosophila (D) Genes of Neurospora

Q.49 There is no alternation of generation in *Escherichia coli* because of the absence of

(A) Syngamy (B) Reduction division

(C) Conjugation (D) Both (A) and (B)

Q.50 The part of the bacterial chromosome that is homolgous to a genome fragment transferred from the donor to the recipient cell in the formation of a merozygote is known as

(A) Exogenote (B) Endogenote (C) Dysgenic (D) Eugenic

Q.51 The following bacterium is associated with denitrification

(A) *Azotobacter* (B) *Rhodosprillum*

(C) *Pseudomonas* (D) *Rhizobium*

Q.52 Broad spectrum antibiotic is that which

(A) Acts on both pathogens and hosts

(B) Acts on ball bacteria and viruses

(C) Acts on a variety of pathogenic microorganisms

(D) Is effective in very small amounts

Q.53 Bacteria which can survive in the absence of oxygen are known as

(A) Obligate anaerobes (B) Facultative anaerobes

(C) Obligate aerobes (D) Facultative aerobes

Q.54 Streptomycin is produced by

(A) *Streptomyces venezuleae* (B) *Streptomyces griseus*

(C) *Streptomyces erythreus* (D) *Streptomyces aureofaciens*

Q.55 Food poisoning is caused by

(A) *Clostridium tetani* (B) *Clostridium botulinum*

(C) *Salmonella typhi* (D) *Mycobacterium tuberculosis*

Q.56 *Rhizobium* is

(A) Symbiotic and Gram negative bacterium

(B) Symbiotic and Gram positive bacterium

(C) Free living nitrogen fixing bacterium

(D) Parasitic and nitrogen fixing bacteria

Q.57 Syphilis is caused by

(A) *Neisseria gonorrhoeae* (B) *Treponema pallidum*

(C) *Hemophilous pertusis* (D) *Pasteurella pestis*

Q.58 Jacob and Wollman coined the term

(A) Plasmid (B) Episome (C) Circular DNA (D) Chromosome

Q.59 Branched chain lipids occur in the cell membranes of

(A) *Archaebacteria* (B) *Mycoplasma*

(C) *Actinomycetes* (D) *Streptomyces*

Q.60 Monerans producing conidia for reproduction belong to

(A) *Eubacteria* (B) *Archaebacteria*

(C) *Actinomycetes* (D) *Mycoplasma*

Q.61 Smallest known moneran lacking cell wall are

(A) *Spirochaete* (B) *Mycoplasma*

(C) *Cyanobacteria* (D) *Archaebacteria*

Q.62 *Cyanobacteria* do not possess

(A) Genere combination (B) Flagella

(C) Plasmids (D) Lamellasomes

Q.63 Heterocyst present in *Nostoc* is specialised for

(A) Fragmentation (B) Nitrogen fixation

(C) Storage (D) Photosynthesis

Q.64 A cyanelle is

(A) A BGA associated with human intestine

(B) A BGA associated with protists

(C) A free living BGA

(D) Any symbiotic BGA

Q.65 'Contagium vivum fluidum' (i.e., living fluid infectant) term has given by

(A) Mayer (B) Ivanowsky

(C) Beijerinck (D) Bawden and Pirie

Q.66 Bacterial cell divides every one minute. It takes 15 minutes a cup to be one-fourth full. How much time will it take to fill the cup?

(A) 30 minutes (B) 45 minutes (C) 60 minutes (D) 17 minutes

Q.67 Anaerobic monerans which are endosymbiotically associated with cattlels rumen are

(A) *Bacillus* (B) *Methanobacterium*

(C) *Halococcus* (D) *Thermoacidophiles*

Q.68 Highly resistance nature of endospore is due to the presence of

(A) Dipicolinic acid and peptidoglycan in spore coat

(B) Peptidogylycan in exosporium

(C) Dipicolinic acid and Ca in cortex

(D) Dipicolinic acid and Ca in cell membrane

Q.69 Gange's water purity is maintained by

(A) *B. dellovibrio* (B) *Clostridium*

(C) *Ferrobacillus* (D) *Tolypothrix*

Q.70 Find the correct match

S. No.	Column – I	S. No.	Column - II
(a)	Streptomycin	(i)	*Streptomyces griseus*
(b)	Terramycin	(ii)	*S. venezuelae*
(c)	Chloramphenicol	(iii)	*S. rimosus*
(d)	Bacitracin	(iv)	*Bacillus licheniformis*

(A) a(i), b(iii), c(ii), d(iv) (B) a(ii), b(i), c(iii), d(iv)

(C) a(iii), b(ii), c(i), d(iv) (D) a(i), b(ii), c(iii), d(iv)

Q.71 Select correct match w.r.t. Whittaker' system of classification

(A) Monera : Unicellular and multicellular, osmotrophs, producers and decomposers, true cellulosic cell wall

(B) Protista : Unicellular, eukaryotic, photoautotrophs and chemoautotrophs

(C) Fungi : Multicellular/loose tissue, eukaryotic, osmotrophs, chitinous wall

(D) Animalia : Multicellular, eukaryotic, organ or organ system, holozoic, no saprobic

Q.72 Read the given features carefully and select incorrect set of features for a respective member.

a. LPS layer present b. Diazotroph c. Peritrichous

d. Sewage disposal e. Obligate anaerobes f. Chemoautotrophs

g. L-Lysine absent h. Aerobic

(A) *Clostridium* – a, c, d, e (B) *Rhizobium* – a, b, g

(C) *Azotobacter* – a, b, g, h (D) *Methanogens* – e, f, a, g

Q.73 Endospores formed by certain bacteria ate actually the means for

(A) Reproduction (B) Perennation

(C) Bioluminescence (D) Red show formation

Previous Years' Questions

Q.1 First phylogenetic system of classification was given by ***(DPMT 2007)***

(A) Hutchinson (B) Whittaker

(C) Takhtajan (D) Engler and Prantl

Q.2 Engler and Prantl proposed their phylogenetic system in ***(Kerala 2005)***

(A) Species plantarum (B) Die Naturlichen Pflanzen familien

(C) Origin of species (D) Phylogeny of flowering aplants

Q.3 In which year, Robert H. Whittaker an Americon taxonomist, proposed his five kingdom system of classification ? ***(MPPMT 2000)***

(A) 1965 (B) 1969 (C) 1972 (D) 1989

Q.4 What is true in the latest classification of biological kingdoms proposed by Whittaker ?

(MPPMT 1994, 97, Kerala 1997)

(A) Eukaryotes are assigned to four of the five kingdoms

(B) Fungi are multicellular eukaryotic osmotrophs

(C) Viruses are not assigned to any kingdoms

(D) All of the above

Q.5 New systematics based on genetic interrelationship is ***(PbPMT 1999, JIPMER 1997)***

(A) Chemotaxonomy (B) Cytotaxonomy

(C) Numerical Taxonomy (D) Experimental Taxonomy

Q.6 What is the name of the book written by Aristotle ? ***(MPPMT 1999)***

(A) Historia Animalium (B) Systema Naturae

(C) Philosophie Zoologique (D) Historia Naturelle

Q.7 On the basis of nucleoid/karyon, viruses should be included in ***(Rajasthan 1998)***

(A) Prokaryotes (B) Progenote

(C) Protovirus (D) None of these

Q.8 The book Genera plantarum was written by ***(CBSE 1999)***

(A) Bessey (B) Engler and Prantl

(C) Bentham and Hooker (D) Hutchinson

Q.9 The outlook of classical systematics is embodied in ***(JIPMER 1997)***

(A) Typological concept (B) Biological concept

(C) Species concept (D) None of above

Q.10 Thallophyta includes ***(JIPMER 2000)***

(A) Algae, Fungi, Bacteria and Lichens (B) Algae and Fungi

(C) Fungi and Bacteria (D) Algae, Fungi and Lichens

Q.11 In five kingdom system, which one is the main basis of classification is ***(CBSE 2002)***

(A) Structure of nucleus (B) Mode of nutrition

(C) Structure of cell wall (D) Asexual reproduction

Q.12 Which one of the following is common to both prokaryotes and eukaryotes? ***(Kerala PMT 2005)***

(A) Mitotic apparatus (B) Histones (C) Mitochondria (D) Genetic code

Q.13 Scientific study of diversity of organisms and their evolutionary relationship is called ***(J & K CET 2011)***

(A) Morphology (B) Anatomy (C) Taxonomy (D) Systematics

Q.14 Inter-breeding animals belong to the same ***(AMU Medical 2011)***

(A) Genus (B) Family (C) Species (D) Order

Q.15 Which of the following is the wall less and smallest living cell? ***(HP PMT 2012)***

(A) Algae (B) Bacteriophage (C) Cyanobacteria (D) Mycoplasma

Q.16 When bacteria are rod like, they are called ***(Orissa 2007)***

(A) Bacilli (B) Cocci (C) Spirilla (D) *Vibrios*

Q.17 Which one of the following has the potential to be an important source of protein because it has 10 times higher yield than wheat ? ***(Chandigarh CET 2010)***

(A) *Spirogyra* (B) *Nostoc* (C) *Rhodospirillum* (D) *Spirulina*

Q.18 Which one of the following parts is wrongly matched ? ***(CBSE 2007)***

(A) *Streptomycetes* Antibiotic
(B) *Methanogens* Gobar gas
(C) Yeast Ethanol
(D) *Coliforms* Vinegar

Q.19 In September 2001, which of the following was used as a bioweapon agent in America in bioterroism ***(MP PMT 07)***

(A) Botulinium (*Clostridium botylinum*) (B) Polio virus
(C) AIDS virus (D) Anthrax (*Bacillus anthracis*)

Q.20 The bacterium (*Clostridium botulinum*) that causes botulism is ***(CBSE 2006)***

(A) A facultative aerobe (B) An obligate aerobe
(C) A facultative anaerobe (D) An obligate anaerobe

Q.21 Some hyperthermophilic organisms that grow in highly acidic (pH 2) habitats belong to the two groups ***(CBSE PMT Prelims 2010)***

(A) Liverworts and yeasts (B) Eubacteria and archaea
(C) Cyanobacteria and diatoms (D) Protists and mosses

Q.22 In biogas plant, which group of bacteria is found ? ***(Chandigarh CET 2010)***

(A) Cyanobacteria (B) Myxobacteria

(C) Mycobacteria (D) Archaebacteria

Q.23 In the Five kingdom classification, bacteria are included in kingdom ***(HP PMT 2010)***

(A) Monera (B) Protista (C) Plantae (D) Animalia

Q.24 The types of ribosomes found in prokaryotic call are ***(Karnataka CET 2011)***

(A) 100 S (B) 80 S (C) 60 S (D) 70 S

Q.25 What is a genophore ? ***(WB JEE 2011)***

(A) DNA in prokaryotes (B) DNA and histones in prokaryotes

(C) DNA and protein in prokaryotes (D) RNA in prokaryotes

Q.26 In the 5-kingdom classification, the kingdom that includes the blue-green algae, nitrogen-fixing bacteria and methanogenic archaebacteria is ***(AMU Medical 2011; J & K CET 2011)***

(A) Protista (B) Monera (C) Plantae (D) Fungi

Q.27 Which one of the following organisms is not an example of eukaryotic cells? ***(CBSE PMT Prelims 2011)***

(A) *Paramoecium caudatum* (B) *Escherichia coli*

(C) *Euglena viridis* (D) *Amoeba proteus*

Q.28 In eubacteria, a cellular component that resembles eukaryotic cell is ***(CBSE PMT Prelims 2011)***

(A) Plasma membrane (B) Nucleus

(C) Ribosomes (D) Cell wall

Q.29 Maximum nutritional diversity is found in the group ***(CBSE PMT Prelims 2013)***

(A) Animalia (B) Monera (C) Plantae (D) Fungi

Q.30 Which of the following is not a free living nitrogen fixing bacterium ? ***(HP PMT 2012)***

(A) *Azotabacter* (B) *Rhizobium* (C) *Bacillus* (D) *Rhodospirillum*

Q.31 Which of the following are likely to be present in deep sea water ? ***(NEET 2013)***

(A) Blue-green algae (B) Saprophytic fungi

(C) Archaebacteria (D) Eubacteria

Q.32 Archaebacteria differ from eubacteria in ***(AIPMT 2014)***

(A) Mode of reproduction (B) Cell membrane structure

(C) Mode of nutrition (D) Cell shape

Q.33 Anoxygenic photosynthesis is characteristic of ***(AIPMT 2014)***

(A) *Ulva* (B) *Rhodospirillum*

(C) *Spirogyra* (D) *Chlamydomonas*

Q.34 Which structures perform the function of mitochondria in bacteria ? ***(AIPMT 2014)***

(A) Mesosomes (B) Nucleoid (C) Ribosomes (D) Cell wall

Q.35 The unicellular eukaryotic organism were placed in ***(HP PMT 2012)***

(A) Protista (B) Monera (C) Fungi (D) Animalia

Q.36 A person suffering from a disease caused by *Plasmodium*, experiences recurring chill and fever at the time when ***(CBSE-PMT Mains 2010)***

(A) The sporozoites released from RBCs are being rapidly killed and broken down inside spleen

(B) The trophozoites reach maximum growth and give out certain toxins

(C) The parasite after its rapid multiplication inside RCBs ruptures them releasing more parasites

(D) The microgametocytes and megagametocytes are being destroyed by the WBCs

Q.37 Isogamy is found in ***(Chandigarh CET 2010)***

(A) *Hydra* (B) *Monocystis* (C) *Planaria* (D) *Plasmodium*

Q.38 Which stage of malarial parasite is infective to man ? ***(Karnataka CET 2011)***

(A) Gametocyte (B) Merozoite (C) Cryptomerozoite (D) Sporozoite

Q.39 Which of the following does not belong to the kingdom Protista ? ***(Kerala PMT 2011)***

(A) *Chrysophytes* (B) *Euglenoids* (C) *Ascomycetes* (D) *Dinoflagellates*

Q.40 Match the following and select the correct combination from the options given below.

(CBSE PMT (Prelims) 2011)

Column I (Kingdom)	Column II (Class)
a. Plantae	1. Archaebacteria
b. Fungi	2. Euglenoids
c. Protista	3. Phycomycetes
d. Monera	4. Algae

(A) a – 4, b – 3, c – 2, d - 1
(B) a – 1, b – 2, c – 3, d – 4
(C) a – 3, b – 4, c – 2, d – 1
(D) a – 2, b – 3, c – 4, d – 1

Q.41 Where will you look for the sporozoites of the malarial parasite ? ***(CBSE PMT (Prelims) 2011)***

(A) Saliva of infected female *Anopheles* mosquito
(B) Red blood corpuscles of human suffering from malaria
(C) Spleen of infected humans
(D) Salivary glands of freshy moulted female *Anopheles* mosquito

Q.42 Which one of the following organisms is not an eukaryote ? ***(CBSE PMT (Prelims) 2011)***

(A) *Paramecium caudatum*
(B) *Escherichia coli*
(C) *Euglena viridis*
(D) *Amoeba proteus*

Q.43 The mode of asexual reproduction in *Euglena* is ***(Chandigarh CET 2011)***

(A) Transverse binary fission
(B) Longitudinal binary fission
(C) Multiple fission
(D) Irregular binary fission

Q.44 In the five kingdom classification, *Chlamydomonas* and *Chlorella* have been included in

(CBSE Main PMT 2012)

(A) Protista (B) Algae (C) Plantae (D) Monera

Q.45 The beautiful diatoms and desmids are placed under ***(AMU 2012)***

(A) *Chrysophytes* (B) *Dinoflagellates* (C) *Euglenoids* (D) Slims moulds

ANSWER KEY

Objective Questions

Q.1 C	**Q.2** C	**Q.3** A	**Q.4** D	**Q.5** B	**Q.6** D
Q.7 C	**Q.8** D	**Q.9** A	**Q.10** B	**Q.11** C	**Q.12** D
Q.13 B	**Q.14** D	**Q.15** C	**Q.16** A	**Q.17** D	**Q.18** B
Q.19 C	**Q.20** A	**Q.21** A	**Q.22** B	**Q.23** A	**Q.24** A
Q.25 C	**Q.26** B	**Q.27** C	**Q.28** B	**Q.29** B	**Q.30** B
Q.31 B	**Q.32** A	**Q.33** D	**Q.34** B	**Q.35** A	**Q.36** A
Q.37 C	**Q.38** C	**Q.39** C	**Q.40** B	**Q.41** B	**Q.42** B
Q.43 C	**Q.44** B	**Q.45** D	**Q.46** B	**Q.47** D	**Q.48** B
Q.49 D	**Q.50** B	**Q.51** C	**Q.52** C	**Q.53** B	**Q.54** B
Q.55 B	**Q.56** A	**Q.57** B	**Q.58** B	**Q.59** A	**Q.60** C
Q.61 B	**Q.62** B	**Q.63** B	**Q.64** B	**Q.65** C	**Q.66** D
Q.67 B	**Q.68** C	**Q.69** A	**Q.70** A	**Q.71** C	**Q.72** A
Q.73 B					

Previous Years' Questions

Q.1 D	**Q.2** B	**Q.3** B	**Q.4** D	**Q.5** D	**Q.6** A
Q.7 A	**Q.8** C	**Q.9** A	**Q.10** A	**Q.11** B	**Q.12** D
Q.13 D	**Q.14** C	**Q.15** D	**Q.16** A	**Q.17** D	**Q.18** D
Q.19 D	**Q.20** D	**Q.21** B	**Q.22** C	**Q.23** D	**Q.24** A
Q.25 A	**Q.26** B	**Q.27** B	**Q.28** A	**Q.29** B	**Q.30** B
Q.31 C	**Q.32** B	**Q.33** B	**Q.34** A	**Q.35** A	**Q.36** C
Q.37 B	**Q.38** D	**Q.39** C	**Q.40** A	**Q.41** A	**Q.42** B
Q.43 B	**Q.44** A	**Q.45** A			