CHAPTER 2

Biological Classification

Syllabus

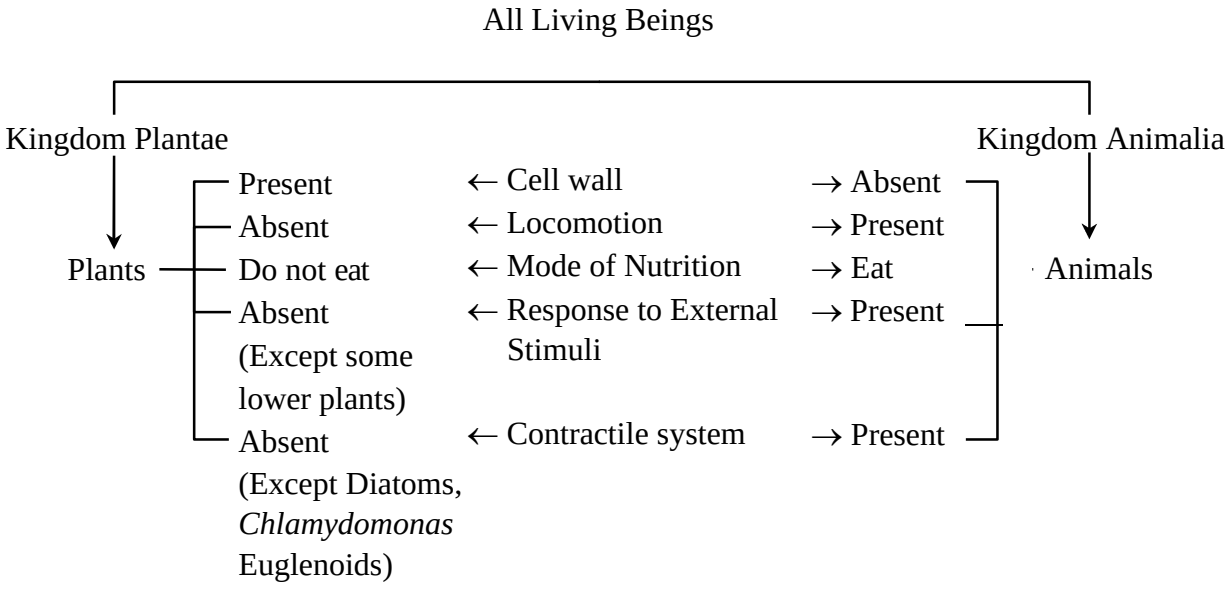
> ***Five kingdom classification; salient features and classification of Monera; Protista and Fungi into major groups; Lichens; Viruses and Viroids***

Chapter Index :

KINGDOM SYSTEMS OF CLASSIFICATION

(1) Two Kingdom Classification: It was given by Linnaeus. Traditionally all the organisms of the world were divided into two kingdoms -the animal kingdom (Animalia) and the plant kingdom (Plantae). The major criterion of classification was the presence or absence of cell wall. Other criterias were locomotion, mode of nutrition, response to external stimuli etc.

Concept Builder



Shortcomings of two-kingdom system of classification:

- This system did not distinguish between the eukaryotes and prokaryotes, unicelled and multicelled organisms, photosynthetic and non-photosynthetic organisms.
- There are few organisms like Chlamydomonas, Euglena and the slime moulds which have been claimed by both zoologists and botanists (organisms which share characteristics of both animals and plants).
- Since there are certain organisms that do not fall naturally into either plant or animal kingdom, it was proposed that a new kingdom is to be established to accommodate such organisms.

(2) Three Kingdom Classification:

- Haeckel, a German zoologist (1866), suggested that a third kingdom Protista, be created to include all unicellular microorganisms.
- This includes a wide variety of unicellular, mostly aquatic eukaryotes like -Fungi, Protozoa, Algae, Bacteria and Slime moulds.
- Thus, he proposed three kingdoms, namely -Plantae, Protista and Animalia.

(3) Four Kingdom Classification:

- Copeland (1956) gave four kingdom of classification and included Monera as fourth kingdom.
- Copeland originally called it as kingdom 'Mychota'.
- It was called '**Monera**' by Daugherty and Allen.
- Kingdom Monera includes all the prokaryotic organisms i.e., eubacteria (including cyanobacteria, formerly known as blue-green algae) and archaebacteria.
- The actinomycetes (filamentous bacteria) are also included in this kingdom.

(4) Five Kingdom Classification:

- According to five-kingdom concept proposed by R.H. Whittaker.
- Whittaker (1969), the organisms are divided into five kingdoms namely Monera, Protista, Fungi, Plantae, Animalia, on the basis of the following criteria:

(a) Complexity of cell structure: prokaryotic vs eukaryotic organisation of cells.

(b) Complexity of body organisation: unicellularity vs multicellularity; simple multicellular forms to complex multicellular forms.

(c) Mode of nutrition: Autotrophic vs heterotrophic (parasitic or saprobic or ingestive organisms). It was the major criteria of this classification system.

(d) Reproduction.

(e) Phylogenetic or evolutionary interrelations

Table 1 : Comparative account of different characteristics of the Five Kingdoms

Characters	Five Kingdoms				
	Monera	**Protista**	**Fungi**	**Plantae**	**Animalia**
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell wall	Noncellulosic (Polysaccharide + amino acid)	Present in some protistes	Present (without cellulose)	Present (cellulose)	Absent

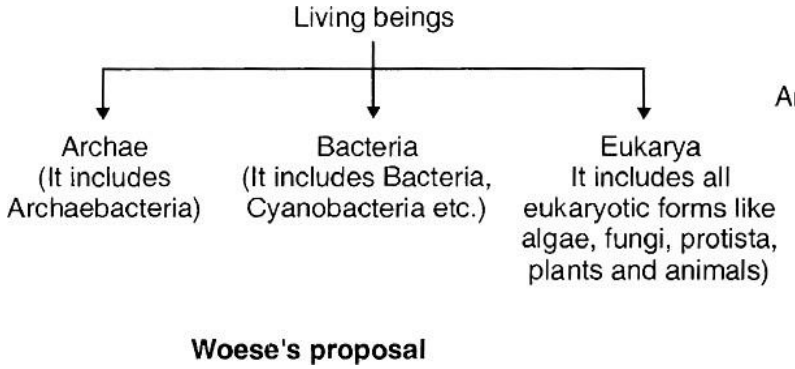
Nuclear membrane	Absent	Present	Present	Present	Present
Body organisation	Cellular	Cellular	Multicellular/ loose tissue	Tissue/organ	Tissue/organ/ organ system
Mode of nutrition	Autotrophic (chemosynthetic and photosynthetic) and Heterotrophic (saprophyte/ parasite	Autotrophic (photosyn-thetic) and Heterotrophic	Heterotrophic (Saprophytic/ parasitic)	Autotrophic (Photosyn-thetic)	Heterotrophic (Holozoic/ Saprophytic etc.)

(5) Six Kingdom Classification :

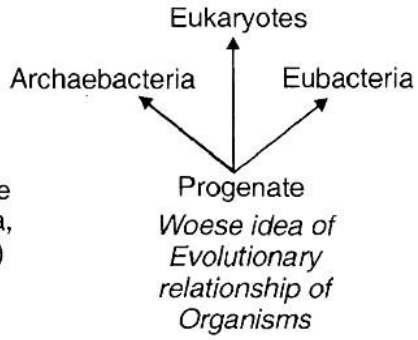
- **Carl Woese** proposed six kingdom classification.
- These six kingdoms are Archaebacteria, Eubacteria, Protista, Fungi, Plantae and Animalia.
- He separated the archaebacteria from eubacteria on the basis of some major differences such as the absence of peptidoglycan in the cell walls of the former and the occurrence of branched chain lipids (a monolayer instead of a phospholipid bilayer) in the membrane.
- Based on the sequence of 16S ribosomal RNA genes, Woese found that the six kingdoms naturally cluster into three main categories.
- He called these **categories as domains of life**.
- These domains are Bacteria, Archae and Eukarya and are believed to have originated from common ancestor called **progenote**.

Three Domains of life

- Based on the sequence of 16 S ribosomal RNA genes, woese found that the six kingdoms naturally cluster into **three domains.**
- These **domains** are *Archae, Bacteria* and *Eukarya,* and are believed to be originated from common ancestor called *Progenate.* Domain is a category higher than kingdom.



Woese's proposal



Woese idea of Evolutionary relationship of Organisms

KINGDOM: MONERA

- The Kingdom Monera includes all prokaryotes.
- Monerans are the most primitive forms of life, originating from more ancient living stock termed progenote.

- The kingdom Monera includes eubacteria and archaebacteria.
- Eubacteria includes Cyanobacteria, Actinomycetes, Mycoplasma, Rickettsiae, Chlamydiae and Spirochaetes etc.

Classification of Monera

(1) In 4 kingdom system, a new kingdom was created to accommodate all prokaryotic organisms i.e, eubacteria and archaebacteria. Copeland called it kingdom Mychota. It was called **'Monera'** by **Daugherty** and **Allen**.

(2) Actually, archaebacteria differ from eubacteria in many respects and resemble eukaryotes in some ways.

(3) (i) **Carl Woese** separated the archaebacteria from eubacteria on the basis of some major differences such as the absence of peptidoglycan in the cell walls of the former and the occurrence of branched chain lipids (a monolayer instead of a phospholipid bilayer) in the membrane.

(ii) Therefore, 6 kingdoms given by **Carl Woese** are

Kingdom-1 -Archaebacteria	Kingdom-2 -Eubacteria
Kingdom-3 -Protista	Kingdom-4 -Fungi
Kingdom-5 -Plantae	Kingdom-6 -Animalia

Salient Features of Monera

1. These are unicellular, colonial, multicellular prokaryotic organisms without nuclear membrane, nucleolus, chromatin and histone proteins.
2. Cell wall is made up of peptidoglycan (exceptions are Archaebacteria and Mycoplasma).
3. Membrane bound organelles are absent.
4. Cyclosis is absent and ribosomes are of 70 S type .
5. Respiratory enzymes are found associated with plasma membrane.
6. Nucleoid or genophore or incipient nucleus or prochromosome is composed of naked DNA, RNA and nonhistone proteins.
7. Reproduction by asexual method.
8. Cell division is amitotic type and lacks spindle formation.

Self Assessment

Position of bacteria in a kingdom system of classification proposed by Linnaeus is

(1) Monera (2) Protista (3) Plantae (4) Mychota

In three kingdom classification, the kingdom Protista includes

(1) Unicellular eukaryotic organisms only

(2) Unicellular prokaryotic organisms only

(3) Wide variety of unicellular, mostly aquatic eukaryotes

(4) Wide variety of unicellular, mostly terrestrial Prokaryotes

Which of the following was given the status of kingdom in the classification system given by Copeland?

(1) Prokaryotes (2) Myxomycetes (3) Monera (4) Protista

Which one of the following is not the basis of five kingdom classification?

(1) Cell type (2) Body organisation

(3) Reproduction (4) Reserve food materials

Multicellular organisms with holophytic mode of nutrition belong to how many kingdoms in Whittaker system?

(1) One (2) Two (3) Three (4) Five

In six kingdom classification, Monera was divided into two separate kingdoms on the basis of

(1) Cell wall composition (2) Lipid nature in plasma membrane

(3) Absence of sap vacuole (4) Both (1) & (2)

Select correct statement w.r.t. monera

(1) All are unicellular

(2) All are chemoheterotrophs

(3) Unicellular, colonial, multicellular prokaryotes

(4) Prokaryotes with 70 S ribosome and histonic DNA

Multicellular with loose tissue body organisation is a characteristic feature of

(1) Monera (2) Protista (3) Plantae (4) Fungi

Cell wall is made of polysaccharide and amino acid in most of the members of

(1) Monera (2) Protista (3) Fungi (4) Animalia

Cyclosis is absent in

(1) Diatoms (2) Eubacteria (3) Algae (4) Plantae

Ans. Q.1 (3), Q.2 (3), Q.3 (1), Q.4 (4), Q.5 (2), Q.6 (4), Q.7 (3), Q.8 (4), Q.9 (1), Q.10 (2)

Let us discuss various monerans in detail :

1. EUBACTERIA

- Bacteria are cosmopolitan and occur in every habitat wherever living or dead organic matter is present.
- **Anton Von Leeuwenhoek** discovered bacteria in rain water which had been allowed to stand for many days and tartar scrapped from teeth.
- In 1695, he published his work **"The Secrets of Nature"**.
- A.V. Leeuwenhoek termed these microorganisms as dierkens which was later translated as animalcules by the Royal society.
- Term microbe for animalcules was coined by **Se' dillot**, but the term microorganism was proposed by **Pasteur**.

Concept Builder

- **Ehrenberg** first of all coined the word 'bacteria'
- Louis Pasteur is considered father of modern microbiology. He introduced the term aerobic and anaerobic for the life in the presence or absence of oxygen respectively.
- **Robert Koch**, a German doctor, demonstrated that the anthrax disease of sheep was caused by bacteria. Koch had followed four experimental steps (Koch's postulates) which help to establish a relationship between a microorganism and a disease.
- Smallest bacterium : *Dialister pneumosintes*
- Largest filamentous bacterium : *Beggiatoa mirabilis*

Shapes of Bacteria

- Bacteria occur in four basic forms or shapes.
- These are spherical (Cocci), rod shaped (Bacilli), Vibrio and Spiral.
- Though most bacterial species have cells that are of a fairly constant and characteristic shape, some species are pleomorphic (*i.e.*, these can exhibit a variety of shapes), *e.g., Rhizobium leguminosarum*.

(a) Coccus : Spherical or nearly spherical, aflagellate, 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 pneumoniae.*
- *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 lutea*.

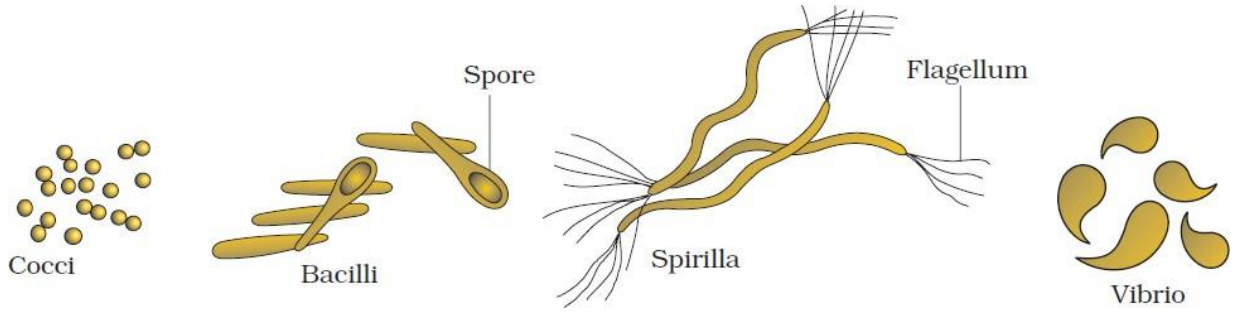
(b) Bacillus : Rod-like forms, either singly or may be arranged differently. They are generally flagellate. It is the most common of all the shapes. They are of following types :

(i) Monobacillus -The bacteria occur singly, *e.g., Bacillus anthracis, Lactobacillus*.

(ii) Diplobacillus -Bacteria are arranged in pairs. *e.g., Bacillus subtilis*

(iii) Streptobacillus -Bacteria form a chain of rods, *e.g., Streptobacillus*.

(iv) Palisade-like -If the cells are lined side by side like match sticks and at angles to one another. *e.g., Corynebacterium diphtheriae*.



Bacteria of different shapes

(c) **Spiral bacteria :** Coiled forms of bacteria exhibiting twists with one or more turns are called spirilla, *e.g., Spirillum volutans.*

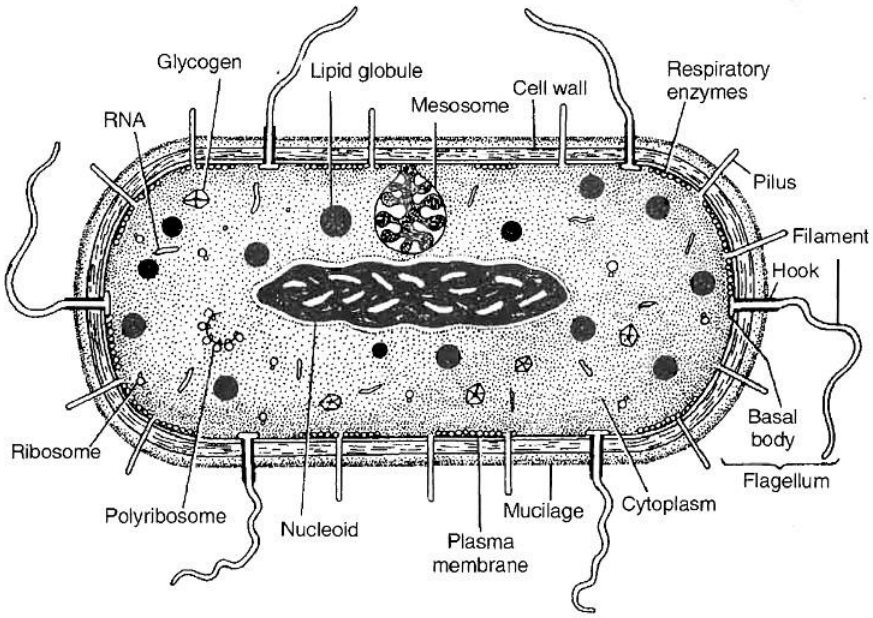
(d) **Vibrio :** Bacteria with less than one complete twist or turn are called vibrio. These resemble a comma (,) in appearance, *e.g., Vibrio cholerae.*

(e) **Stalked bacteria :** The body of bacterium possesses a stalk, *e.g., Caulobacter*.

(f) **Budding bacteria :** The body is swollen at places, *e.g., Rhodomicrobium*.

Bacterial Cell Structure

Bacterial cell structure is very simple although they are very complex in behaviour. They show the most extensive metabolic diversity. Electron microscope can only reveal the detailed structure of bacterial cell. It consists of following structures:



Cell structure of bacteria under electron microscope

1. Glycocalyx:

(i) It is outermost part of cell envelope (Glycocalyx, cell wall, plasma membrane)

(ii) Represented by either **slime layer** or **capsule**

(a) **Slime layer** is composed of dextran, dextrin and lavan sugars and protect the cell against desiccation and loss of nutrients.

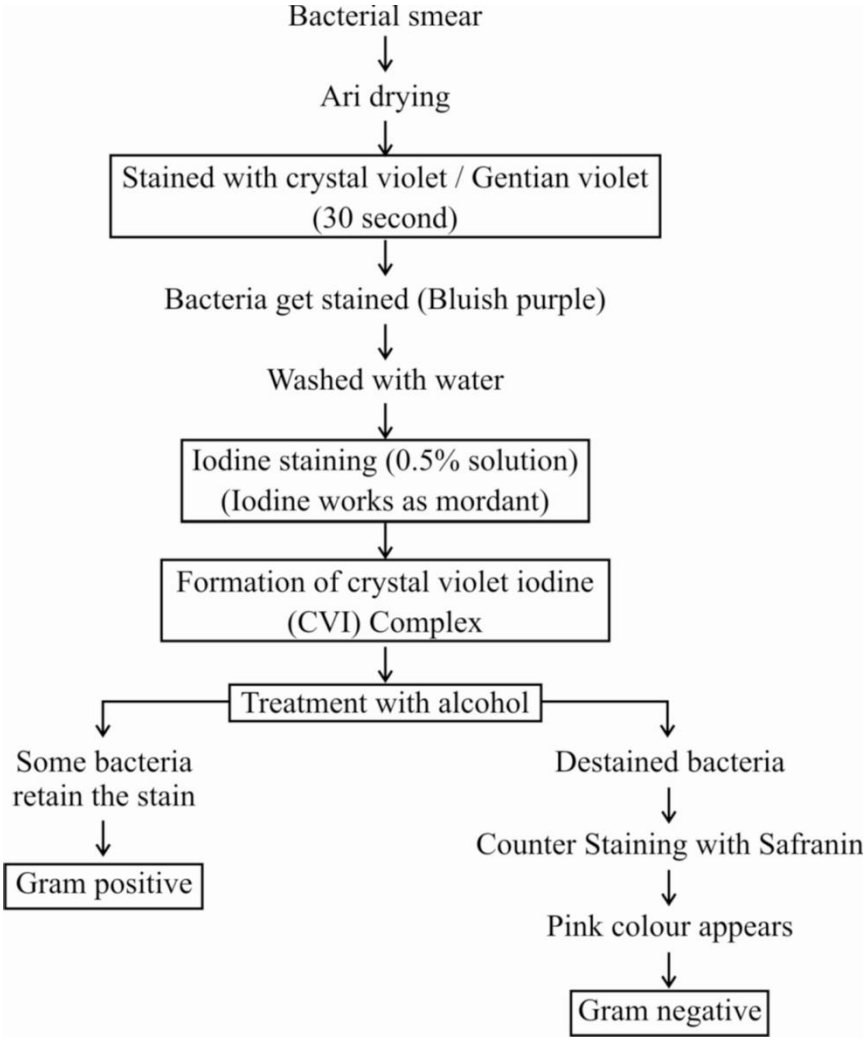
(b) **Capsule** is made up of polysaccharides and D-glutamic acid. It provides gummy or sticky character and virulent property to the cell.

2. Cell wall :

- It is present outside the cell membrane and is a rigid structure.
- Due to its rigidity, it protects the internal structures of the cell and provides shape to the cell.
- However, its main function is to prevent the cell from expanding and bursting because most bacteria live in hypotonic environments, and are likely to take in much water and eventually burst.
- The cell walls of almost all the eubacteria (true bacteria) are made up of peptidoglycan, also called **murein** or **mucopeptide**.
- It is found only in prokaryotes.
- As the name suggests, the peptidoglycan consists of two components-a peptide portion which is composed of amino acids connected by peptide linkages, and a glycan or sugar portion.
- The glycan portion, which forms the backbone of peptidoglycan, is composed of alternating units of amino sugars **N-acetyl-glucosamine** (NAG) and **N-acetylmuramic acid** (NAM) joined together by -1, 4 linkages.
- The peptidoglycan chains are laterally linked by short chains of four amino acids which are attached to N-acetylmuramic acid residues.
- The four amino acids of this tetrapeptide are 0 -alanine, L-alanine, D-glutamic acid and L-Iysine (in Gram +ve bacteria) or diaminopimelic acid (in Gram -ve bacteria).
- The tetrapeptide chains are also interlinked by a peptide bridge between the carboxyl group of an amino acid in one tetrapeptide chain and amino group of an amino acid in another tetrapeptide chain.
- The cross linkages can occur between tetrapeptides in different chains, as well as between adjacent tetrapeptide chains. As a result, peptidoglycan forms a rigid, multilayered sheet.
- Another component, teichoic acid, an acidic polymer consisting of a carbohydrate (e.g., glucose), phosphate and an alcohol is found in cell walls of Gram +ve bacteria.
- Teichoic acid has several functions such as binding metals, acting as receptor sites for some viruses and maintaining cells at low pH to prevent degradation of cell walls by self-produced enzymes.
- The walls of Gram positive bacteria contain very little amount of lipids.
- The cell walls of Gram negative bacteria are much more complex.
- The peptidoglycan layer is very thin making up only 10% or less of the cell wall.
- However, the most interesting feature is the presence of an outer membrane that covers a thin underlying layer of peptidoglycan.
- The outer membrane is a bilayered structure consisting chiefly of phospholipids, proteins and lipopolysaccharides (LPS).
- The outer membrane serves as a barrier to prevent the escape of important enzymes from the space (periplasmic space) between the cytoplasmic membrane and the outer membrane.
- It also prevents the entry of various chemicals that could damage the cell.

- It acts as main surface antigen in cell wall.
- However, permeability of outer membrane to nutrients is provided by proteins called **porins** which form channels in the membrane through which substances of hydrophilic nature and low molecular weight can diffuse.
- **Christian Gram** (1884) developed a staining method for bacteria, using Gram stain (crystal violet).
- On the basis of stainability with Gram Stain, bacteria are classified into two groups; Gram positive and gram negative.

Flow chart representing Gram staining technique

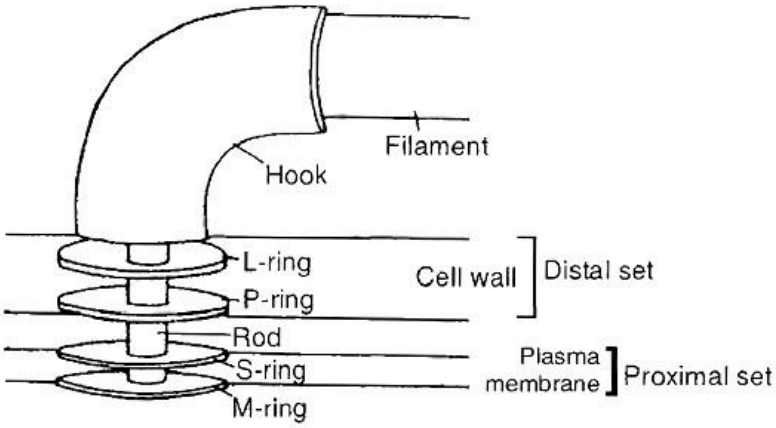


3. Surface Appendages : These include flagella and fimbriae (or pili).

(a) Flagella are long, fine, wavy, filamentous appendages that protrude through the cell wall, responsible for the motility of bacteria. These are much thinner than the flagella or cilia of eukaryotes.

- **Structure of Flagella:** The entire flagellar apparatus is made up of three distinct regions: basal body, hook and filament.
- **Basal body:** It is most complex portion of flagellum and has four rings (L, P, S and M), only two rings S and M are present in gram +ve bacteria. L and P rings in cell wall constitute distal set, while S and M rings are present in plasma membrane, forming proximal set.

- **Hook:** Made up of different protein units.
- **Filament:** Bacterial flagella are made up of identical spherical subunits of a protein called flagellin. Longitudinal chains of flagellin molecules run longitudinally around each other to form a wavy helical or rope-like structure. Therefore, a cross section of the flagellum reveals a number of flagellin molecules around a central space.

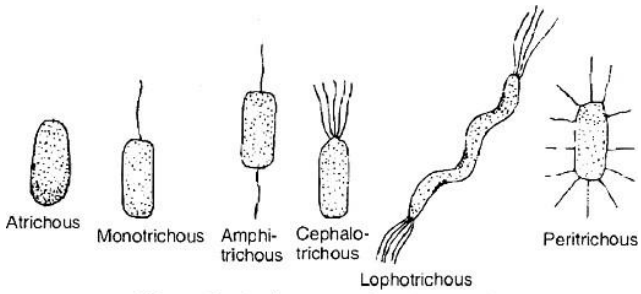


A sectional view of a bacterial cell showing the detailed structure of the flagellum and attachment of flagellum to the bacterial cell

Concept Builder

Depending upon the presence or absence, number and position, following types of flagellar arrangements are observed among bacteria :

- **Atrichous:** Flagella absent, *e.g., Pasteurella, Lactobacillus*.
- **Monotrichous:** Only one flagellum attached at one pole of the organism, *e.g.,Thiobacillus, Vibrio*.
- **Amphitrichous:** One flagellum at both ends, *e.g., Nitrosomonas*.
- **Cephalotrichous:** Two or more flagella attached at one end, *e.g., Pseudomonas fluorescence*.
- **Lophotrichous:** Two or more flagella attached at both ends, *e.g., Spirillum volutans*.
- **Peritrichous:** Flagella distributed all over the surface of the cell, *e.g., Escherichia coli, Clostridium tetani*.



Flagellation types in bacteria

(b) Pili and fimbriae are hollow, non helical, filamentous appendages projecting from the walls of Gram-negative bacteria. These are thinner and shorter and more in number than the flagella. These are made up of specific proteins called **pilin**.

There are different types of pili which serve different functions. One type, known as type I pili, (somatic pili) playa 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.

Differences between Gram positive and Gram negative bacteria

Gram Positive Bacteria	Gram Negative Bacteria
1. They retain the blue colour of Gram stain even after washing with alcohol	1. They get stained blue with Gram stain initially but lose it after washing with alcohol
Cell wall	
2. The cell wall is 150-200 Å thick. The cell wall is not covered by lipopolysaccharide layer, *i.e.*, it is a single layer.	2. The cell is 75-120 Å thick. Cell wall is covered by lipopolysaccharide layer, *i.e.* , it is a double layer.
3. Cell wall is more rigid due to high percentage (80%) of peptidoglycan	3. Cell wall is less rigid due to low percentage (3-12%) of peptidoglycan
4. Muramic acid content 70-95%	4. Muramic acid content 5-20%
5. Lipid content is low, *i.e.* ,2-4%	5. Lipid content is high, *i.e.* , 20-30%
6. Phospholipid absent in cell wall	6. Present
7. Teichoic acid present	7. Absent
8. Fewer amino acids in cell wall	8. Several types of amino acids in cell wall
9. Diaminopimelic acid (DAPA) is absent in the cell wall, instead L-Lysine is present	9. DAPA present in cell wall in place of L-Iysine
10. Wall is more sensitive to antibiotics such as penicillin	10. Wall is-not sensitive to penicillin
11. Wall is resistant to alkalies and insoluble in 1% KOH solution	11. Wall is sensitive to alkalies and soulble in 1% KOH solution
12. Mostly noncapsulated	12. Mostly capsulated
13. Protoplast is produced by the reaction with lysozyme	13. Sphaeroplast is formed by the reaction with lysozyme (LPS remains unaffected)
Other Structures	
14. Mesosomes are very common	14. Mesosomes are rare
15. Pili usually absent	15. Pili very common
16. Flagellationless common	16. Flagellation very common
17. Basal body of flagellum has 2 rings (S, M) only	17. It has four rings (L, P, S and M)
18. Only few forms are pathogenic and may produce exotoxins *e.g. Bacillus, Clostridium, Lactobacillus, Streptococcus, Leuconostoc, Staphylococcus, Corynebacterium*	18. More forms are pathogenic and may produce endotoxins *e.g.* E. *coli, Salmonella, Acetobacter, Azotobacter, Vibrio, Agrobacterium, Shigella, Xanthomonas*

4. **Protoplast:** Cell wall encloses the protoplast, the living matter. It includes (i) Cell membrane (ii) Cytoplasm, (iii) Nucleoid and may have plasmid and episome.

(i) Cell membrane:

- It lies inner to the cell wall, actually representing the outermost layer of the protoplast.
- It is living and semipermeable, controlling the movements of various dissolved substances in and out of the cells.
- Functionally, the cell membrane of bacteria resembles mitochondria of eukaryotic cells as respiratory ETS enzymes and succinate dehydrogenase (Krebs Cycle) are associated with the membrane.
- The cell membrane gets invaginated and folded to form a structure called **mesosome** (chondroid) in some bacteria, particularly the Gram positive bacteria.
- These may be central or peripheral in position and they are supposed to playa role in replication of DNA during cell division, as these are often attached to the nuclear body.
- Besides, these increase the surface area of absorption and help in septa formation during binary fission.

(ii) Cytoplasm:

- It is homogenous colloidal mass of carbohydrates, fats, proteins, lipids, nucleic acids, minerals and water.
- It does not show streaming movements.
- It lacks sap vacuoles and gas vacuoles (may be present in some bacteria which live in aquatic condition).
- Typical membrane bound organelles of eukaryotic cells like endoplasmic reticulum, mitochondria, golgi complex and plastids are absent.
- The cytoplasm appears granular due to the presence of ribosomes.
- However, these are 70S type in bacteria as compared to 80S type in eukaryotes.
- Ribosomes lie scattered freely in the cytoplasm, but sometimes may form a small chain of 4-6 ribosomes attached to mRNA constituting polyribosome or polysome.
- Various non living inclusions like glycogen particles, fat bodies, volutin granules (polymetaphosphate -source of energy) and lipid molecules acting as food reserve lie dispersed in the cytoplasm.
- The cytoplasm is usually colourless, lacking pigments.
- However, in photosynthetic bacteria, the cytoplasm contains pigments like bacteriochlorophyll and bacterioviridin.
- The pigments either lie dispersed in the cytoplasm or present in membrane bound spherical vesicles called chromatophores.
- These pigments are capable of entrapping solar energy for photosynthesis.

(iii) Nucleoid (Prochromosome, Genophore, Incipient nucleus) –

- Bacterial cell lacks a well organized nucleus.
- It consists of a long double stranded DNA molecule repeatedly folded with the help of RNA to form a circular ring.

- DNA has no free ends and not associated with histone proteins (polyamines present). Circular DNA ring, without histones is often termed bacterial chromosome.

Plasmid (Minichromosome) :

- Term plasmid was given by **Lederberg** and **Hays**.
- These are small, extrachromosomal, non-essential, circular, double stranded, free naked DNA molecules.
- The genes present on them have no vital role in survival and growth of bacteria.
- These perform autonomous replication.
- If plasmids temporarily integrate with bacterial chromosome, then they are called **episomes**.

Concept Builder

Types of plasmids :

(a) **F-Plasmid:** It forms sex pilus and is responsible for process of conjugation or fertility factor transfer.

(b) **R-Plasmid:** These plasmids have resistance gene (Resistance Transfer Factor, RTF) for antibiotics like penicillin, tetracycline.

(c) **Col-Plasmid:** Genes of this plasmid are responsible for production of colicins (bacteriocin) for killing other bacteria.

(d) **Ti Plasmid:** From *Agrobacterium tumefaciens*, used in genetic engineering

(e) Degradative plasmid of *Pseudomonas putida* (superbug) helps to decompose hydrocarbons of petroleum in oil spills.

5. Bacterial Life Processes

Discussion of bacterial life processes revolves around the study of the prominent metabolic activities like respiration and nutrition.

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

(a) **Obligate or strict aerobes :** These bacteria can live only in presence of oxygen as they possess the enzyme system for aerobic respiration only. In the absence of oxygen, they cannot respire and thus, die, *e.g., Bacillus subtilis*.

(b) **Facultative anaerobes :** They normally respire aerobically. However, they are capable of switching over to anaerobic mode to get energy for their survival, if sufficient oxygen to sustain aerobic respiration is not available in the environment, *e.g., Pseudomonas*.

(c) **Obligate or strict anaerobes:** These bacteria respire anaerobically only. The growth of such bacteria will certainly be slower as anaerobic respiration liberates much less amount of energy as compared to aerobic respiration. They lack enzymes necessary for carrying out aerobic respiration *e.g., Clostridium botulinum*.

(d) **Facultative aerobes:** They normally respire anaerobically, but are capable of respiring aerobically as well, if oxygen is available. Most of the photosynthetic bacteria are facultative aerobes *e.g., photosynthetic bacteria Chlorobium*.

Concept Builder

(i) **Aerotolerant anaerobes:** Bacteria that continue to perform anaerobic respiration even in the presence of oxygen, e.g., Lactic acid bacteria.

(ii) **Anaerotolerant aerobes:** Aerobic bacteria continue to perform aerobic respiration even in absence of free oxygen by using oxygen of oxidised salts, e.g., Denitrifying bacteria.

(B) Nutrition :

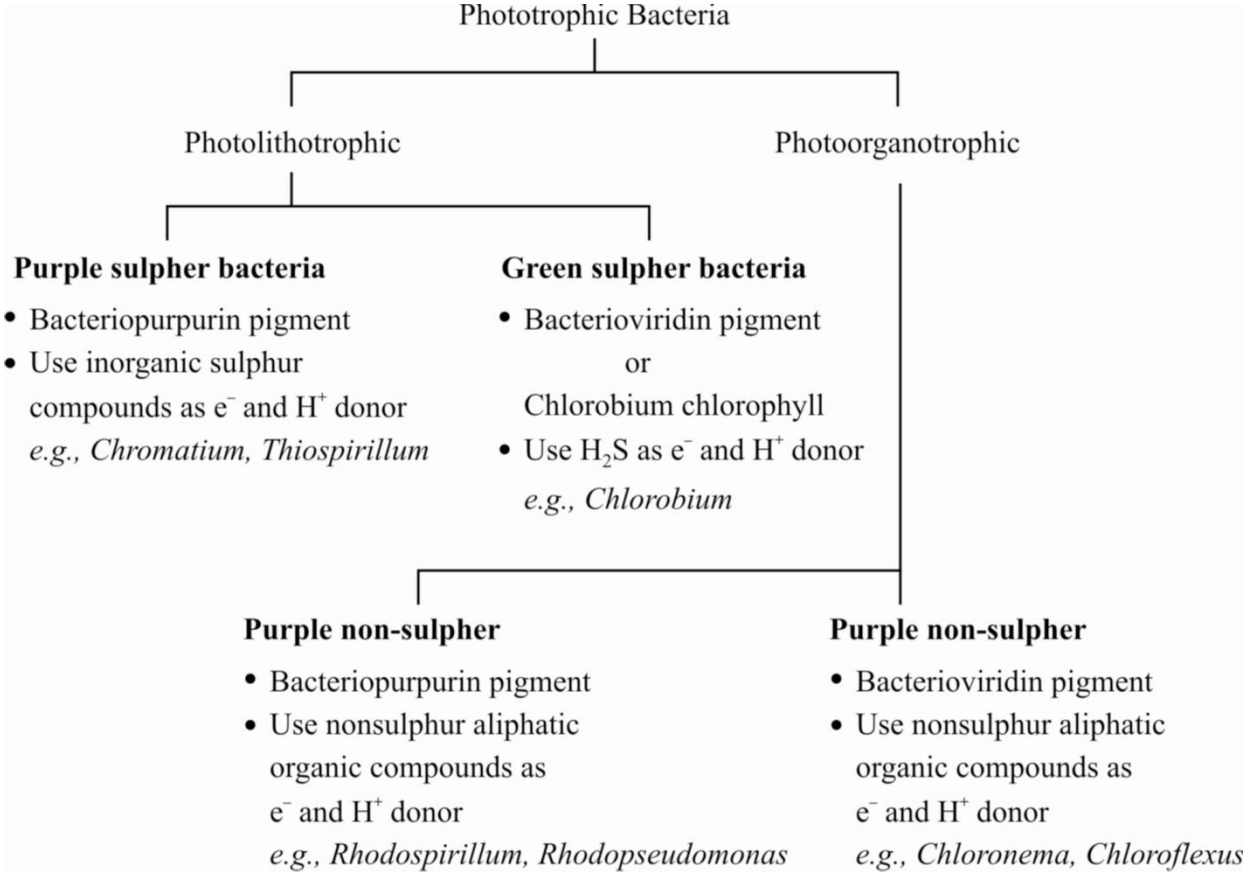
- Nutrition in bacteria is of two types i.e. autotrophic and heterotrophic.
- Bacteria having autotrophic mode of nutrition may be photoautotrophs and chemoautotrophs, carrying out photosynthesis and chemosynthesis, respectively.

(I) Autotrophic Nutrition

(i) Photoautotrophic bacteria:

- These bacteria are capable of entrapping solar energy and utilizing it for the synthesis of complex food materials due to the presence of pigments like bacteriochlorophyll (bacteriopurpurin) and bacterioviridin.
- Purple sulphur bacteria (*e.g., Thiospirillum*) and green sulphur bacteria (*Chlorobium limicola*) are the most familiar examples containing pigment bacteriochlorophyll, bacteriopurpurin and bacterioviridin respectively.

Concept Builder



- Bacterial photosynthesis, however, differs from photosynthesis of higher plants in not liberating oxygen.
- This type of photosynthesis, characteristic of bacteria, is termed as anoxygenic.
- Normal photosynthesis, occurring in higher plants, is termed as oxygenic.
- In bacterial photosynthesis water is not the source of electron that acts as reducing power to convert CO_2 into glucose.
- The bacteria obtain reducing power from various compounds such as hydrogen sulphide, thiosulphate or even some organic compounds.
- No oxygen is evolved as it does not involve splitting of water.
- Hydrogen released by various compounds mentioned above is **picked up by NAD^+** which gets reduced to $NADH_2$ acting as reducing power.
- $NADH_2$ alongwith ATP, produced generally by entrapping solar energy are used to reduce CO_2 to glucose.
- Simple equation for anoxygenic photosynthesis may be written as follows :

$$CO_2 + \underset{\substack{\text{(or any other compound acting as } e^- \text{ donor)}}}{H_2S} \xrightarrow[\text{enzymes}]{\text{Solar energy}} \text{Sugar} + (\text{Sulphur or other oxidised compound}) + H_2O + \text{energy}$$

- Most of the photosynthetic bacteria are anaerobes (facultative aerobes).

(ii) Chemoautotrophic Bacteria:

- Bacteria belonging to this category obtain energy for the synthesis of food by oxidising certain inorganic substances like ammonia, nitrates, nitrites, 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 nitrogen, phosphorous, iron, sulphur.

(a) Hydrogen bacteria. These bacteria oxidise hydrogen in the presence of oxygen, e.g., Hydrogenomonas.

(b) Nitrifying bacteria obtain energy by oxidizing ammonia into nitrate, oxidation of ammonia occurs in two steps. Each step is carried out by a specialised group of bacteria.

- In the first step, ammonia is oxidised into nitrites by the species of the genus *Nitrosomonas* and *Nitrococcus*.
- In the second step, the nitrite is converted into nitrate. This is brought about by species of the genus *Nitrobacter* and *Nitrocystis* which use this energy for chemosynthesis.

(c) Sulphur bacteria. These bacteria obtain energy either by the oxidation of elemental sulphur or oxidation of H_2S.

- **Oxidation of elemental sulphur.** Sulphur bacteria (*Thiobacillus thioxidans*) oxidise elemental sulphur to sulphuric acid and utilise energy produced in this process. These bacteria can survive even in extreme acidic environment.

- **Oxidation of H_2S to S.** Some bacteria like *Beggiatoa* use the energy from oxidation of H_2S and store the sulphur so produced in the form of granules.

(d) Iron bacteria. These bacteria (*e.g., Ferrobacillus, Leptothrix*) inhabit water which contain iron compounds. These bacteria convert ferrous ions to ferric form. The ferric ion is deposited as insoluble ferric hydroxide. The energy so released, is utilised in the assimilation of CO_2.

(e) Methane bacteria. *Methanomonas,* is one example which oxidises methane to carbon dioxide.

(II) Heterotrophic bacteria :

- These bacteria are most abundant in nature and are incapable of synthesizing their own food from simple raw materials.
- They obtain nourishment either from dead and decaying organic matter or directly from a living host.
- All heterotrophic bacteria are segregated into three main categories, *i.e*., saprophytic, symbiotic and parasitic forms.

(i) Saprophytic bacteria :

- They are free living bacteria, obtaining nourishment from organic remains such as dead animals, animal excreta, fallen leaves, decaying vegetables, fruits, bread and other products of animal and plant origin.
- These bacteria secrete digestive enzymes into the substrate and the complex insoluble Substances are converted into simple soluble compounds like water, hydrogen sulphide, ammonia, CO_2 etc.
- Some of the simpler substances are absorbed and assimilated by the bacteria, whereas the others are added to the soil and atmosphere to complete the nature's material cycle.
- Anaerobic breakdown of carbohydrates and proteins is termed fermentation and putrefaction respectively.
- Aerobic breakdown of organic compounds is called **decay**.

(ii) Symbiotic bacteria :

- They are mainly Gram negative type.
- A familiar example of symbiotic bacteria is *Rhizobium leguminosarum,* associated with roots of leguminous plants.
- They are capable of fixing atmospheric nitrogen as ammonia, inside the nodule only and not in free state.
- However, some bacteria like *Azotobacter*, *Beijerinckia*, *Klebsiella* are free living, aerobic and capable of nitrogen fixation in free state, enriching the soil.
- *Clostridium pasteurianum* is anaerobic N_2 fixing bacteria.

(iii) Parasitic bacteria :

- These bacteria draw nourishment and obtain special organic compounds required for growth from living organisms, either plants or animals, called **hosts**.
- The disease causing bacteria are termed pathogenic and the ones not causing any disease are termed as non-pathogenic.

6. Reproduction

Bacteria reproduce mainly by asexual method and also show sexual recombination (True sexual reproduction is absent).

A. Asexual Reproduction :

- Bacteria produce several types of asexual spores like, sporangiospores, oidia, conidia and endospores. However, the most common mode of asexual reproduction is binary fission.
- Under favourable conditions of nutrient availability, moisture and temperature, daughter cells may repeat binary fission many times and may forms a large population.
- Fortunately, such a rapid rate is seldom achieved.
- The process gradually slows down and ultimately stops because of:

(i) Shortage of space.
(ii) Lack of nutrient availability.
(iii) Accumulation of waste products (making environmental conditions unfavourable for growth).
(iv) Development of bacteriophages, destroying bacteria.

(a) Binary Fission :

- It is the most common method under favourable conditions of temperature, moisture and availability of nutrients.
- Mature bacterial cell divides into two daughter cells.
- In this process the cell division is amitotic type i.e., not involving the spindle formation.

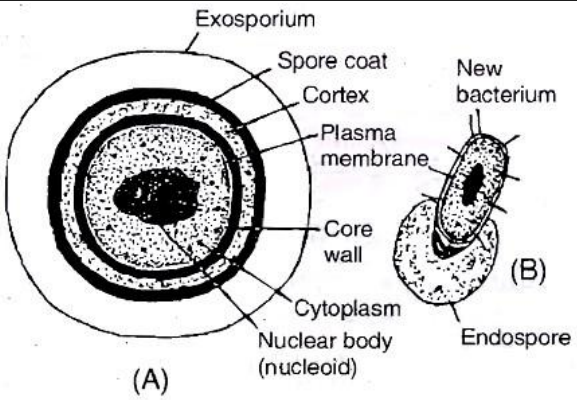
(b) Endospores :

- Cells of certain bacteria, *e.g.*, *Bacillus, Clostridium* etc. form 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.

Concept Builder

Structure of Endospore :

- The endospore consists of a central core made up of nuclear material and spore cytoplasm.
- The cytoplasm includes DNA, RNA and proteins, lipid, Ca, Mn.
- The central core is surrounded by a delicate membrane called **core wall**.
- Around the wall is another layer, which is much thicker and is of relatively low density.
- This layer, called **cortex**, mainly consists of peptidoglycan and calcium dipicolinic acid (CaDPA).
- It is an anticoagulant which provides resistance to heat.
- This complex may also be present in spore cytoplasm.
- Endospore is highly resistant to desiccation, chemicals and radiations.
- The cortex, in tum, is enclosed in spore coat which may be smooth, grooved, or raised into ridges. The whole structure may be wrapped in an exosporium.



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

- The endospores are formed probably upon induction by the exhaustion of nutrients (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.
- It gets surrounded by different layers.
- These can withstand temperature as high as 1000e or as low as -100°C, so these can remain unharmed during pasteurisation.
- The remarkable resistance shown by endospores is due to :

(i) Thick and impermeable spore coat
(ii) Low water content
(iii) Low metabolic activity
(iv) Ca-DPA Complex

- Under favourable conditions, endospore absorbs water, becomes metabolically active, ruptures thick spore coat and the bacterium surrounded by thin cell wall emerges out.
- Endospores are actually the means of perennation and not reproduction as only one endospore is formed per cell and subsequently each endospore grows into single bacterium cell after the commencement of favourable conditions.

Conceptual Questions

1. Outermost part of bacterial cell envelope is____, which is made of_____,_____and_____ sugars. It protect the cell against and loss of nutrients.
2. Give one word for bacteria which are able to synthesise 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 gives anticoagulant nature to endospore?
5. Most common mode of bacterial reproduction is by _____

Ans. 1. Glycocalyx, Dextran, Dextrin, Levan, Desiccation; 2. Pholoorganotroph ; 3. Structure, behaviour ; 4. Ca-DPA; 5. Binary fission

B. Sexual Recombination (Genetic Recombination) :

- The bacteria exhibit a primitive form of 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 discovery, these are transformation, conjugation and transduction.

(a) Transformation :

- Griffith (1928) worked on the effect of *Diplococcus* or *Streptococcus pneumoniae* 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.
- This ability to pick up DNA from the solution is called competence.
- Two strains of *D. pneumoniae* are :
  Capsulated or S-III (Virulent strain) and Non-capsulated or R-II (non-virulent strain).
- Four steps were performed in experiment:

  (i) S-III bacteria $\xrightarrow{\text{Injected into}}$ Healthy mice $\longrightarrow$ Mice died.

  (ii) R-II bacteria $\xrightarrow{\text{Injected into}}$ Healthy mice $\longrightarrow$ Mice survived.

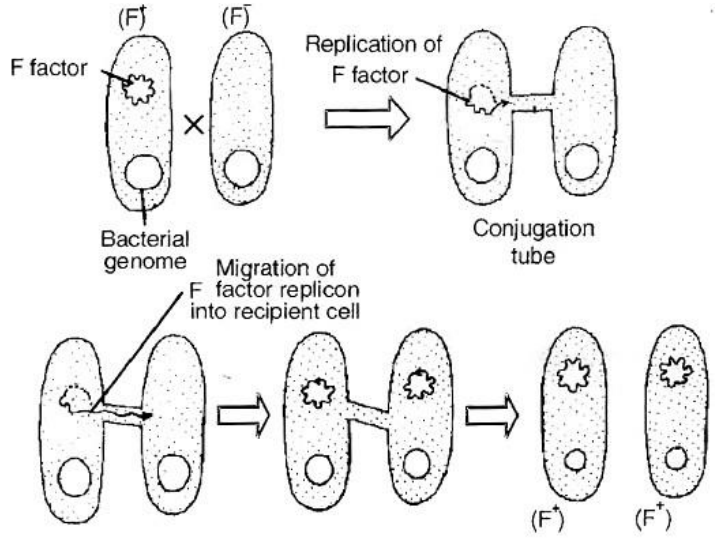
  (iii) S-III bacteria (Heat killed) $\xrightarrow{\text{Injected into}}$ Healthy mice $\longrightarrow$ Mice survived.

  (iv) R-II (living) + S-III (heat killed) bacteria $\xrightarrow{\text{Injected into}}$ Healthy mice $\longrightarrow$ Mice died.
  (But R-II is not virulent and S-III lost its virulent capacity upon heating).
- **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:

- **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 cells 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 :

- During transduction, a small double stranded piece of DNA is transferred from donor to recipient by a bacteriophage.
- This mode of genetic recombination in bacteria was first demonstrated by **Zinder** and **Lederberg** (1952) while working with *Salmonella typhimurlum*.
- Some viruses have the ability to integrate their DNA with bacterial DNA, which is replicated at the same time as the host DNA and is passed from one bacterial generation to the next.
- Such bacteria carrying phage (viral) DNA with their own DNA are called **lysogenic bacteria**.
- Occasionally, the phage DNA becomes active and codes for the production of new virus particles.
- A number of phage particles are synthesised followed by the destruction of the host cell and release of phage particles.
- Upon release, the phage particles attack sensitive bacterial cells, multiply and release more phage particles.
- However, sometimes faulty detachment of phage DNA from bacterial DNA results in the incorporation of a small amount of bacterial DNA into tne phage DNA.
- Subsequent infection of another bacterium with this aberrant phage called **transducing phage**, introduces the piece of foreign bacterial DNA into the recipient's chromosomes, producing a genetic change.

Types of transduction:

- The ability of the bacteriophage to carry the genetic material from any region of bacterial DNA is called **generalised transduction**, e.g., T_4-phage.
- On the other hand, there are bacteriophages such as lambda phage (λ) of E coli which can carry only a specific region of the bacterial DNA to a recipient.
- This is called **specialised transduction** (or restricted transduction).
- Sometimes, the DNA brought by the phage does not integrate with the genome of the recipient bacterium and is lost after one or two generations.
- Such a transduction is called **abortive transduction**.

7. Economic Importance of Bacteria

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

A. Beneficial activities

(a) Role in agriculture

(i) Decay and decomposition of organic matter :

- They bring about decay and decomposition of dead remains of plants and animals.
- These are the most important for mineral cycling to occur.

(ii) Sewage disposal :

- The bacteria decompose the organic matter present in the sewage, converting into simpler inorganic substances.
- The inorganic substances thus formed, being soluble, pass out through filter alongwith water which is highly useful for irrigation purposes, *e.g., Clostridium, E. coli*.

(iii) Nitrogen cycle :

- The proteins present in dead remains of living organisms are converted into amino acids by different types of saprophytic bacteria.
- Amino acids are converted into ammonia by ammonifying bacteria (*Bacillus vulgaris, B. ramosus*).
- Nitrifying bacteria convert ammonium salts first into nitrites (*Nitrosomonas, Nitrococcus*) which are subsequently converted into nitrates (*Nitrobacter*).
- In presence of denitrifying bacteria (*Pseudomonas denitrificans*), nitrates and nitrites of soil are converted to gaseous nitrogen.

(iv) Nitrogen fixation :

- It is the biological process in which atmospheric nitrogen is converted into nitrogenous compounds by nitrogen fixing bacteria.
- These bacteria are of 2 types :
  (a) Free living
  (b) Symbiotic

  (a) Free living bacteria are *Azotobacterand Beijerinckia* (aerobic) & *Clostridium* (anaerobic).

  (b) Common symbiotic bacteria are *Rhizobium leguminosarum* and *Xanthomonas*. These convert nitrogen into ammonia which is directly converted into amino acids by plants.

(v) Manure preparation :

- Saprotrophic bacteria help in preparation of farmyard manure by converting farm refuse, dung and other organic wastes into humus.

(b) Role in Industry :

- Man has utilized the metabolic activities of bacteria in preparation of a number of industrial products as listed below :

(i) Butter milk and sour cream

(ii) Yoghurt

(iii)Cheese

(iv)Vinegar

(v) Retting of fibres : Retting is a controlled microbial decomposition for separation of fibres. The tissues are immersed in water tanks where anaerobic butyric acid bacteria dissolve the pectin of middle lamella of cells, thus, separating the fibres. *Clostridium perfringens* and *Pseudomonas fluorescence* are useful in this process.

(vi) Curing of leaves: To improve the flavour and taste in tea, using Micrococcus candidans and in tobacco leaves by Bacillus megatherium.

(vii) Single cell proteins (SCP) : Like -*Methylophilus methylotropus* and *Rhodopseudomonas capsulata*.

(c) Role in Medicine :

- Bacteria have been used extensively in preparation of antibiotics, vaccines, serums and vitamins.

(i) Antibiotics :

- The term antibiotic was given by **Waksman**, who discovered **streptomycin**.
- These are the organic substances produced by microorganisms which inhibit the growth of other organisms (mostly pathogens) but do not affect the growth of organisms secreting these.
- The first commercial antibiotic penicillin was discovered by **Flemming** (1959) from a fungus called ***Penicillium***.

Some antibiotics of eubacterial origin:

(a) Bacitracin .....*Bacillus licheniformis*

(b) Polymixin .....*Bacillus polymyxa*

(c) Gramicidin.....*B. brevis*

(d) Subtilin .....*B. subtilis*

(ii) Vaccine production

- Vaccines and serums against typhoid, cholera TB, pertussis, tetanus and diphtheria are made with the help of bacteria or their toxins e.g., DPT (against diphtheria, pertussis and tetanus), TI(against tetanus), BCG (Bacille of Calmette-Guerin against TB), DT (against diphtheria and tetanus).

(iii) Vitamins :

- *Escherichia coli* present in human intestine produces large quantities of B-complex vitamins and vitamin *K. Bacteria* are utilized in industrial production of a number of vitamins like riboflavin from *Clostridium butylicum*, Cobalamine (B12) from *Bacillus megatherium* and *Pseudomonas denitrificans*.

(iv) Pollution control :

- *Pseudomonas putida* degrades petroleum wastes.
- *Flavobacterium* can decompose 2, 4-0. DDT can be decomposed by **Acetobacter aerogens**.
- Gange's water contains *Bdellovibrio bacteriovorus* that maintains purity of its water.

(v) Poly-β-hydroxybutyrate is used to produce biodegradable plastic.

B. Harmful activities

(i) Spoilage of food : Saprophytic bacteria cause decay of vegetables, fruit, meat, bread and other foods, making these unfit for human consumption. Some bacteria even produce strong toxins in the infected food stuffs which cause food poisoning when consumed.

(ii) Deterioration of Domestic Articles : Some saprophytic bacteria like *Cellulomonas*, *Spirochaete cytophaga* cause deterioration of domestic articles of daily use such as leather, woolen, canvas articles etc.

(iii) Denitrification of Soils : Denitrifying bacteria like *Thiobacillus denitrificans, Micrococcus denitrificans* and *Pseudomonas* convert nitrates and nitrites present in the soil into gaseous nitrogen, thus depleting the soil nitrogen, thereby decreasing soil fertility.

(iv) Desulphurification : *Desulphovibrio desulphuricans*.

(v) Diseases : Common disease of humans, animals and plants are listed below respectively –

Table: 2

S.No.	Name of causal organism	Name of the human diseases
1.	*Clostridium botulinum*	Botulism
2.	*Vibrio cholerae*	Cholera
3.	*Corynebacterium diphtheriae*	Diphtheria
4.	*Salmonella typhimurium Staphylococcus aureus*	Food poisoning
5.	*Clostridium perfringens*	Gangrene
6.	*Neisseria gonorrhoeae or Salmonella schottmulleri*	Gonorrhoea
7.	*Mycobacterium leprae (Hensen 's bacillus)*	Leprosy
8.	*Neisseria meningitidis*	Meningitis
9.	*Yersinia pestis*	Plague
10.	*Diplococcus pneumoniae*	Pneumonia
11.	*Treponema pal/idum*	Syphilis
12.	*Clostridium tetani*	Tetanus
13.	*Streptococcus pyrogenes*	Tonsilitis
14.	*Mycobacterium tuberculosis*	Tuberculosis
15.	*Salmonella typhosa* / *typhi*	Typhoid
16.	*Bordetella pertussis* / *Hemophilous pertusis*	Whooping cough
17.	*Salmonella typhimurium*	Enteric fever (paratyphoid)

Table : 3

S.No.	Name of causal organism	Name of the plant diseases
1.	*Pseudomonas solanacearum*	Potato wilt
2.	*Xanthomonas citri*	Citrus canker
3.	*Agrobacterium tumefaciens*	Crown gall
4.	*Erwinia amylovora*	Fire blight of apple
5.	*Xanthomonas oryzae*	Bacterial blight of rice
6.	*Xanthomonas malvacearum*	Angular leaf spot of *Gossypium*
7.	*Pseudomonas rubrilineans*	Red stripe of sugarcane
8.	*Erwinia cartovora*	Soft rot of carrot
9.	*Corynebacterium tritici*	Tundu(bacterial rot) of wheat
10.	*Xanthomonas campestris*	Black rot of cabbage
11.	*Streptomyces scabies*	Potato scab

Self Assessment

Spherical bacteria with chain like arrangement of different length is

(1) Diplococcus (2) Staphylococcus (3) Streptococcus (4) Sarcina

Select incorrect statement w.r.t. eubacteria

(1) Have very simple structure

(2) Peptidoglycan nature of cell wall

(3) Heterotrophs are most abundant in nature

(4) Show most simple metabolic diversity

Gram positive bacteria differs from Gram negative bacteria in the

(1) Presence of NAG and NAM (2) Absence of diaminopimelic acid

(3) Presence of L-alanine (4) Absence of D-glutamic acid

Bacterial cell envelope is

(1) Glycocalyx only (2) Cell wall only

(3) Glycocalyx and nucleoid (4) Glycocalyx, cell wall and plasma membrane

Nucleoid is

(1) Histoneless linear ss-DNA (2) Circular DNA with histone proteins

(3) Circular DNA packaged with polyamines

(4) DNA with free ends

Bacteria capable of switching over to anaerobic mode to get energy for their survival, are called

(1) Facultative anaerobes (2) Obligate anaerobes

(3) Obligate aerobes (4) Facultative aerobes

Find odd one out w.r.t. phototrophic nutrition

(1) Chromatium and Chlorobium (2) Rhodopseudomonas and Thiospirillum

(3) Chloronema and Chloroflexus (4) Pseudomonas and Clostridium

Mark the incorrect option (w.r.t. nitrifying bacteria)

(1) Nitrococcus (2) Leptothrix (3) Nitrobacter (4) Nitrocystis

Q.19 Genetic recombination in which a small double stranded piece of DNA is transferred from donor bacterium to recipient bacterium by a bacteriophage was first demonstrated by

(1) Griffith (2) Lederberg and Tatum

(3) Zinder and Lederberg (4) Avery *et.al.*

Q.20 Select correct match

Column-I	**Column-II**
a. Retting of fibres	(i) Pseudomonas putida
b. Pollution control	(ii) Pseudomonas fluorescence
c. Riboflavin	(iii) Bacillus brevis
d. Gramicidin	(iv) Clostridium butylicum

(1) a(ii), b(i), c(iv), d(iii) (2) a(ii), b(i), c(iii), d(iv)

(3) a(i), b(ii), c(iv), d(iii) (4) a(iii), b(i), c(iv), d(ii)

Ans. Q.11 (3), Q.12 (4), Q.13 (2), Q.14 (4), Q.15 (3), Q.16 (1), Q.17 (4), Q.18 (2), Q.19 (3), Q.20 (1)

II. CYANOBACTERIA

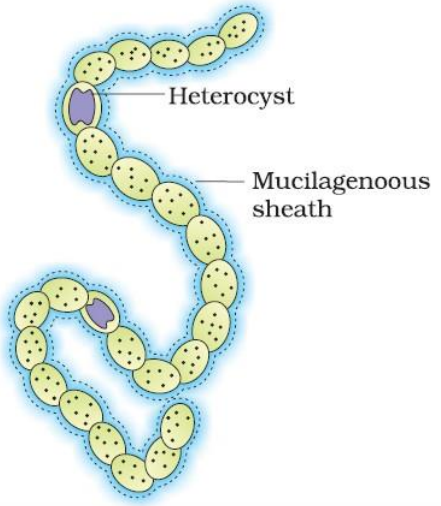
- Cyanobacteria are Gram negative photosynthetic prokaryotes, being the most primitive organisms to have **oxygenic photosynthesis.**
- They added oxygen to the atmosphere, which is indispensible for the existence of aerobic forms of living organisms.
- They are also known as BGA (Blue green algae) and are classified variously under **cyanophyceae or myxophyceae.**

Occurrence

- They are mainly fresh water forms, though few are marine.
- **Red sea** is named so because of abundant occurrence of a cyanobacterium *Trichodesmium erythraeum,* which imparts red colouration to water.
- They occur in symbiotic association with almost every 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,* an aquatic fern.
- *Anabaena cycadeae* is associated with coralloid roots of **Cycas.**
- In many lichens (symbiotic association of algae and fungi), the algal partner may be a cyanobacterium.
- When they live endozoically in protozoans they are **called cyanelle.**

Structural Organization

- These may be unicelled or multicelled. The latter may be filamentous or colonial.
- Filamentous form consists of one or more cellular strands, called **trichomes**, surrounded by mucilagenous sheath.
- Cyanobacteria are characterised by the absence of flagellum throughout life cycle.



A filamentous blue-green algae – Nostoc

Cell Structure

- The cell structure in cyanobacteria is typically prokaryotic.
- The cell lacks a well defined nucleus and the chromatin material is centrally located, resembling the bacterial chromosome.
- The cell wall is 4 layered and is invariably covered by mucilagenous sheath, composed largely of mucopeptides.
- Protoplasm in cyanobacterial cell can be distinctly divided into two parts the centroplasm and chromoplasm.
- The central colourless centroplasm contains the chromatin material.
- The peripheral protoplasm is coloured or pigmented because of the presence of thylakoids, called as **chromoplasm**.
- The protoplast lacks membrane-bound organelles like endoplasmic reticulum, golgi bodies, mitochondria, lysosomes, plastids and contains 70S ribosomes.
- Similar to the mesosome of bacteria, a group of coiled membrane called **lamellasome** is found which connects nucleoid to the cell membrane.
- It helps in respiration and replication of DNA.
- The cell membrane lack sterols. The sap vacuoles are absent.
- Instead, the cell may contain gas filled vacuoles which help to regulate the buoyancy of the organism in water.
- The characteristic feature of cyanobacterium cell is the presence of a system of photosynthetic lamellae called **thylakoids**.

- The characteristic photosynthetic pigments present in the thylakoids are chlorophyll a and phycobilins *i.e.*, phycocyanin (blue coloured), phycoerythrin (red coloured) and allophycocyanin (light blue coloured).

  The cyanobacterial cell contains reserve food material in the following forms

  (i) Cyanophycean granules (Protein)

  (ii) β-granule (Fat droprets)

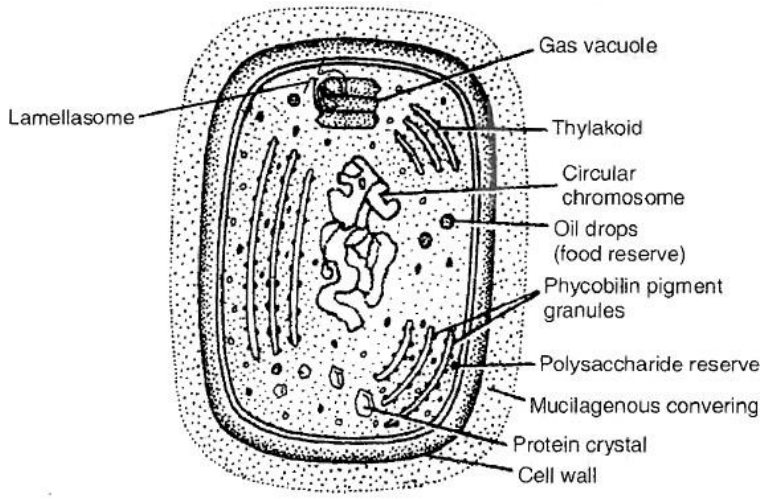
  (iii) Cyano-or myxophycean starch or α-granule (Similar to glycogen but negative to iodine test)

  (iv) Volutin body (Reserve phosphate)

  (v) Polyhedral body (Rubisco rich)

Concept Builder

Gaidukov's phenomenon *or complementary chromatic adaptation -Cyanobacteria or blue green algae can adaptively change their body colour according to different wavelengths of available light, e.g., Trichodesmium erythraeum. It is also known* as *"red sea" causing alga.*



Ultrastructure of a cyanophycean cell

Metabolism

- They are the most self-dependent organisms, because most of these are capable of converting atmospheric nitrogen into ammonium compounds besides utilizing atmospheric CO_2 for synthesis of organic food during photosynthesis.
- Biological nitrogen fixation is an anaerobic process as nitrogenase enzyme required for the process acts efficiently in the absence of oxygen.
- Nitrogen fixation under anaerobic conditions occurs mainly in large, specialized cells called **heterocysts** as in Nostoc.
- Heterocyst has terminal pores which at maturity develops a polar granule.
- Thickened cell wall of these cells is impermeable to oxygen so this creates anaerobic environment in the cell even under aerobic conditions.

- Besides this, heterocysts also lack PS II activities and CO_2 fixation is done only by vegetative cells.
- Oxygen is not evolved due to absence of PSII.
- However, PSI remains active in heterocyst which generates ATP required to fix nitrogen.
- Besides N_2 fixation heterocyst promotes fragmentation.
- This property of nitrogen fixation, most of the BGA enrich the soil by releasing nitrogenous compounds in the surroundings.

Reproduction

- Cyanobacteria reproduce asexually. Typical sexual reproduction is absent.
- Asexual reproduction occurs by following methods :

(i) **Binary fission:** It occurs in unicellular forms. The daughter cells formed by amitotic division separate immediately after the division.

(ii) **Fragmentation:** It occurs in filamentous forms. The filament breaks up into short pieces or fragments which grow to form new filaments.

(iii) **Heterocysts :** Under special conditions, the heterocysts germinate to form new filaments.

(iv) **Hormogonia:** Due to the formation of biconcave, mucilage filled dead cells called **necridia**, in between living cells of trichome, the filament breaks into hormogonia.

(v) **Akinetes:** Vegetative cells are transformed into thick walled akinetes due to the deposition of food material followed by the thickening of wall. On the arrival of favourable conditions, they germinate to form new filaments.

Importance of Cyanobacteria

(i) They are the most ancient organisms having oxygenic photosynthesis and thus, played a significant role in the evolution of aerobic forms of life.

(ii) They convert atmospheric nitrogen into ammonium compounds and excess of these compounds is excreted out, enriching the soil. The death and decay of these also increase the soil fertility, particularly the nitrogen content of the soil. *Tolypothrix* and *Aulosira* fix N_2 non-symbiotically in rice fields .

Cyanobacteria like *Nostoc* and *Anabaena* have been used for reclaiming usar soils. As they can live in damp or aquatic habitat, they enrich the root environment in any wetland condition as in rice fields.

(iii) Cyanobacteria are associated in symbiotic relationship with almost every group of plants. They benefit the partner by providing nitrogenous compounds because of their capability of nitrogen fixation.

(iv) Some cyanobacteria serve as food to several aquatic animals. Spirulina is edible, non-toxic, fast growing cyanobacterium. It is cultivated in tanks as source of protein rich animal food (SCP).

(v) Extract of Lyngbya is used for the manufacture of antibiotic.

(vi) Some cyanobacteria like *Microcystis aeruginosa*, *Anabaena flos-aquae*, *Aphanizomenon flos-aquae* are known to cause algal blooms in water bodies. These also secrete toxins into the surroundings, which are harmful to aquatic animals and even to human beings. Water from such sources is harmful and may even prove fatal for organisms drinking it. They also deplete the oxygen from the water reservoir and thereby, cause large scale death of the fishes and other aquatic animals.

III. MYCOPLASMA

- *E. Nocard* and *E.R. Roux* (1898)-two French Scientists, discovered these organisms from pleural fluid of cattles suffering from pleuropneumonia.
- These are pleomorphic and were called PPLO (Pleuropneumonia Like Organisms) or Jokers of plant kingdom.
- This organism was later on given the name *Asterococcus mycoides* by Borrel et al. (1910).
- Nowak (1929) placed *Asterococcus mycoides* under the genus Mycoplasma.
- All such organisms are now called **Mycoplasma**, or MLO's (Mollicutes like organisms).
- These are sometimes placed in a separate class called **Mollicuta**.
- Mycoplasma infects animals (e.g., dog, sheep, mice and man) and plants (e.g., potato, corn, brinjal etc.).
- They are generally found in soil, sewage water, plants and animals.

Structure:

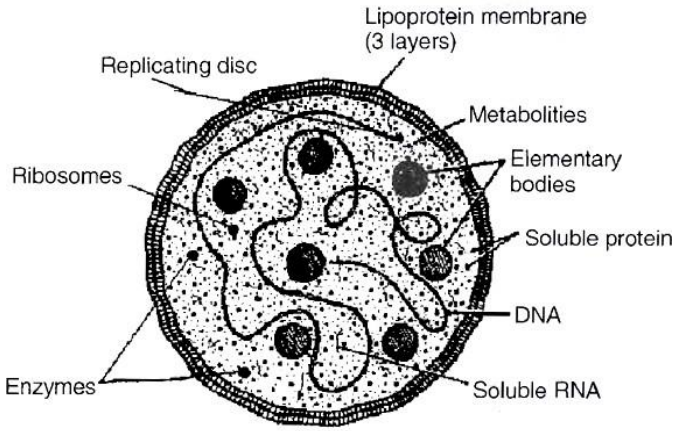
- These are unicellular, simplest free living prokaryotes.
- They do not have cell wall so they are highly pleomorphic and can assume various shapes like spherical, granular, filamentous, coccoid etc.
- Cell membrane is the outermost limiting layer.
- It is trilamellar unit membrane structure.
- In culture, colonies of mycoplasma show a characteristic fried egg appearance with an opaque central area and translucent peripheral zone.
- The cells are generally non motile, but a few are gliding type.
- The protoplasmic matrix contains ribosomes (70S type), fatty substances and proteins.
- Organized nucleus, endoplasmic reticulum, plastids, mitochondria, golgi bodies, Iysosomes, centrioles, flagella, etc. are absent.
- Mycoplasma has both RNA and DNA.
- RNA is single stranded, present in both ribosomes and cytoplasm and DNA is double stranded, long coiled thread extending almost throughout the cell.
- Enzymes are present freely in the cytoplasm as well as associated with the plasma membrane.
- Replicating disc assist in replication and separation of the genetic material.

Nature of *Mycoplasma*:

- *Mycoplasma* can pass through bacteriological filters and lack cell wall.
- This shows that they are not bacteria.
- Since they can multiply in abiotic medium having sterols, so they are not considered as virus.
- Due to many similarities with bacteria they are said to be **"Bacteria with their coats off"**.
- Mode of nutrition is heterotrophic.
- Some are saprophytic, but mostly they are parasitic.
- They are parasitic, because they are unable to synthesize required growth factors, *e.g.*, *M. gallisepticum* (0.3 to 0.5 µm, smallest prokaryote).
- They can survive without oxygen.

Sensitivity to Antibiotics:

- Mycoplasma are Gram negative, insensitive to penicillin but sensitive to streptomycin, erythromycin, chloramphenicol (metabolic inhibitors) etc.,
- They are insensitive to penicillin because they are wall less and penicillin interferes in the synthesis of peptidoglycan, a component of cell wall of bacteria.
- **Reproduction** - Much is not known about reproduction of Mycoplasma but they mainly reproduce by means of elementary bodies.



Mycoplasma : structural details

Concept Builder

- Mycoplasmas cause various diseases in plants, animals and human beings.
- Some are given below :

1. **Plant diseases:** The Mycoplasma diseases are generally transmitted through insects such as leaf hopper, mites and flies.

(i) Witches' broom
(ii) Aster yellow
(iii) Brinjal little leaf
(iv) Bunchy top of Papaya
(v) Sesame phyllody
(vi) Sandal spike

2. Diseases in animals

(i) Pleuropneumonia in cattle

(ii) Inflammation of genitals

3. Diseases in human beings

(i) Infertility in man

(ii) Primary atypical pneumonia

IV. ARCHAEBACTERIA

- They are believed to have evolved immediately after the origin of life on earth, as even now these are living under extremely adverse conditions such as extreme salty areas (halophiles), hot springs (thermoacidophiles) and marshy areas (methanogens).
- Very few other organisms can survive under such environmental conditions. So these are termed as "living fossils".
- These possess introns in DNA, their ribosomal proteins are highly acidic, these prokaryotes possess histone proteins different from that of eukaryotes.
- These being the most primitive and ancient most bacteria.
- Archaebacteria differ from other bacteria in having a different cell wall structure and this feature is responsible for their survival in extreme conditions.
- The cell wall in archaebacteria contains proteins and non-cellulosic polysaccharides.
- It lacks peptidoglycan, the characteristic cell wall material in bacteria and cyanobacteria.
- It consists of glycoprotein, pseudomurein and non cellulosic polysaccharide.
- Pseudomurein is like bacterial peptidoglycan, but contain N-acetyltalosaminuronic acid instead of NAM and lacks D-Amino acid.
- The cell membrane contains branched chain lipids (phytanyl side chains) which decreases membrane fluidity.
- This chemical composition of the cell membrane enables these organisms to withstand extremes of temperature and pH.
- Archaebacteria are divided into three groups· methanogens, halophiles and thermoacidophiles.

(a) Methanogens:

- They are obligate anaerobes occurring in marshy habitats.
- They are capable of converting CO_2, methanol and formic acid (HCOOH) into methane and hence the name methanogens.
- This property is exploited commercially in the production of fuel gas and methane in go bar gas plants (biogas fermenters).
- Some of the methanogens live in rumen of herbivorous animals like buffalo, cow etc. (ruminants).
- These microorganisms assist in fermentation of cellulose in such animals, e.g., *Methanococcus*, *Methanobacterium*, *Methanosarcina*, *Methanospirillum*.

(b) Halophiles:

- They are aerobic chemoheterotrophic coccoid forms and are Gram negative. They occur in high salt concentration medium like sea, salt lake, brines, marshes, salted fish etc.

- In high light intensity a reddish pigment bacteriorhodopsin develops in their membrane to trap sun light to produce ATP, but they cannot use this ATP in food synthesis.
- Sap vacuoles are absent in halophiles, hence, they cannot get plasmolysed in high salt concentration.
- They maintain a high osmotic concentration of KCl in their cells.
- These bacteria get lysed if NaCl level falls below 10%, e.g., *Halococcus, Halobacterium*.
- These can grow well in a medium containing 25-30% of NaCl.

(c) Thermoacidophiles:

- They are capable of tolerating high temperature as well as high acidity and hence, the name thermoacidophiles.
- They often live in hot-water springs where the temperature is as high as 80°C and the pH as low as 2.
- They oxidise sulphur to sulphuric acid under aerobic conditions and the energy obtained in this reaction is utilized for the synthesis of organic food.
- The medium becomes highly acidic due to the production of sulphuric acid. Under anaerobic conditions sulphur is reduced to H_2S, *e.g., Thermoplasma, Thermoproteus, Thermococcus*. Hence, these are chemosynthetic in nature.

Concept Builder

Thermoacidophiles are capable of withstanding extremely low pH and high temperature due to:

(a) The cell membrane containing branched chain lipids

(b) The presence of resistant enzymes which can operate under acidic conditions.

It seems probable that archaebacteria, living in extreme environmental conditions got separated from the main line of bacterial evolution quite early. They survived through long period of geological changes successfully, existing at present and are perhaps the oldest "living fossil".

Conceptual Questions

Halophiles develop reddish pigment_____in their_____to trap sunlight for ATP production.

(a) What is the name of specialized cell responsible for nitrogen fixation in Nostoc?

(b) Which group of monerans are considered as connecting link between bacteria and fungi?

Read the given statements carefully and select correct statements for methanogens.

(a) Obligate anaerobes

(b) Smallest wall-less monerans

(c) Radiating mycelial structure in culture solution

(d) Pseudomurein

(e) Pleiomorphic

(f) Marshy habitats

Ans. Q.1 Bacteriorhodopsin, Cell membrane,

Q.2 (a) Heterocyst, (b) Actinomycetes, Q.3 a, d and f

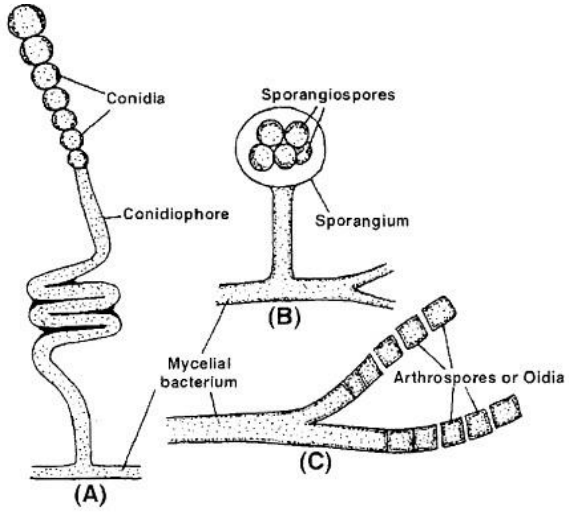
V. ACTINOMYCETES (Ray Fungi)

(1) These are branched, filamentous bacteria and are considered as intermediate form between bacteria and fungi, *e.g.*, Nocardia, Mycobacterium, Corynebacterium, Frankia, Streptomyces.

(2) These filaments form radiating colonies in cultures so are also called mycelial bacteria.

(3) Cell wall contains peptidoglycan and is Gram positive in nature. It contains mycolic acid.

(4) They are facultative anaerobic, saprophytic, non-motile and are important decomposers of dead organic matter.



Modes of asexual reproduction in Actinomycetes : (A) Conidia **(B)** Sporangiospores **(C)** Arthrospore or oidia

(5) They reproduce commonly by conidia, sporangiospore, oidia and fragmentation.

(6) They are acid fast in nature.

Concept Builder

- Economic Importance of Actinomycetes : They are the source of more than 100 antibiotics. Most common antibiotics used in medicine are produced by filamentous bacteria and are listed below :

Antibiotic	**Actinomycetes source**
(a) Streptomycin	Streptomyces griseus
(b) Terramycin or Oxytetracycline	S. rimosus
(c) Erythromycin	S. erythreus
(d) Chloromycetin or Chloramphenicol	S. venezuelae and S. lavendulae
(e) Neomycin	S. fradiae
(f) Viomycin	S. puniceus
(g) Novobiocin	S. niveus
(h) Nystatin	S. noursei
(i) Chlorotetracycline	S. aureofaciens

- *Frankia can fix N_2 symbiotically by root nodule formation in non legumes like -Alnus, Myrica and Casuarina.*
- *Earthy or musty smell of freshly ploughed soil or soil after first shower of rain, is due to oily secretion geosmin by some members like Nocardia, Micromonospora and Streptomyces.*

Self Assessment

Archaebacteria do not show

(1) Peptidoglycan and D-amino acids in cell wall

(2) Introns in DNA

(3) Branched chain lipids in cell membrane

(4) Ribosomal proteins with highly acidic nature

Methanogens are nutritionally

(1) Photolithotrophs (2) Chemolithotrophs

(3) Photoheterotrophs (4) Chemoheterotrophs

Thermoacidophiles are capable of withstanding extremely low pH and high temperature due to the

(1) Presence of branched chain of lipid in cell membrane

(2) Presence of resistant enzyme which can operate in basic conditions

(3) Presence of higher concentration of KCl in their cells

(4) More than one option is correct

Smallest wall-less monerans .

(1) Develop fried egg appearance in culture (2) Are motile

(3) Have definite shape (4) Are mostly saprophytic

Which one of the following organism reproduces by means of elementary bodies formation?

(1) Frankia (2) Ecoli (3) PPLO (4) BGA

Which group of monerans played significant role in the evolution of aerobic forms of life?

(1) Mycoplasma (2) Cyanobacteria (3) Archaebacteria (4) Actinomycetes

The characteristic photosynthetic pigments in cyanobacteria are

(1) Chlorophyll a and c (2) Chlorophyll a and carotenes

(3) Chlorophyll a and phycobilins (4) Chlorophyll a, carotenoids and phycobilins

Heterocystous blue-green algae are

(1) Anabaena and Lyngbya (2) Nostoc and Aulosira

(3) Phormidium and Oscillatoria (4) Spirulina and Oscillatoria

Gram positive filamentous bacteria with mycolic acid in their cell wall are known as

(1) Archaebacteria (2) Ray fungi (3) Club fungi (4) Blue green algae

Witches broom disease in plants is caused by

(1) Rhizobium (2) Mycoplasma (3) Actinomycetes (4) Cyanobacteria

Ans. Q.21 (1), Q.22 (2), Q.23 (1), Q.24 (1), Q.25 (3), Q.26 (2), Q.27 (3), Q.28 (2), Q.29 (2), Q.30 (2)

Concept Builder

(1) In 1798, **Edward Jenner** used cowpox virus for immunising people against small pox.

(2) Pasteurization simply kills bacteria but does not sterilize milk. It frees the latter of all vegetative cells of pathogens, but not the endospores.

(3) Mycobacterium and Xanthomonas form nodules in leaves of Ardisia, Pavetta.

(4) Bacterial cell membrane contains pentacyclic sterol like molecule termed as hopanoids as membrane stabiliser.

(5) **Kleinberger** discovered tuberculosis and anthrax bacteria & developed "L-form" bacteria.

(6) **H. T. Ricketts** described some new types of organisms (now considered a type of bacteria) in the blood of victims of Rocky Mountain spotted fever and similar organisms were called **Rickettsiae**, in honour of Ricketts. They occur as obligate intracellular parasites. The Q fever is caused by Coxiella burnetti. Rocky mountain fever is caused by **Rickettsia rickettsii**.

(7) **Chlamydiae:** They are obligate intracellular parasite of vertebrates. They reproduce by elementary bodies. They do not have their own ATP generating system and obtain this energy from host. So that they are called **energy parasite**.

Diseases

Trachoma (eye disease)	– *C. trachomatis*
Conjuctivitis	– *C. trachomatis*
Psittacosis (influenza like)	– *C. psittaci*

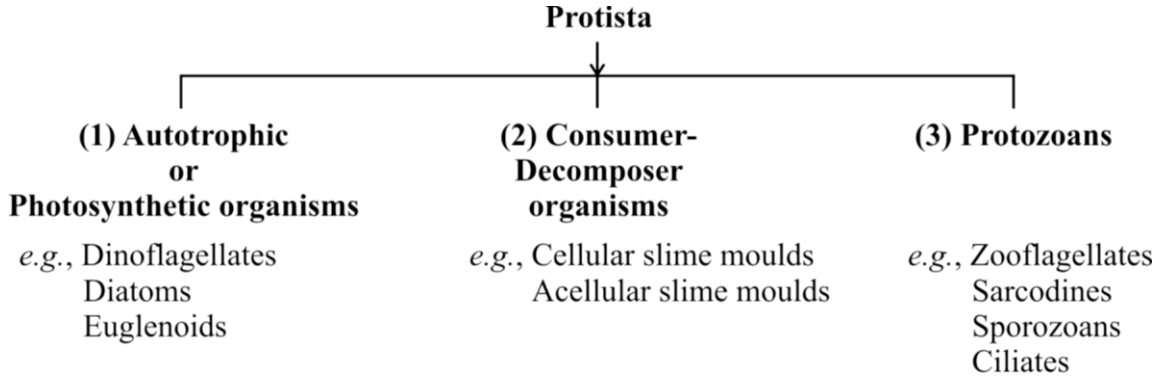
(8) **Joseph Lister** developed the technique of aseptic cultures.

(9) **Nostoc** develops symbiotic associations with *Gunnera stem* and *Trifolium roots*.

KINGDOM : PROTISTA

All unicellular eukaryotes, irrespective of their mode of nutrition, are included in the kingdom **Protista** in Whittaker's system. The term protista was coined by **Ernst Haeckel.** This kingdom forms a link between kingdom Monera on one hand and other three kingdoms *i.e.* , Plantae, Fungi and Animalia on the other hand. Protistans are ancestors of all multicellular eukaryotes (plants, fungi and animals).

Kingdom Protista includes



General Characteristics of Protista

1. Unicellular, eukaryotic organisms. Some are colonial without much cellular differentiation. Organisation at tissue level is absent.
2. Mostly aquatic organisms.
3. Cell structure is eukaryotic type having all kinds of membrane bound organelles and **80 S cytoplasmic** ribosomes and cells may possess cellulosic cell wall.
4. Flagella and cilia have **(9+2)** pattern of microtubule organization consisting of **tubulin** protein.
5. Movement by pseudopodia, flagella or cilia where ciliary mode is fastest.
6. Mode of nutrition may be photosynthetic (holophytic), holozoic (ingestive), saprobic or parasitic (absorptive). Some have **mixotrophic** nutrition (photosynthetic and saprobic) as in *Euglena.*
7. Reproduction occurs by asexual and sexual means.
8. Life cycle is of 2 types-(i) Showing **zygotic meiosis** (ii) Showing **gametic meiosis.**
9. These are decomposers, photosynthetic or parasites. Parasitic protists may cause diseases like dysentery, malaria, sleeping sickness etc.

Photosynthetic protists and Slime moulds are described below:

(1) Photosynthetic Protists

These are popularly called protistan algae. Protistan algae constitute the major portion of the phytoplanktons.

A. Diatoms

Diatoms are golden brown photosynthetic protists and are called *Chrysophytes* **(including both diatoms and desmids).** They are both aquatic and terrestrial. Some are marine. They support much of marine life. Their important characters are

- These are microscopic organisms possessing varying colours.
- They are basically unicellular, but may form pseudofilament and colonies, **lacking flagella except in the reproductive stage.** They may be free floating (phytoplanktonic) due to presence of light weight lipids.
- The cellulosic cell wall is impregnated with silica to form transparent siliceous shell, known as **frustule**. Depending upon the symmetry, diatoms may be pennate type, having bilateral symmetry *(e.g., Navicula)* and centric type, having radial symmetry *(e.g., Melosira).*
- The cell wall is characteristic, made up of two halves; one half covering the other (epitheca over hypotheca) resembling a soap box.
- The cell wall encloses the peripheral layer of cytoplasm (primordial utricle) surrounding a large central vacuole.
- Nucleus lies in the central vacuole, suspended with the help of cytoplasmic strands.
- Mode of nutrition is holophytic (photoautotrophic), photosynthetic pigments are chlorophyll a, chlorophyll c, β-carotene and special carotenoids containing fucoxanthin; xanthophylls like diatoxanthin, diadinoxanthin.

- The reserve food is oil and a polysaccharide called leucosin (chrysolaminarin), volutin granules are also present.
- They are responsible for almost 50% of the total organic matter synthesized in the biosphere.
- Movement occurs by mucilage propulsion.
- They mainly undergo asexual reproduction. The common mode of asexual reproduction is binary fission.
- During binary fission, one half of the cell wall is retained by each of the daughter cells formed. The other half of the cell wall is secreted afresh.
- Resting spores are called statospores (centric diatoms).
- They reproduce sexually as well. Sexual reproduction varies from isogamy to oogamy. It involves gametic meiosis as diatoms are generally diploid (diplontic life cycle).

Concept Builder

1. *Silica shells of dead diatoms are nearly indestructible and thus, get accumulated at the sea bed. Such huge rock-like deposits of hard shells of diatoms constitute diatomaceous earth, which is mined to obtain* a *whitish powder called diatomite or kieselguhr or diatomaceous earth. Diatomite is rough and gritty. Because of these features, it is used in filters in brewing industry, sugarcane refineries, in polishes for metals, tooth pastes, for making insulating bricks, in insulation of refrigerators, houses and for making the latter sound proof, in the manufacture of dynamite, water glass or sodium silicate and strong acids. This is added to paint to increase their night visibility.*
2. *They are very good indicators of water pollution. Common examples of diatoms are Triceratium, Melosira, Navicula, Cymbella.*

B. Dinoflagellates

- Dinoflagellates are **golden brown photosynthetic protists,** belonging to class **Dinophyceae (Pyrrophyta).** They are mainly marine, though few are fresh water forms.
- They may appear red, yellow, green, brown or blue depending upon the main pigment present in cell.

General characters :

- Unicellular, motile, biflagellate, golden brown photosynthetic protists (some are non-motile, amoeboid, palmelloid or filamentous).
- They are mostly marine, some are found in fresh water.
- The body is enclosed by a rigid coat called **theca or lorica** consisting of 2 to many articulated or sculptured plates of **cellulose** and **pectin ,** hence are also called **armoured dinoflagellates.**
- Theca has generally two grooves *i.e.,* longitudinal called **sulcus** and transverse called **cingulum** or **annulus or girdle.**

- Flagella are **heterokont** (different). One is longitudinal and other is transverse. The flagella pass out through the pores in the lorica and lie in the grooves. The transverse flagellum lies in the circular groove and the longitudinal flagellum in the longitudinal groove. The **longitudinal flagellum** is narrow, smooth directed posteriorly and the **transverse flagellum** is ribbon like. Both are oriented at right angle to each other producing spinning movements. Therefore, these protists are also called **'whirling whips'.**
- Most of the species have brown, green or yellow chromatophores with **chlorophyll a, c, -carotene, xanthophyll** *(e.g., Peridinin*). Plastids are generally surrounded by 3-membrane envelope and contain 3-thylakoid lamellae. They are autotrophic or photosynthetic *(Ceratium),* a few are saprobic or parasitic.
- **Reserve food** is carbohydrate and oils.
- Nucleus is relatively larger in size, has condensed chromosomes even in interphase, chromosomes do not have histone. Nuclear envelope and nucleolus remain present even during cell division. This organisation is called **Mesokaryon** (Dodge, 1966).
- A non-contractile vacuole called **pusule** is present near the flagellar base. It may have one or more vesicle and takes part in **floatation** and **osmoregulation.**
- Some dinoflagellates possess **trichocysts** and **cnidoblasts** like those of coelentrates.
- Reproduction is commonly asexual and occurs through cell division.
- Isogamous and anisogamous sexual reproduction is reported from some dinoflagellates *e.g., Ceratium.*
- Life cycle involves **zygotic meiosis** *(Ceratium, Gymnodinium).* Gametic meiosis occurs **in** *Noctiluca.*

Concept Builder

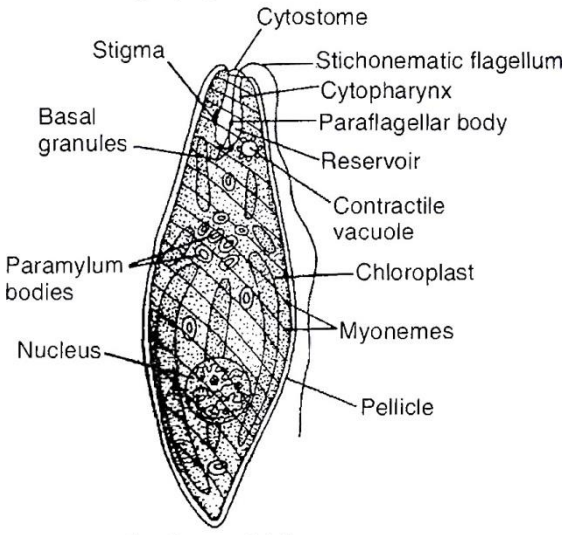
1. *Some marine dinoflagellates show **bioluminescence,** i.e., emit light, e.g., Noctiluca, Pyrodinium, Pyrocystis. Due to phosphorescence the sea glows at night.*
2. *Some dinoflagellates like Gonyaulax catenella produce a toxin called **saxitoxin** into the sea water which is highly poisonous to vertebrates, e.g., fishes and other aquatic animals. Marine shell fish consume dinoflagellates and accumulate the poison which is not harmful to the shell fish (mussel) but upon being consumed causes severe illness in man called **paralytic shell fish poisoning (PSP)** and even prove fatal.*
3. *Some dinoflagellates proliferate in large number and cause **red tide** of the sea, e.g., Gonyaulax, Gymnodinium.*

C. Euglenoid (Euglena-like)

It is a group of chlorophyllous and non chlorophyllous flagellate protists. Largest genera being *Euglena* amongst them.

- Euglenoids are unicellular, flagellate protists found in water or damp soil. Majority of them are fresh water organisms found in stagnant water.

- Body is spindle shaped with blunt anterior end and pointed posterior end.
- **Cell wall is absent** but a covering periplast or **pellicle** is present which is proteinaceous (elastic) in structure.
- Locomotory organs are flagella.
- The cell bears a single long tinsel type flagellum **(stichonematic)** arising at the anterior end. Actually, there are two flagella but one of these is reduced. The longer flagellum has two branches at the base each having its own basal granule. **In the area of union of two flagella is present a photosensitive paraflagellar body.**
- Myonemes are oblique but parallely arranged strips in pellicle. Euglenoids perform creeping movement of contraction and expansion with the help of myonemes which is called **metaboly** or euglenoid movement.
- The apical end of the cell bears an invagination with three distinct parts, *i.e.,* mouth (cytostome), canal (gullet or **cytopharynx)** and **reservoir.** It helps in the ingestion of solid food particles.
- **Stigma** or an eye spot is attached to the membrane of the reservoir at the level of paraflagellar body and along with it seems to be involved in perception of light stimulus. It contains **photosensitive red-orange pigment called astaxanthin.**



Euglena viridis

- A **contractile vacuole** occurs in the anterior end of the cell just below the reservoir, meant for osmoregulation and excretion.
- Single large nucleus lies near the centre of the protoplast.
- Nutrition in *Euglena viridis* is photoautotrophic. However, it is capable of getting nourishment from dead and decaying organic matter in the substrate by secreting digestive enzymes (saprophytic nutrition) in the absence of light. This dual mode of nutrition is termed as **mixotrophic.** Holozoic nutrition is absent in *Euglena.* Some forms are holozoic *(Paranema)* or saprobic *(Rhabdomonas).*
- Photosynthetic pigments are **chlorophyll a, chlorophyll** b, xanthophyll and β-carotene.
- Reserve food material is **paramylon,** stored in cytoplasm in the form of paramylum granules. They are chemically β 1,3-glucans.

- Under favourable conditions, they mainly reproduce by longitudinal **binary** fission. During unfavourable conditions, **palmella stage** and **cysts** are formed for perennation. Sexual reproduction is not known to occur in euglenoids, *e.g.*, *Euglena* and *Paranema.*

Concept Builder

1. *Euglena* is producer-decomposer protist.
2. It is studied as plant as well as animal and is called as plant animal.
3. Plant characters of *Euglena:*
   (i) Presence of chloroplast with photosynthetic pigments.
   (ii) Holophytic nutrition
4. Animal characters of *Euglena:*
   (i) Absence of cell wall and presence of proteinaceous pellicle.
   (ii) Presence of stigma and paraflagellar body.
   (iii)Presence of contractile vacuole.
   (iv)Presence of longitudinal binary fission.

(2) Slime moulds or consumer-decomposer protists

They were included in class myxomycetes of fungi in two-kingdom classification. They were called **mycetozoa by DeBary** as they are closely related to animals. Mycologists include them in **gymnomycota.** Because of their nature they are called **protistan** fungi.

General characteristics of the slime moulds are :

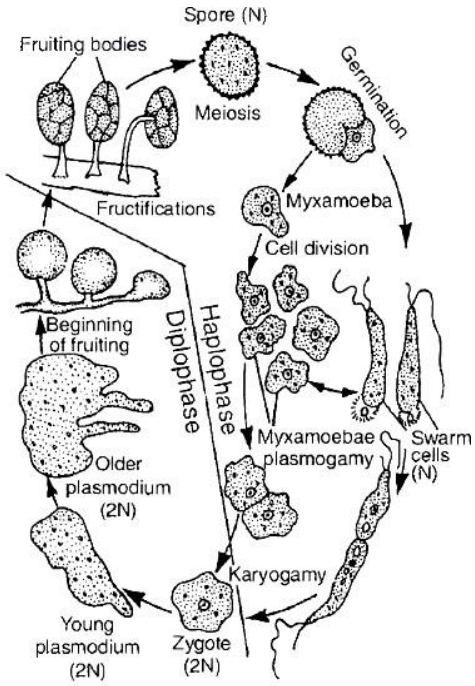
- They are usually free-living, creeping over debris like fallen leaves and rotting logs of wood.
- They have naked protoplast, not covered by any cell wall in vegetative stage.
- They lack chlorophyll and have **saprobic or phagotrophic** mode of nutrition.
- During life cycle they are amoeboid and non-cellulosic, but spores have cellulosic wall so that their vegetative phase resembles with animals while reproductive phase resembles with plants.
- Amoeboid plasmodial stage resembles protozoa and spore forming nature is like fungi.
- Spores are extremely resistant and survive for many years, even under adverse conditions. The spores are dispersed by air currents.
- Reproduction is both asexual and sexual. This group is represented by two separate types of organisms *i.e.* **acellular** and cellular.

A. Acellular or Plasmodial slime moulds

General characters:

- Slimy masses found on decaying leaves and lumber.
- Somatic body is free living, multinucleate, naked, diploid mass called **Plasmodium.** Movement occurs by means of **pseudopodia.**
- During unfavourable conditions, entire plasmodium forms many fructifications/fruting bodies **(polycentric).** The fruiting body is called sporocarp which contains a stalk having a sporangium at its tip. The wall of sporangium is called **peridium.**

- Sporangium has an intricate network of cytoplasmic threads called **capillitium.**
- DiploId protoplast forms **haploid spores by meiosis.**
- Spore wall is double, outer wall is spiny and sculptured.
- On germination, spores produce biflagellate **swarm cells** or **non-motile myxamoebae** which act as gametes.
- Sexual reproduction is **isogamous.**
- Diploid zygote directly forms the plasmodium which becomes multinucleate by repeated mitotic divisions of the diploid nucleus.
- Chief mode of nutrition is **saprotrophic.**
- Vegetative reproduction is by fission .
  e.g., Physarum, Physarella, Fuligo, Dictydium, Lycogala.

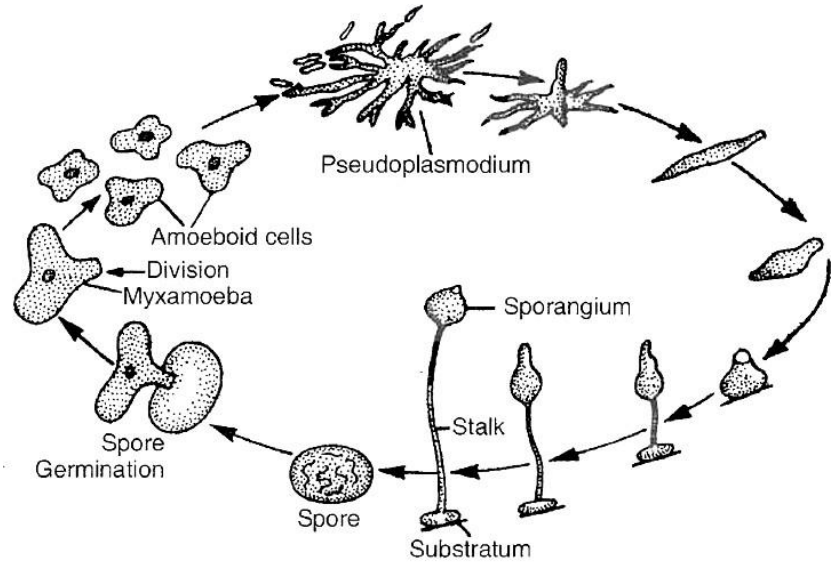


Life cycle of an acellular slime mould

B. Cellular slime moulds or communal slime moulds

General characters :

- Wall less, uninucleate **myxamoebae** present. Complete absence of flagellated cells during life cycle.
- Formation of pseudoplasmodium stage as a result of chemotactic movement of myxamoebae due to release of cAMP and acrasin.



Life cycle of Cellular slime moulds (*Dictyostelium*)

- Sporangia are naked.
- Spores have cellulosic wall.
- Sexual reproduction is **anisogamous.**

- Common cellular slime mould, *Dictyostelium*, is a colonial form in which hundreds of uninucleate, haploid amoeboid cells are aggregated without any fusion to form a colony.
- The colony gives the appearance of single multinucleate mass of protoplasm and thus, called **pseudoplasmodium.**
- Under exhausted food supply and stimulation by **cAMP** and chemical **acrasin,** many cells come close together by **chemotactic movement** during the formation of pseudoplasmodium.
- Pseudoplasmodium exhibits primitive form of **multicellularity and division of labour.**
- So these are also called as **communal slime moulds**.
- On these basis cellular slime moulds are **regarded as advanced protists and primitive fungi.**
- During unfavourable conditions, the myxamoebae may form a cyst called **microcyst** for perennation and dispersal.
- Under dry conditions, the pseudoplasmodium produces stalked **sporocarp,** which may be branched or unbranched, each branch bearing single sporangium terminally **(monocentric).**
- Sporangium is wall less. Within the sporangium, amoeboid cells become rounded to secrete a spore wajl around.
- On the approach of favourable conditions, spores are liberated.
- Each spore germinates by rupturing cellulosic wall to form myxamoeba and the myxamoebae may live independently, multiply by repeated mitotic divisions or get aggregated to form pseudoplasmodium.
- **Sexual reproduction is anisogamous** type. During sexual reproduction, a number of myxamoebae form a clump.
- One of the myxamoeba becomes larger and engulfs the surrounding smaller myxamoebae.
- The plasmogamy occurs and the fused protoplast secretes a thick wall around to form **macrocyst.**
- In the macrocyst, karyogamy occurs and it thus, becomes **zygote.**
- **It is followed by meiosis** and several mitotic divisions to form a large number of haploid myxamoebae, which are released by rupture of macrocyst wall.
  e.g., Dictyostelium, Polysphondylium.

(d) egetative stage of slime moulds resembles with due to absence of cell wall.

(e) *Euglena* does not show _____nutrition.

Q.3 What is the type of meiosis in acellular and cellular slime moulds respectively?

Ans. Q.1. (a). (c) and (d) ; Q.2. (a) Bilateral (b) Statospore (c) Pusule, (d) Animals (e) Holozoic; Q.3. Sporic and zygotic meiosis

Self Assessment

Which kingdom includes nutritionally most diversed group of organisms and has no well defined boundaries?

(1) Monera (2) Protista (3) Fungi (4) Plantae

Chrysophytes are

(1) Diatoms and desmids (2) Diatoms and dinoflagellates

(3) Slime moulds and desmids (4) Slime moulds and diatoms

Red tide is caused by rapid multiplication of

(1) BGA (2) Desmids (3) Diatoms (4) Dinoflagellates

Which of the following option for diatoms is correct?

(1) Pecto-cellulosic cell wall (2) Silicified cell wall

(3) Multicellular eukaryotes (4) Produce saxitoxin

Acellular slime moulds show

(1) Haploid uninucleate plasmodium (2) Naked sporangia

(3) Autotrophic nutrition (4) Isogamous type reproduction

Ans. Q.31 (2), Q.32 (1), Q.33 (4), Q.34 (2), Q.35 (4)

KINGDOM : FUNGI

- This kingdom contains achlorophyllous, eukaryotic, heterotrophic, spore producing, thalloid organisms. The study of fungi is called **mycology.**
- **Pier Antonio Micheli is** considered as father or founder of mycology.
- Mycologist **H.A. de Bary** is the father of modern mycology.
- The father of Indian mycology is **E.J. Butler.**

General Characters

- They are cosmopolitan and occur in air, water, soil and on animals and plants. They are mostly terrestrial. They prefer to grow in warm and humid places.
- They may grow on tree bark, dung, wood, burnt wood and keratinous material *(e.g.,* hair, horns) and are called **corticolous (bark), coprophilous (cow dung), epixylic (wood), xylophilous (burnt wood)** and **keratinophilous (keratin)** respectively.
- The body is **haploid** (n) and thalloid, *i.e.,* not differentiated into root, stem and leaves. They are multicellular (except **Yeast** and *Synchytrium).*

- The fungal body is made up of thread like elongated tubular structures, called **hyphae.** These cris-cross with one another to form a network known as **mycelium.**
- The hyphae may be **aseptate** and multinucleate. Such a hypha is termed **coenocytic.** In most of the fungi, the mycelium is **septate.**
- The septum, however, is not complete, but has a pore through which continuity of the cytoplasm of the adjoining cells is maintained.
- The septum may have **simple central pore** as in **ascomycetes,** but in higher fungi **(class basidiomycetes),** the septum is **dolipore septum,** in which central pore possesses a barrel shaped inflation.
- In septate mycelium, individual cell may contain single nucleus **(monokaryotic** -feature of primary mycelium) or an intermediate phase of two nuclei **(dikaryotic** -feature of secondary mycelium).
- The cell wall of the hyphae is made up of **chitin or fungal cellulose,** which is a polysaccharide containing nitrogenous compound and it is basically made up of **acetylglucosamine.**
- In some fungi, the cell wall is made up of **cellulose** *(e.g., Phytophthora, Pythium* and other oomycetes). Reserve food material is stored in the form of **oil** and **glycogen.**
- Cells have unicisternal golgi bodies.
- Mitosis in somatic cells is **Karyochorisis** type (mitosis with intranuclear spindle formation).
- Nutrition is heterotrophic which includes saprophytes, parasites and symbionts.
- In most of the fungi, there are two distinct phases in the life cycle, the **vegetative or assimilative phase** and the **reproductive phase.**
- In vegetative phase, fungus is microscopic hidden in the substratum and is hardly visible to the naked eyes.
- The fungus enters into reproductive phase after attaining maturity in the vegetative phase.
- In unicellular yeasts, the same cell performs both assimilative and reproductive functions.
- Such type of fungal bodies in which entire cell gets transformed into reproductive structures are known as **holocarpic.**
- Fungal body is termed **eucarpic** in which a part of mycelium is used up in the development of reproductive structures.

Concept Builder

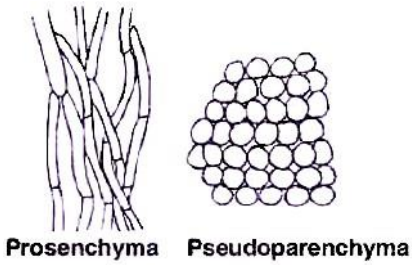
Modification of mycelium:

(a) Plectenchyma :

- When hyphae of a mycelium grow together like plates and intertwine with one another forming a thick woven structure, it is called **plectenchyma**.
- Plectenchyma may have :

(i) Prosenchyma : Loosely interwoven structure whose hyphal components lie more or less parallel to each other and are recognizable.

(ii) Pseudo parenchyma : Hyphae are compactly arranged and hyphal components have lost their identity and appear isodiametric and continuous in section resembling parenchyma of higher plants.



Fungal tissues

(b) Sclerotia (Singular Sclerotium) :

- In some fungi like *Claviceps* the mycelium may pass into a dormant or resting stage by the formation of **hard resting bodies** resistant to unfavourable conditions.
- Each sclerotium is composed of central prosenchymatous and peripheral pseudoparenchymatous arrangement which are again surrounded by a ring of pigmented hyphae.

(c) Rhizomorph:

- When the fungal hyphae aggregate together below surface they behave as an organized unit to form a root like strand with a thick hard cortex.
- It also develops a growing tip somewhat resembling that of a root tip, *e.g.*, *Agaricus.*

(d) Appressorium: Terminal swollen structure of germ tube for attachment, and penetration.

(e) **Haustoria:** Terminal swollen structure for absorption of food, *e.g.*, *Albugo.*

(f) **Snares/hyphal traps:** Helps in capturing nematodes in predaceous fungi, *e.g.*, *Arthrobotrys*, *Dactylaria*

Reproduction in Fungi

- Fungi reproduce by all the three modes, *i.e.,* **vegetative, asexual** and **sexual.**

1. Vegetative reproduction: It occurs by the following methods:

(a) Fragmentation : The mycelium breaks up into two or more fragments due to mechanical injury, decay or some other reasons. Each fragment grows into independent mycelium.

(b) Fission: Here, simple splitting of vegetative cells into two daughter cells takes place by simple constriction.

(c) Budding: Some fungi like yeast produce small outgrowths, *i.e.,* buds from their vegetative body. Eventually, the buds are cut off from parent cell and mature to form new individuals.

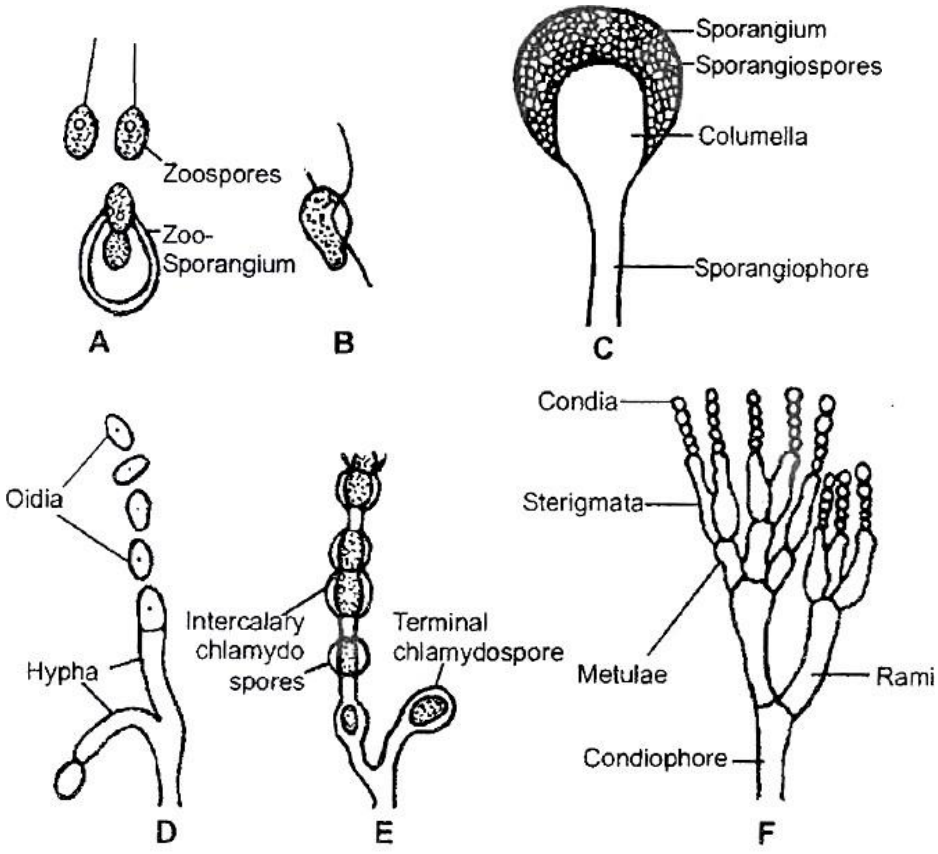
2. Asexual reproduction:

- It occurs through spores.
- These are single celled specialized structures which separate from the organism, get dispersed and germinate to produce new mycelium after falling on suitable substrate.
- The spores produced during asexual reproduction in fungi are formed by mitotic division and are thus termed, **mitospores.**

- **The various means of asexual reproduction are as follows** :

(a) Zoospore :

- Many fungi, especially aquatic members produce these types of spores.
- Zoospore may be **uniflagellate,** *e.g., Synchytrium* or **biflagellate,** *e.g., Saprolegnia, Pythium* and are **naked uninucleate** structures formed in zoosporangia.
- They germinate to give rise to new mycelium.
- Biflagellate zoospores are of two kinds *(e.g., Saprolegnia)* **pear shaped or pyriform** with 2 flagella placed at anterior end (primary zoospore) and **kidney shaped or bean shaped,** bearing two laterally inserted flagella (secondary zoospore).
- This phenomenon of having two types of zoospores is called **diplanetism.**



A – F. Different modes of asexual reproduction

(b) Sporangiospore :

- Sporangiospores are thin walled non-motile spores produced **endogenously** in a sporangium during favourable conditions, which after liberation give rise to new mycelium, *e.g., Rhizopus, Mucor.*

(c) Conidia:

- Conidia are non motile, thin walled **exogenous spores** produced at the tips of erect hyphae called **conidiophore.**
- They are arranged in chains upon the conidiophore, *e.g., Aspergillus* and *Penicillium.*

(d) Chlamydospore:

- In some fungi the hyphae under unfavourable conditions, forms thick walled resting resistant spores which later get separated from each other.

- They may be terminal or intercalary.
- They may remain viable for several years.
- On return to favourable conditions they germinate to give rise to new individuals.
- Thus, chlamydospores are structures for perennation also, *e.g., Rhizopus.*

(e) Oidia:

- Non-motile thin walled spores developing under sugar rich conditions in medium.
- Their budding condition is called torula stage.

3. Sexual reproduction:

- Sexual reproduction is reduced in fungi and takes place by two fusing gametes.
- It includes 3 stages :

(a) Plasmogamy:

- There is union between two haploid protoplasts which results in bringing the fusing nuclei of different parents close together.
- In some fungi, plasmogamy is immediately followed by karyogamy.
- However, in Ascomycetes and Basidiomycetes, an intermediate dikaryotic (n + n) condition occurs. This phase is called **dikaryophase**.

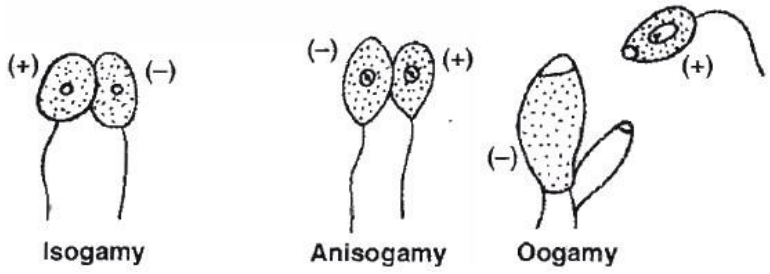
(b) Karyogamy: The two haploid nuclei which come together in plasmogamy fuse and thus, a diploid zygote is produced.

(c) Meiosis: Reduction division takes place in the zygote thus, reducing the number of chromosomes to half.

Plasmogamy occurs by the following methods :

(a) Planogametic copulation / Gametic fusion:

- This is the simplest form of sexual reproduction.
- In this process, fusion of two gametes of opposite sex or strains takes place.
- One or both of the fusing gametes are motile.
- It results in the formation of a diploid zygote, *e.g., Allomyces.*
- This process is usually of three types: Isogamy, Anisogamy, Oogamy.

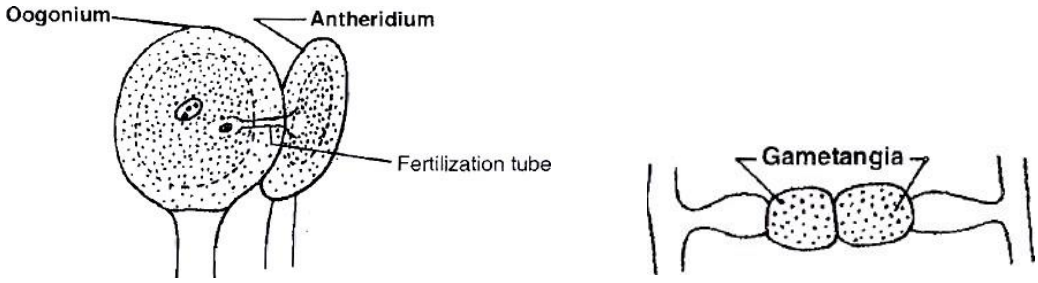


(a) Planogametic copulation

(b) Gametangial contact :

- In this process two gametangia come in contact with one another.
- A fertilization tube is developed to facilitate the migration of entire contents of male gametangium into the female gametangium.

- Both the gametangia never fuse together losing their identity, *e.g., Pythium, Albugo* (Oomycetes).



(b) Gametangial contact, (c) Gametangial copulation

Different modes of plasmogamy in fungi

(c) Gametangial copulation :

- In this process, direct fusion of entire contents of two gametangia is accomplished by dissolution of their common walls resulting in the formation of a single cell, in which protoplasts of two gametangia fuse, *e.g., Mucor, Rhizopus* (Zygomycetes).

(d) Spermatization :

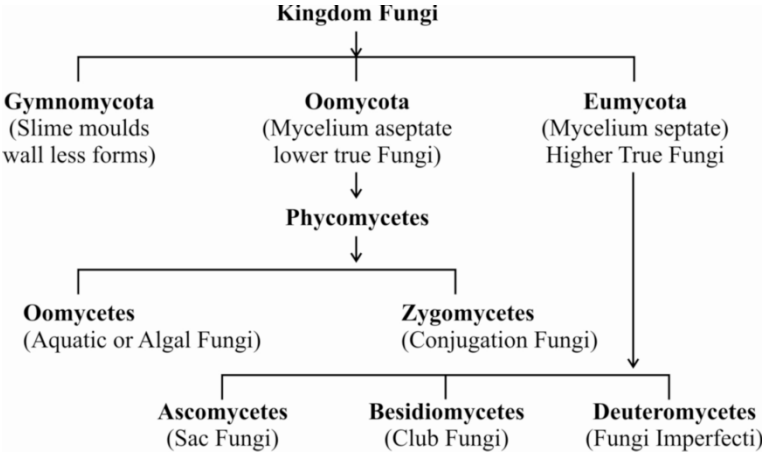
- Some fungi produce many minute, spore like, single-celled structures called **spermatia** (non motile male gametes) on **spermatiophores** (hyphae).
- These structures are transferred through agencies like water, wind and insects to special female receptive, hyphae (Basidiomycetes).
- The contents migrate into receptive structure.
- Thus, dikaryotic condition is established, *e.g., Puccinia.*

(e) Somatogamy :

- This takes place in most of the higher true fungi, where formation of gametes is absent.
- In such fungi, direct fusion of somatic hyphal cells occur to establish dikaryophase, *e.g., Agaricus.*

Classification of Fungi

- A number of criteria are used for classifying fungi.
- Morphology of mycelium, mode of spore formation and fruiting bodies form the basis for the classification of this kingdom.
- A common systematic presentation is given below :



I. Oomycetes : The algal fungi

- Hyphal wall contains cellulose and other glucans in many members.
- The mycelium is coenocytic (multinucleate and aseptate).
- Asexual reproduction involves the formation of spore containing sacs or sporangia. In aquatic forms, the sporangia produce zoospores.
- Zoospores generally have two laterally inserted flagella with heterokont condition, in which one flagellum is smooth (whiplash) while the other is of tinsel type (having fine surface outgrowths called mastigonemes).
- Sexual reproduction is by planogametic fusion or gametangial contact.
- The product of sexual reproduction and site of meiosis is oospore.

Concept Builder

(i) *Phytophthora infestans* causes late blight of potato and occasionally of tomato as well. Great Irish famine of 1845 -1847 was due to late blight of potato.

(ii) *Albugo candida (Cystopus candidus)* causes white rust of crucifers and is characterised by the appearance of irregular white blisters on the leaves and stems.

(iii) *Pythium debaryanum* causes damping off disease in seedlings of tomato, chillies, castor, mustard.

(iv) *Sclerospora graminicola* causes downy mildew in cereals particularly, Pennisetum typhoides (vern. Bajra) green ear disease.

(v) *Peronospora parasitica* causes downy mildew in a number of plants, such as mustard, spinach, onion etc.

(vi) Saprolegnia causes salmon disease of gills in fishes.

II. Zygomycetes: The conjugation fungi

- It is class of terrestrial fungi which are mostly saprotrophic and rarely parasitic.
- Hyphal wall contains **chitin** or fungal cellulose.
- The mycelium is **coenocytic** (multinucleate, aseptate) like the one found in Oomycetes.
- Motile cells (zoospores or planogametes) are **absent.**
- Mitospores are non motile. They are called **sporangiospores** as the spores are formed inside **sporangia** that are borne at the tips of special hyphae called **sporangiophores.**
- Sexual reproduction occurs through **gametangial copulation or conjugation.** Because of it, zygomycetes are also called **conjugation fungi.**
- The gametes are commonly multinucleate and are called **coenogametes.**
- Sexual reproduction produces a resting diploid spore **called zygospore.** Because of the presence of zygospore, the group of fungi is called **zygomycetes**. Zygospore differs from oospore in that, for its formation a distinct food laden, non motile, large female gamete is not produced.

- Zygospore is the site of meiosis and does not give rise to new mycelium directly. Instead it produces a new sporangium called **germ sporangium** (previously called zygosporangium). Germ sporangium forms meiospores called germ spores.
- Sometimes, gametangia fail to fuse. Gametangia become surrounded by a thick wall resulting in formation of **azygospore** (parthenogenetically produced zygospore).

Concept Builder

(i) *Rhizopus stolonifer* (= *R. nigricans*) is popularly known as **black bread mould.** *Mucor mucedo* is called **dung mould or pin mould.** *Rhizopus* and *Mucor* are the common saprotrophic fungi that attack a variety of food stuffs. **Soft rot** or leek disease of strawberry, apple, jack fruit, sweet potato etc. is due to Rhizopus. Mucor pusillus causes infection of internal organs in human beings. Absidia corymbifera causes **bronchomycosis.**

(ii) Ramysin (antibiotic) is obtained from Mucor ramannianus.

Life Cycle of *Rhizopus*

- *Rhizopus* is a saprophytic fungus, commonly found on dead organic matter rich in carbohydrates.
- Mycelium is made up of white narrow thread like hyphae growing on the surface of substratum.
- Two types of vegetative hypha **(Rhizoidal** and **Stoloniferous)** arise from definite points called **hold fast / apparent nodes**.
- Third hypha is asexual, called **Sporangiophore** and fourth type is sexual hypha called **zygophore.**
- The absorptive hyphae are called **rhizoidal hyphae** which penetrate into the substratum.
- The hyphae appeared over the surface of substratum are in the form of stolons.
- From the nodes of stolons arise branched rhizoidal hyphae on the under surface and a group of aerial structures called **sporangiophore** (asexual hypha) from the upper surface of 'apparent nodes'.
- The apical portion of each sporangiophore ends into a swollen structure called **sporangium** which is filled with spores.
- The hyphae are coenocytic, aseptate and branched. It has many nuclei, oil drops, glycogen bodies and vacuoles in the cytoplasm.
- The reproduction in *Rhizopus* is vegetative, asexual and sexual.

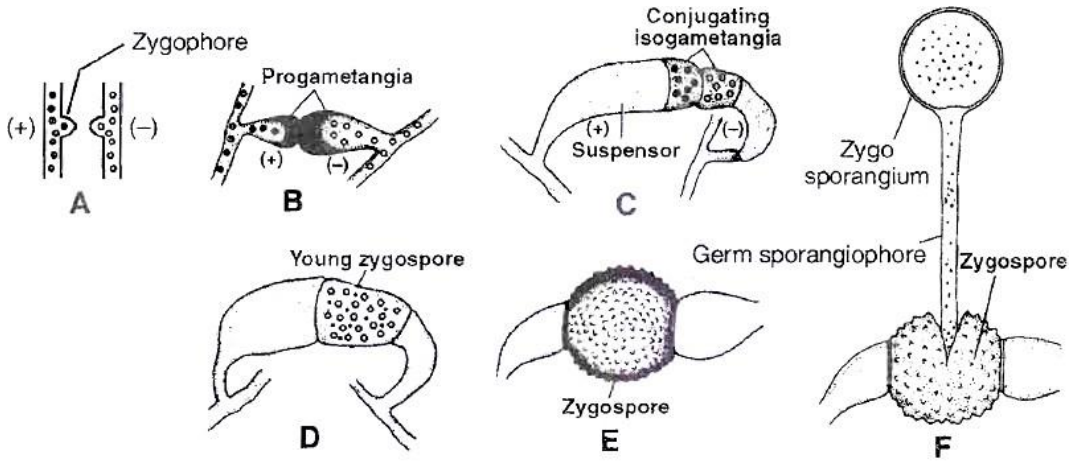
1. **Vegetative reproduction:** This takes place by fragmentation of hyphae.
2. **Asexual reproduction** :

- Asexual reproduction takes place by the formation of non-motile spores inside a sporangium.
- The tip of aerial hypha swells in which cytoplasm migrates with nuclei.
- The tip swells considerably and the nuclei divide repeatedly.

- The contents of the young swollen tip differentiate into a central zone called **columellaplasm** mainly filled with vacuolated cytoplasm surrounded by a peripheral zone called **sporangioplasm** containing dense cytoplasm and many nuclei.
- Vacuoles ultimately form a continuous vacuolated layer by fusing laterally one after the other and ultimately develop into a dome shaped septum known as **columella** (sterile part).
- In the meantime, cleavage of sporangioplasm takes place resulting into innumerable, small 2-10 nucleate portions which round up, become invested with spore membranes, and develop into nonflagellate spores, the **sporangiospores.**
- These are formed under **most favourable conditions.** Thus, the sporangium is large, globose and contains many spores.
- Spores are dispersed by bursting of the thin wall of the sporangium due to pressure that is set up in the columella.
- Other two asexual spores are oidia and chlamydospores (formed under unfavourable conditions).
- The spores on germination produce a germ tube giving rise to new mycelium.

3. Sexual Reproduction :

- Sexual reproduction in *Rhizopus* takes place by the formation of two multinucleate gametangia.
- Both the gametangia are similar externally but are different physiologically *i.e.* they are of (+) and (-) type.
- It is called **heterothallism** (This was discovered by **Blakeslee** in ***Rhizopus stolonifei).***
- Another species called *Rhizopus sexualis* is a homothallic species.
- When two mycelia of opposite strains, (+) behaving as male and (-) behaving as female respectively, come near one another, under influence of a chemical called **trisporic acid,** this stimulates the formation of special sub-aerial hypha called **zygophores.**
- This hypha produces small outgrowths, called **progametangia.**
- Their apical ends are swollen and filled with multinucleate protoplasm.
- This apical portion of these progametangia, comes in contact with one another.
- A septum is laid down, separating the terminal portion which is now termed **gametangium.** The remaining part of progametangia is called **suspensor.**
- The multinucleate undifferentiated protoplast of each gametangium is termed as **coenogamete.**
- As the gametangia mature, the separating wall dissolves from the middle to outward and intermingling of the contents of two gametangia takes place **(Gametangial copulation).**
- Nuclear pairing and fusion of one (+) and another (-) nuclei gives rise to a large number of diploid nuclei.
- The young zygospore lying within the parent gametangial wall enlarges considerably and secretes several layers of thick wall (5 layered**,** 2 layered exosporium and 3 layered endosporium) around it.
- The zygospore matures it breaks up the original gametangial wall into small pieces that fall apart exposing the outer thick, spiny and black exosporium.



***Rhizopus*–Different stages in the sexual reproduction**

- Meiosis occurs at the time of germination of zygospore.
- The zygote germinates after rest period.
- On germination, the exosporium cracks and endosporium produces a germsporangiophore (promycelium) that terminally develops a germ sporangium (zygosporangium) which bears large number of spores.
- The meiosis produces 4 haploid nuclei where only one remain functional.
- This divides repeatedly to produce coenocytic mycelium with many haploid nuclei.
- Occasionally, failure of gametangial copulation results in parthenogenetic development of zygospore, which are called **azygospores (parthenospores).**

III. Ascomycetes: The sac fungi

- The mycelium consists of **septate** hyphae. (Yeasts are an exception in that they are basically unicellular).
- They are saprophytic, decomposers, parasitic or coprophilous (growing on dung).
- The septa possess central pores called **septal pores.** The pores allow communication and transport between adjacent cens.
- Cell wall contains **chitin.**
- **Motile structures do not occur in the life cycle.**
- **In** majority of ascomycetes, the common mode of asexual reproduction is through the formation of **conidia .** Conidia are borne on branched or unbranched hyphae called **conidiophores ,** *e.g., Penicillium, Aspergillus.*
- Female sex organ is called ascogonium.
- Plasmogamy occurs by means of -
  (i) Gametangial contact *(e.g., pyronema)*
  (ii) Conjugation *(e.g.,* Yeast)
  (iii) Spermatization *(e.g., Ascobolus)*
  (iv) Somatogamy *(e.g., Peziza)*
  (v) Autogamy *(e.g., Morchella).*

- Karyogamy is delayed after plasmogamy. A new transitional phase appears in the life cycle. It is called **dikaryophase.** The cells of dikaryophase are called **dikaryotic cells**. Each such cell possesses two different nuclei (Dikaryon). **This forms a shorter phase of life cycle.**
- Once a cell becomes dikaryotic, it transfers the nucleus to other cells by the **crozier method** (method of dikaryotization) to make them dikaryotic.
- Some dikaryotic cells function as **ascus mother cells.** This converts the cells into **asci** (singular ascus). Ascus is a sporangial sac peculiar to Ascomycetes. **Ascus is the site of karyogamy and meiosis.** 4 to 8 haploid meiospores named **ascospores** are produced **endogenously** in each ascus. **In** most of the cases, half the number of ascospores belong to one mating type(+) while the other half belong to the second mating type (-).
- Ascospores may be arranged linearly *(Neurospora)* or unorderly (yeast).
- The asci may occur freely or get aggregated into specific fructifications called **ascocarps.** Ascocarps are of many types : cup-like **(apothecium,** *e.g., Peziza),* flask-shaped **(perithecium,** *e.g., Neurospora, Claviceps)* , elongated with a slit **(hysterothecium),** closed **(cleistothecium ,** *e.g., Penicillium)* cushion like, chambered **(Ascostroma,** *e.g., Pleospora).* The fructifications of some ascomycetes are edible, *e.g.*, morels, truffles.

Conceptual Questions

Give one word for aggregated mass of fungal hyphae into root like strand with thick hard cortex.

Which of the following members are related with Phycomycetes, Ascomycetes or Basidiomycetes?

(a) Penicillium (b) *Synchytrium* (c) *Mucor* (d) *Albugo*
(e) *Agaricus* (f) *Saccharomyces* (g) *Phytophthora* (h) *Saprolegnia*
(i) *Rhizopus*

Match the Column I with Column II

	Column-I	**Column-II**
a.	Algal fungi	(i) Gametangial copulation
b.	Conjugation fungi	(ii) Zoospore
c.	Sac fungi	(iii) Basidiospore
d.	Club fungi	(iv) Conidia

Ans. **Q.1.** Rhizomorph;

Phycomycetes - (b), (c), (d), (9), (h), (i); Ascomycetes - (a), (f); Basidiomycetes - (e)

a(ii), b(i), c(iv),.d(iii)

Concept Builder

Members of this class are said to be our worst fungal enemies.

(i) **Morels** are Ascomycetes with edible ascocarps having fleshy sponge-like conical cap or pileus and a stalk like stipe, *e.g., Morchella esculenta (vern. Guchhi), M. deliciosia*.

(ii) **Truffles:** They are edible tuber-like subterranean ascocarps, *e.g., Tuber aestivum*.

(iii) ***Claviceps purpurea*** causes ergot of rye and *C. microcephala* causes ergot of bajra in which ears are filled with sclerotia of the fungus. Eating of infected cereals produces ergotism**.** (It produces an alkaloid called **ergotine** which causes abortion, if eaten, unknowingly). This is used as a drug to promote expulsion of foetus.

(iv) ***Neurospora crassa*** (Pink bread mould), is often employed in experimental genetics, so is called **Drosophila** of plant kingdom**.**

(v) **Erisyphe:** The fungus produces powdery mildew (fungal disease in which pathogen results in a powdery coating of spores on the sut1ace of the host), *e.g., Erysiphe graminicola*.

(vi) ***Penicillium chrysogenum*** is used in commercial production of the antibiotic penicillin. The later was the first commercial antibiotic. It was discovered from *P. notatum*. The fungus is employed in ripening of cheese, *e.g., P.roqueforti* and *P. camemberti*.

(vii) **Aspergillus:** It is common green smoky mould which not only contaminates laboratory cultures (hence called **weed of laboratory),** but also various food stuffs including bread, butter etc. Aspergillus flavus is highly poisonous due to the presence of aflatoxins**.** *A. oryzae* is the source of diastase enzyme.

(viii) **Brewing Industry:** Under anaerobic conditions, sugary solutions inoculated with yeasts are converted into alcoholic beverages, *e.g.*, beer, wine, cider, toddy. The two common yeasts used by brewing industry are *Saccharomyces cerevisiae* (Beer or Baker's yeast) and *S. ellipsoidens* (Wine yeast).

(ix) **Gibberellins:** They were first discovered in the extracts of *Gibberella fujikuroi* growing on rice (bakanae disease of rice). It is the perfect stage of fungus *Fusarium moniliforme* (Deuteromycete). Gibberellins are natural plant growth hormones.

Life cycle events of (A) Yeast and (B) *Penicillium* are described below:

(A) Yeast

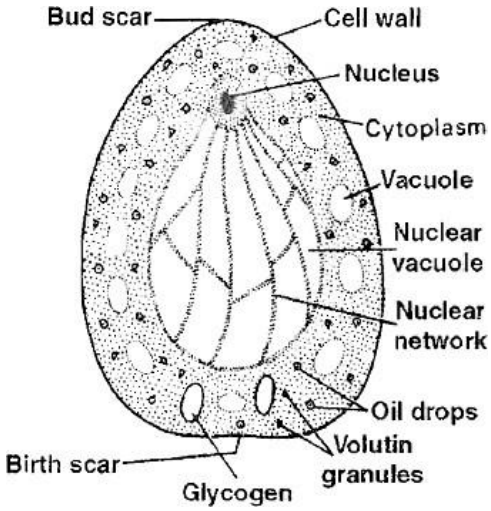
- Yeasts are a group of non mycelial or pseudomycelial ascomycetes which multiply asexually by budding or fission and where asci are not organised into ascocarps**.**
- These are facultative aerobes.
- Depending upon the mode of asexual reproduction, yeasts are of three types -budding yeast *(e.g., Saccharomyces),* fission yeast *(e.g., Schizosaccharomyces)* and helobial yeast (both budding and fission, *e.g., Saccharomycoides).*
- Yeasts in which ascus formation is known are named as **true yeasts.**
- Related forms which resemble yeasts in main characterstics, but where ascus formation is not reported, are called **false yeasts**, *e.g., Candida, Mycoderma, Geotrichum, Cryptococcus* (false yeasts belong to deuteromycetes).

Life cycle of Yeast

- It is a saprophytic fungus found on substratum which is rich in sugars, *e.g.*, sugarcane juice, fruits (banana, plums, grapes), milk etc.

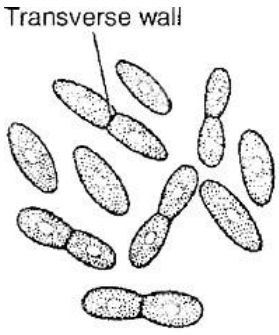
Structure:

- This is a circular or elliptical, unicellular, colourless fungi not having a typical mycelium.
- Their cell wall contains mannans, glucans, lipids, proteins and chitin.
- Protoplasm of yeast can be differentiated into two regions.
- Outer region called **ectoplasm** in the form a thin layer and **endoplasm** which is granular.
- The protoplasm has stored foods in the form of glycogen bodies and volutin granules and fats.
- Mitochondria and ribosomes are found in the cytoplasm.



Structure of a yeast cell

1. **Vegetative Reproduction** : Yeast reproduces vegetatively either by Transverse wall fission or by budding. Depending on this character, they are grouped as **fission yeast *(Schizosaccharomyces)*** and **budding yeast *(Saccharomyces).***



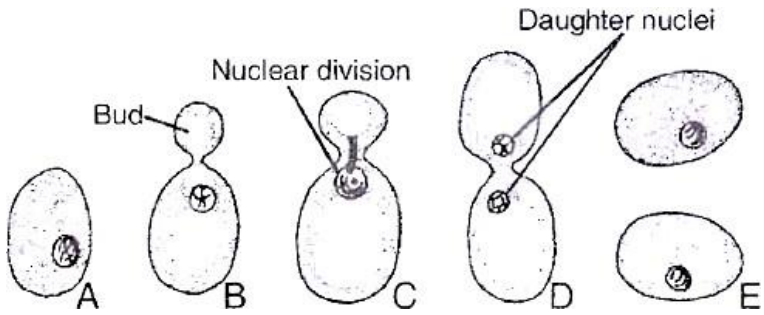
Fission in yeast

(a) By fission:

- During reproduction by fission the parent cell elongates, the nucleus divides into two daughter nuclei and gradually a transverse partition wall is laid down somewhat near the middle, starting from periphery to the centre dividing the mother cell into daughter cells.
- The two daughter cells so formed, may remain together for sometime and begin to divide again or they may separate soon and then divide.

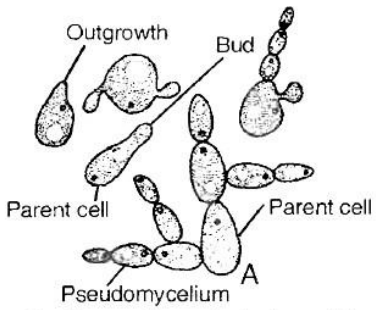
(b) By budding:

- Budding yeasts are rather common than the fission yeast. At the commencement of budding a small portion of the cell wall, usually near the end, softens.
- The protoplast of the mother cell covered by a thin membrane bulges out in the form of a bud which ultimately develops into a daughter cell.
- Meanwhile, the nucleus of the mother cell divides mitotically, (according to some, the division is amitotic).
- One of the two daughter nuclei migrates into the enlarging bud.
- The bud grows until it attains the size of the mother cell.
- The daughter cell then becomes separated from the mother cell and the process may be repeated indefinitely.



Budding in yeast

- Under conditions of rapid growth, the daughter cell also starts producing buds before being detached from the mother cell and the process may be repeated several times, giving rise to chains or groups of yeast cells.
- This results in the formation of branched or unbranched **pseudomycelium.** The cells in chains of pseudomycelium are loosely joined together.



Yeast– Formation of chains of buds

- Sooner or 'A later, however, the chains break into their constituent cells.

2. Sexual Reproduction:

- It takes place by the union of two cells (more often similar in size).
- The copulating pair of cells may be vegetative cells or ascospores.
- Yeasts may be **homothallic or heterothallic** and stages of fusion are extremely variable.
- Three life cycle patterns are distinguishable among yeasts. These are :

(a) Haplontic life cycle: This is exhibited by *Schizosaccharomyces octosporus* **(fission yeast).**

(b) Diplontic life cycle: This is exhibited by *Saccharomycoides ludwigii* (Helobial yeast).

(c) Diplohaplontic life cycle: This is exhibited by *Saccharomyces cerevisiae* (Budding yeast).

Concept Builder

- In addition to the above given methods of sexual reproduction of yeast, the following methods are also found:

(a) **Adelphogamy:** Copulation between two adjoining sister cells. This is isogamous and the cells which fuse, do not separate after fission but remain united to form short chains.

(b) **Pedogamy:** It is copulation between mother and the daughter cell formed by budding. The daughter remains attached to the mother and the nucleus of the bud migrates into the mother.

- *Saccharomyces cerevisiae* = Brewer's Beer yeast or Baker's yeast
  S.ellipsoidens = Wine yeast
- *Torulopsis utilis* and *Endomyces vermalis* are rich in proteins. *Rhodotorula* is rich in vitamin A and *Ashbya gossypii* is rich in **vitamin** B_2.
- Yeasts are used in curing cocoa beans.
- **Diseases caused by yeast**
  (a) Candidiasis/moniliasis – *Candida albicans*
  (b) Blastomycosis – *Blastomyces dermatidis*
  (c) Histoplasmosis – *Histoplasma capsulatus*
  (d) Cryptococcosis – *Cryptococcus neoformans*
- Some yeasts reduce the yield of silk industry by attacking silkworms.
- Species of Nematospora attack cotton, tomato and beans.

Self Assessment

Mark the odd one (w.r.t. fungi)

(1) Unicisternal golgi bodies

(2) Show a great diversity in morphology and habitat

(3) Most of the members are aquatic

(4) Reverse food material is stored in the form of oil and glycogen

Fungi with cellulosic wall belong to the class

(1) Oomycetes (2) Zygomycetes (3) Ascomycetes (4) Basidiomycetes

Select incorrectly matched pair

(1) *Rhizopus* -Sporangiospore *(2) Penicillium* -Ascocarp

(3) Mucor -Dikaryophase *(4) Aspergillus* -Conidia

Which one of the following organism performs plasmogamy by gametangial contact?

(1) Puccinia (2) *Albugo* (3) *Rhizopus* (4) *Agaricus*

Coenocytic dimorphic vegetative mycelium is found in

(1) Neurospora (2) *Rhizopus* (3) *Penicillium* (4) *Ustilago*

Choose incorrect match w.r.t. different classes of fungi

(1) Oomycetes -zoospore -gametic copulation

(2) Zygomycetes -sporangiospore -zygophore

(3) Ascomycetes -conidia -monokaryotic aseptate mycelium

(4) Phycomycetes -algal and conjugation fungi -coenocytic mycelium

Q.42 Fungi often employed in experimental genetics is the member of

(1) Egg fungi (2) Conjugation fungi

(3) Sac fungi (4) Club fungi

Q.43 Select correct match

	Column-I	**Column-II**
a.	Soft rot of apple	*(i) Absidia*
b.	Bronchomycosis	*(ii) Rhizopus*
c.	White rust disease	*(iii) pythium*
d.	Damping off disease	*(iv) Albugo*

(1) a(ii), b(i), c(iv), d(iii) (2) a(i), b(ii), c(iv), d(iii)

(3) a(iv), b(iii), c(ii), d(i) (4) a(ii), b(i), c(iii), d(iv)

Q.44 In which of the following yeast ascus contains eight ascospores?

(1) *Saccharomyces* (2) *Saccharomycoides*

(3) *Schizosaccharomyces* (4) More than one option is correct

Q.45 Asci are not organised into ascocarps in

(1) True yeast (2) *Drosophila* of plant kingdom

(3) Pigmented mould (4) Morels

Ans. Q.36 (3), Q.37 (1), Q.38 (3), Q.39 (2), Q.40 (2), Q.41 (3), Q.42 (3), Q.43 (1), Q.44 (3), Q.45 (1)

(B) Penicillium

Important characters

- Facultative parasite and saprophytic fungi.
- Mycelium is branched septate, with simple septal pore and each cell is uni or multinucleate depending upon the species.
- Asexual reproduction occurs by **conidia.**
- Conidiophores are often branched.
- The first branch level is called **rami** and second or ultimate branches are called **metulae** having bottle shaped **sterigmata.**
- Each sterigmata produces a chain of conidia.
- The conidia in chain are arranged in **basipetal order.**
- Each conidium is uninucleate, non motile, two layered, dispersed by air and germinates to form new mycelium.
- **Sexual reproduction:** It exhibits dikaryophase and produces ascocarp.
- The ascocarp is cleistothecium type.
- Each ascus has 8 ascospores.
- Ascospore germinates to form new mycelium.

Conceptual Questions

Penicilfium is multicellular and saprophytic fungi (true/false).

Select the correct sequence of sexual reproduction events in sac fungi w.r.t. *Penicillium,*

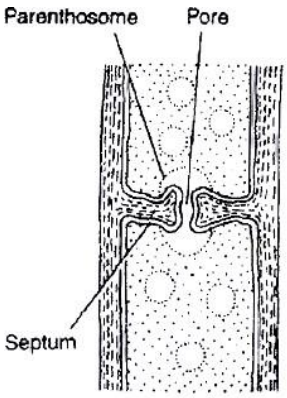
(a) Meiosis (b) Dikaryophase (c) Development of sex organs

(d) Plasmogamy (e) Karyogamy (f) Ascospore

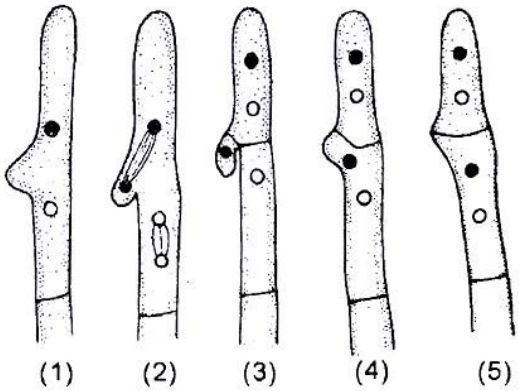
Ans. Q.1. Ture; Q.2. (c) → (d) → (b) → (e) → (a) → (f)

IV. Basidiomycetes: The Club Fungi

- They are the most advanced and most commonly seen fungi. Their fructifications are often large and conspicuous, *e.g.*, mushrooms, toadstools, puff balls, bracket fungi etc.
- Basidiomycetes are among the best decomposers of wood. They are able to decompose both cellulose and lignin. Lignin is not metabolised by most other fungi and even bacteria. *Ganoderma* species causes decay of wood even on standing trees.
- Motile structures or cells are absent.
- Mycelia are of two types, primary and secondary. Primary mycelium contains monokaryotic cells and is short lived.
- Monokaryotic phase or primary mycelium may multiply by oidia, conidia-like spores and pycniospores.
- Secondary mycelium is long lived and dominant phase of life cycle. It is represented as dikaryophase. It consists of profusely branched septate hyphae.
- Septa possess dolipores or central pores with barrel-shaped outgrowths (except rusts and smuts).
- Handle like outgrowths are found on the sides of septa. They are called clamp connections. Clamp connections are meant for proper distribution of dikaryons at the time of cell division.



Dolipore Septum



Clamp connections and formation of dikaryotic hyphae

- Secondary mycelium can perennate in the soil or wood by means of sclerotia or rhizomorphs.
- Dikaryophase or secondary myceium may multiply by different types of spores chlamydo-spores, aecidiospores, uredospores, teleutospores etc.
- There is often differentiation of two mating types (+) and (-) in thallus.

- Sexual reproduction does not involve sex organs. Instead fusion occurs between basidiospores and other monokaryotic spores, between a spore or spermatium and a hypha or between two hyphal cells of primary mycelia.
- **Karyogamy and meiosis** occur in club-shaped structures known as **basidia** (singular - basidium). The name of the class is based after them.
- A basidium commonly produces four meiospores or basidiospores **exogenously** at the tips of fine outgrowths called **sterigmata** or directly on the basidium.
- The fungi may or may not produce fructifications called **basidiocarps.** The basidiocarps vary from microscopic forms to large macroscopic structures. Some puff balls and brackets can be over 50 cm in diameter.

Concept Builder

(i) **Smuts :** They produce thick-walled, black-coloured resting spores called **smut spores.** Smuts are of two types, **covered** and **loose.** In covered smut, the spore mass remains within the membranous covering of sorus, *e.g., Ustilago hordei* **(covered smut of barley),** *Ustilago maydis* **(smut of corn).** In loose smut the spores are exposed while attached to the host, *e.g., Ustilago nudatritici* **(loose smut of wheat),** *U. avenae* **(loose smut of oat).**

(ii) **Mushrooms :** They are edible and non edible Agaricales which possess umbrella like basidiocarp. Common examples of edible mushrooms are *Agaricus campestris, A. bisporous, Volvariella volvacea* **(Paddy straw mushroom),** *Pleurotus ostreatus etc.*

(iii) **Toadstools:** Toadstools are poisonous mushrooms which generally have white spores. *Amanita caesarea* **(Caeser's mushroom)** was used in poisoning Roman emperor Caesar. The other toadstools are-*Amanita phalloides* **(Death cup),** *A. muscaria* (Fly agaric) and *Gynomitra esculenta* (heat labile carcinogenic toxin).

(iv) **Rusts :** They are characterised by the formation of rusty pustules containing the spores.

(a) *Puccinia graminis tritici* -Black rust of wheat.

(b) *Puccinia glumarum* or *P striiformis* -Yellow rust of wheat.

(c) *P recondita* -Brown rust of wheat

(v) **Hallucinogens:** *Psilocybe mexicana* **(Sacred mushroom)** has hallucinating properties similar to LSD. It is used by Mexican Indians during certain religious ceremonies.

(vi) **Armillaria (largest fungi):** *A. mellea* **(Honey mushroom)** is a serious root parasite of both hardwoods and conifers. The fungus develop rhizomorphs into the phloem of the host and hence, blocks the food supply.

(vii) **Puffballs:** The basidiocarp is a stalked rounded structure which, upon ripening, releases out puffs of spores. The fructification may grow above or below the substratum, *e.g., Lycoperdon oblongisporum, L. giganteurn*.

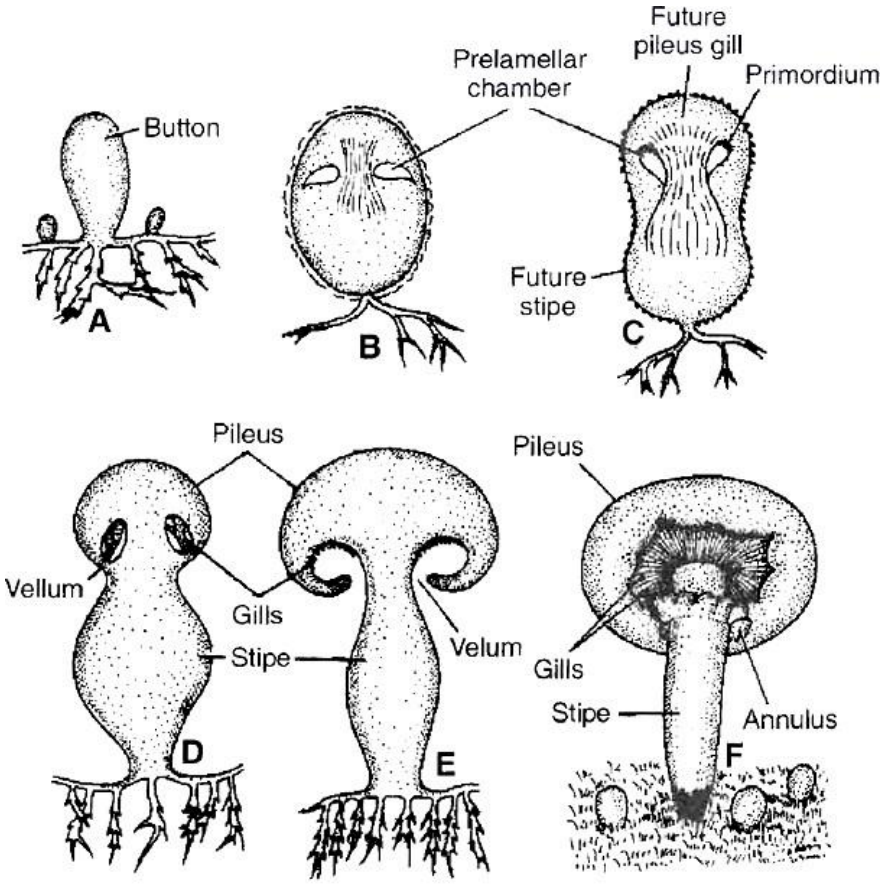
(viii) **Bracket fungi (Shelf fungi)** : They are basidiomycetes whose basidiocarps or fructifications appear on tree trunks, logs, lumber etc. just as brackets or shelves, *e.g., Fomes applanatus, Polyporus sulphureus, Ganoderma*.

(ix) **Predator fungi** : *e.g., Dactylaria, Arthrobotrys*.

(x) **Stinkhorn.** *Phallus impudicus* (Dead man's finger). Spore mass produces a stinking odour to attract flies.

Life History of a Mushroom

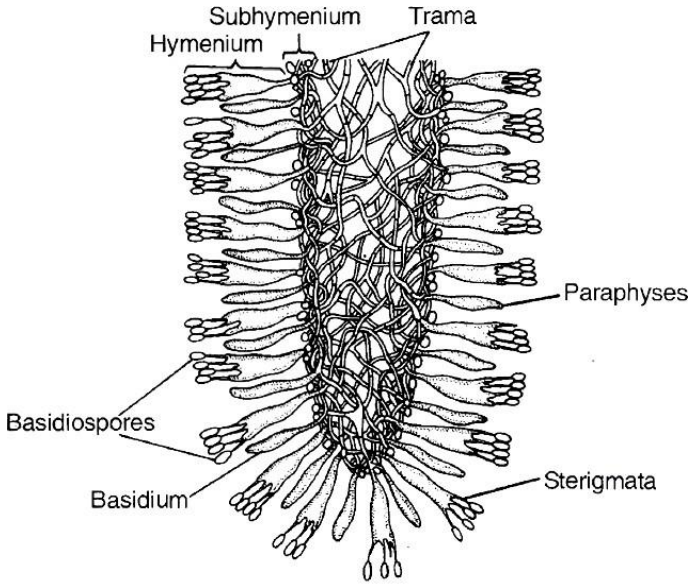
- *Agaricus campestris* is the common field mushroom which has edible basidiocarp. The fungus is **saprotrophic.**
- The vegetative or assimilative part of mycelium is subterranean. It is found in moist humus rich soil of open fields, grassland, piles of straw or within rotting togs.
- The mycelium multiplies by **fragmentation;** occasionally by oidia and chlamydospores.
- Life cycle of mushroom contains two types of mycelia, **primary** and **secondary. Sex organs do not differentiate.**
- Primary mycelium is short lived. It consists of septate hyphae having monokaryotic cells. The mycelia are **heterothallic.**
- The hyphae of two mating types come in contact and show **somatogamy.** However, only plasmogamy occurs at this time.
- It gives rise to a dikaryotic cell that grows, divides and produces a long-lived and extensive dikaryotic or **secondary mycelium.**
- The hyphae of secondary mycelium show **clamp connections** and **dolipore septa.** Its celis possess two haploid nuclei instead of single diploid nucleus.



***Agaricus* : Stages in the development of basidiocarp**

- Under favourable conditions, hyphae of secondary mycelium collect at places and give rise to rounded or pyriform compact masses of hyphae called **buttons.**
- The buttons enlarge and produce aerial fructifications or basidiocarps.

- The latter are popularly termed as **mushrooms.** In contrast the secondary mycelium, from which mushrooms develop, is known as **spawn.**
- The basidiocarps or mushrooms often lie in rings. The latter are called as **fairy rings,** its diameter increases centrifugally every year.



***Agaricus* : Internal structure of gill**

- Each basidiocarp or mushroom is cream to pinkish brown in colour and consists of two parts, **stipe** and **pileus.**
- The stipe or stalk is fleshy. It is slightly swollen at the base.
- Pileus is umbrella-like cap of the mushroom. In the button stage, the pileus is connected to stipe by membrane called **veil or velum.**
- It ruptures during growth of pileus. However, its remains can be seen on the upper part of stipe as **annulus.**
- The pileus is circular in outline. Its upper surface is more or less convex. The under surface is flat or concave.
- It bears 300-600 radiating rows of vertical plates named **gills** (lamellae).
- The two sides of vertically placed gills are lined by thousands of club-shaped **basidia** alongwith sterile **paraphyses**.
- The two, together constitute the fertile layer or **hymenium** of the gill. Hymenium is subtended by compact subhymenium.
- The centre consists of interwoven hyphae called **trama**. Each basidium functions as the site for both **karyogamy** and **meiosis**. The two nuclei fuse to form a short-lived diploid synkaryon.
- The latter, then divides meiotically giving rise to four haploid nuclei, two of (+) strain and two of (-) strain. The free end of the basidium now develops four peg-like outgrowths called **sterigmata**.
- Each sterigmata bears an ovoid pinkish-purple meiospore termed as **basidiospore**. A droplet appears at the tip of sterigmata which creates tension and hanging basidiospores are carried away by air currents.

- The basidiospores are liberated successively for several days. After falling on a suitable substratum, each basidiospore germinates to produce monokaryotic primary mycelium.

Life Cycle of *Puccinia graminis tritici*

- *P. graminis tritici* is a macrocyclic (producing many dikaryotic spores), Heteroecious (requires more than one host *i.e.*, primary host -wheat, secondary or alternate host -barberry).
- It produces uredospores and teliospores on the wheat plant, basidiospores in soil and pycniospores and aeciospores on barberry.
- It causes black or stem rust of wheat. Hence, we describe the various stages of life cycle on the basis of the host.

A. Stage of life cycle on wheat (primary host)

(i) Uredia and uredospores :

- The dikaryotic aeciospores germinate on the leaves of wheat on both the surfaces and may also germinate on the stem.
- They form the dikaryotic mycelium.
- The germ tube protrudes out which swells up to form an elongated appressorium near the stomata.
- A peg like outgrowth now arises from the appressorium and penetrates the stomata. It ramifies repeatedly to form a mass of mycelium this mycelium forms the uredospore.
- As a result, some pressure is exerted on the epidermis which bursts exposing the uredospore. These clusters of uredospores have been variously referred to as uredosori or urediopustules.
- A uredospore is reddish-brown, unicelled, oval or globose, stalked, dikaryotic spore. Its wall is three layered, the outer being somewhat spiny.
- The uredial stage multiplies through the uredospores which germinate on fresh wheat plants (due to the red colour of spores this stage is called red rust stage).

(ii) Telia and teliospores (black rust stage) :

- Towards the end of the season, the dikaryotic mycelium of the uredosorus begins to produce **teliospores** (or **teleutospores)** in the same sorus.
- They are dark **brown or black, stalked, thick walled, bi-celled spores.** The upper cell is pointed, **both the cells are** binucleate.
- The pustules containing teliospores are called as **tella or teleutosori.**
- The teliospores also exert pressure on the epidermis which bursts open, exposing the spores.
- It is at this stage the symptoms develop in stem also, **so the disease is named black stem rust of wheat.**
- Karyogamy occurs inside each cell of teliospore and as a result they **become diploid.**
- The teliospores cannot infect fresh wheat plants. They germinate in soil to form the basidiospores.

(iii) Basidia and basidiospores:

- The two cells of the teliospores now act as **hypobasidium.** They germinate in soil and form a tube called **promycelium.**
- The diploid nucleus migrates into **epibasidium** and then undergoes meiosis to form four haploid nuclei each of them develops as a **basidiospore** on the sterigmata.
- Of these, two basidiospores belong to +ve strain and two to -ve strain.
- These spores are not capable to infect a wheat plant. Each spore is **unicelled, monokaryotic** and **unstalked.**
- These can infect the barberry plant *(Berberis vulgaris)* which is the **secondary or alternate host** occurring on the hills in India.

B. Stage of life cycle on barberry

(i) Spermatia or pycniospores:

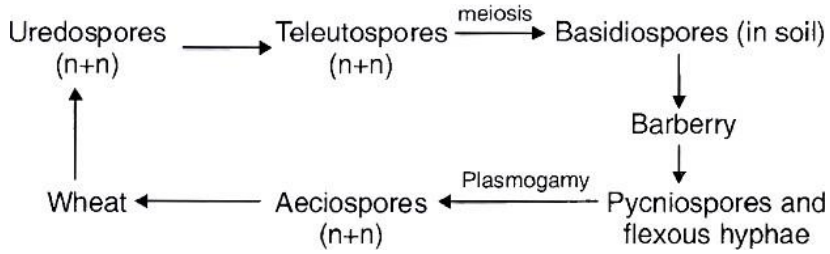
- The basidiospores of both the strains (+ and -) can germinate on upper surface of barberry leaf.
- They produce haplophase or primary mycelium of the respective strains which grows through the intercellular spaces.
- Soon the mycelium forms a palisade like mat which organises like a flask shaped structure near the upper epidermis called as **spermogonia** or **pycnidium**.
- They open by a single pore called **ostiole**.
- The spermogonium is lined by palisade Ilike uninucleate cells called **spermatiophores**.
- From the tips of spermatiophores are pinched off a large number of uninucleate cells called **pycniospores** or **spermatia**.
- Besides, some sterile hyphae also arises which grow out through the ostiole.
- They are called as **periphysis**.
- In addition to these, some thin walled hyphae are also given out which become more elongated.
- They are called as flexuous hyphae or receptive hyphae.
- While the spermatia function as the male cells, the flexuous hyphae behave as the female hypha.
- The pycniospores or spermatia protrude out of the ostiole in a nectar.
- The insects feeding on this nectar transfer the spermatia from one spermogonium to the other.
- Spermatization is brought about when spermatia of one strain come in contact with the trichogyne of flexuous hyphae of the other strain.
- The nucleus of pycniospore or spermatium passes into the flexuous hyphae, thus bringing about dikaryotization.

(ii) Aecia and aeciospore :

- An aecium or aeciosorus is produced on the lower surface of barberry leaves. It arises just beneath pycnium. The dikaryotized mycelium aggregates sub-epidermally.
- This gives rise to a group of elongated dikaryotized cells which function as aecial mother cell. The mother cells differentiate a row of binucleate cells.
- The alternate binucleate cells enlarge and they are identified as aeciospores. The alternate cell

remaining small is disjunctor or sterile cell.

- The sterile wall of the aecial cup called **peridium** or **pseudoperianth** presses the lower epidermis which eventually bursts open. Thus, the aeciospores are set free.
- The aeciospores are **polyhedral or ovate, binucleate, unicelled** and **double layered.** The outer thick wall is called **exine** and the inner as **intine.**
- They are set free in spring. They cannot infect the barberry bushes. These are carried from hills to the plains where they infect wheat plants. They germinate on the leaf surface from a germ tube which enters the host through stomata.



Schematic representation of life cycle of wheat rust

Annual Recurrence of Rust in India:

- It was first studied by **Prof. K.C. Mehta.**
- He concluded that, in India, the annual recurrence of rust on wheat takes place through uredospores.
- The alternate host, *Berberis vulgaris* plays no role in our country. According to Mehta, if no wheat is grown on hills, the intensity of its infection in plains can be reduced.
- He also suggested the involvement of certain collateral hosts like *Briza minor*, *Bromus* and *Thalictrum* for multiplication of uredospores during non-growing season of wheat.

V. Deuteromycetes: (The Fungi Imperfecti)

- Deuteromycetes is an artificial class **(form class)** of fungi which has been created to include all those fungi in which sexual stage (or perfect stage) is not known (absent or not reported) .
- The mycelium is septate and branched. Coenocytic forms are not known.
- Asexual reproduction often occurs by **conidia.**
- Once perfect (sexual) stages of members of Deuteromycetes were discovered they were often moved to Ascomycetes and Basidiomycetes but most members of Deuteromycetes are actually related to ascomycetes.
- Some members are saprophytes or parasites while a large number of them are decomposers of litter and help in mineral cycling.

Concept Builder

(i) **Leaf spot of rice :** Helminthosporium oryzae causes leaf spot disease of rice commonly called **brown leaf spot of rice.** It caused Bengal famine in 1942-43.

(ii) Early blight: Alternaria solani causes early blight of potato. The leaves develop small oval brown spots with concentric rings **(target board symptom).**

(iii) **Tikka disease** : Circular necrotic dark brown or blackish leaf spots develop in groundnut due to Cercospora personata.

(iv) **Red rot:** Colletotrichum falcatum produces red rot of sugarcane.

(v) **Wilts :** Many economically important plants (*e.g.*, cotton, pigeon pea) show sudden signs of wilting due to blockage of tracheary elements by growth of fungus, Fusarium especially *F. oxysporum, F. udum*.

(vi) Ringworm of foot/Athlete's foot is caused by Trichophyton interdigitate.

Common names of some fungi:

Fungus/Group	**Common names**
Rhizopus	Black/Bread mould
Morchella	Morels (sponge mushroom)
Saccharomyces	Yeasts (sugar fungus)
Phallus	Stink horns
Hydnum	Tooth fungi (Hedge hog fungi)
Agaricus	Gill fungi (Mushroom)
Ganoderma, Polyporus	Wood / Bracket / Shelf fungi
Aspergillus and Penicillium	Pigmented moulds
Aspergillus	Laboratory mould
Aspergillus flavus	Guinea pig of plant kingdom
Mucor mucedo	Dung mould
Penicillium	Blue/green mould
Peziza	Cup fungi
Lycoperdon, Clavatia	Puff balls
Cyathus	Bird's nest fungus
Clavaria	Coral fungi
Amanita	Toad stool
Tremella	Jelly fungi/Trembling fungi
Pleurotus ostreatus	Oyster mushroom
Agaricus bisporus	Button mushroom
Neurospora crassa	*Drosophila* of plant kingdom

Concept Builder

Common Fungicides and their composition

1. Bordeaux mixture – ($CuSO_4$: $Ca(OH)_2$: H_2O). First fungicide discovered by RMA Millardet Commonly known as **holy water of plant pathology**

2. Burgandy mixture – Mixture of $CuSO_4$ + Na_2CO_3 + H_2O was discovered by Mass.

3. Chestnut mixture – Ammonium carbonate + copper sulphate.

Self Assessment

Mark the odd one (w.r.t. *Penicillium)*

(1) Asexual reproduction by conidia (2) Obligate parasite

(3) Sac fungi (4) 8 ascospores in each ascus

Ultimate branches of conidiophore in *Penicillium* is

(1) Rami (2) Phialide (3) Sterigmata (4) Metulae

Ascospore in sac fungi is a that is formed

(1) Meiospore, exogenously (2) Meiospore, endogenously

(3) Mitospore, endogenously (4) Mitospore, exogenously

The common type of asexual spore in sac fungi is

(1) Uninucleate and motile (2) Unilayered and non-motile

(3) Two layered and non-motile (4) Multinucleate, two layered and motile

Fungi as best decomposers of wood are

(1) Ascomycetes (2) Basidiomycetes (3) Deuteromycetes (4) Zygomycetes

Secondary mycelium is long lived and dominant phase of life cycle in

(1) Club fungi (2) Sac fungi

(3) Ray fungi (4) More than one option is correct

The name of the class is based on sexual structure as the site of karyogamy and meiosis.in

(1) Phycomycetes and Actinomycetes (2) Deuteromycetes and Zygomycetes

(3) Ascomycetes and Basidiomycetes (4) Basidiomycetes and Actinomycetes

In *Agaricus,* clamp connections and dolipore septa are shown by the hyphae of

(1) Primary mycelium (2) Secondary mycelium

(3) Monokaryotic mycelium (4) Coenocytic mycelium

In the life cycle of wheat rust fungi, spermatization occurs on the

(1) Upper surface of leaf of primary host (2) Lower surface of leaf of alternate host

(3) Upper surface of leaf of secondary host (4) Lower surface of leaf of primary host

Bengal famine disease was caused by a pathogen which belongs to the class

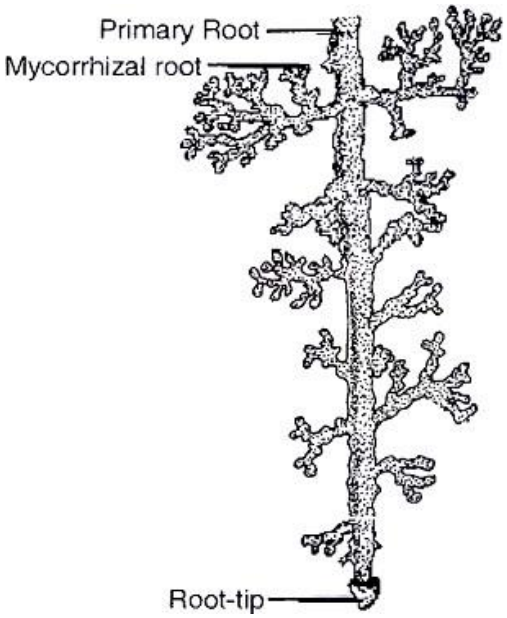
(1) Ascomycetes (2) Basidiomycetes (3) Deuteromycetes (4) Phycomycetes

Ans. Q.46 (2), Q.47 (4), Q.48 (2), Q.49 (3), Q.50 (2), Q.51 (1), Q.52 (3), Q.53 (2), Q.54 (3), Q.55 (3)

MYCORRHIZA (FUNGAL ROOTS)

- The mutually beneficial or symbiotic association of a fungus with the roots of higher plants is termed **mycorrhiza.** Mycorrhizal roots differ in shape from normal roots and often show a wooly covering. **These roots lack root cap and root hairs.**
- A fungus may get associated with roots of a number of plants and a particular plant may form association with a number of fungi. Depending upon the location of the fungus, the mycorrhiza is of two types, *i.e.*, **ectomycorrhiza** and **endomycorrhiza.**

- **In ectomycorrhiza,** the fungal hyphae are mainly external, forming a wooly covering on external surface of root and forms network of mycelium **(Hartig net)** in the intercellular spaces of the cortex. Fungal partner is commonly basidiomycetes, *e.g., Pinus* roots
- **In endomycorrhiza,** the fungal hyphae enter the tissue of the root, spreading intercellularlly and intracellularly.
- The fungus is able to break the cell wall in a limited way and is restricted to cortical region of the root. Some hyphae send small projections into cortical cells without destroying them.
- Such fungi are termed **VAM (Vesicular Arbuscular Mycorrhiza),** *e.g.,* Orchid roots.



Ectomycorrhiza on *Pinus* roots

- Mycorrhizal association is a **symbiotic relationship** as both the partners are mutually beneficial to each other. The fungal partner obtains nourishment from the cortical cells of the root and depends upon the plant for shelter.
- The root cells excrete sugars and other soluble gradients which are used by fungal hyphae spreading in intercellular spaces. The hyphae may get nourishment from the cells directly and also by sending small projections into cortical cells.
- The fungus seems to be essential for the growth of the plant having mycorrhiza.
- The plant also gets benefit from the association as the fungal hyphae spreading in soil substantially increases the surface area of absorption, thereby **enabling the plant to get enhanced supply of water, nitrogen, phosphorus and other minerals** from the soil.
- Orchids seldom occur without mycorrhiza. Certain forest trees like pines, birches show stunted growth if their roots are not associated with fungus.

LICHENS

- Lichens are **dual (composite) organisms** or entities which contain a permanent association of a fungal partner or **mycobiont** and an algal partner or **phycobiont.**

- **Mycobiont** is dominant partner and mostly belongs to ascomycetes (Ascolichens -, *e.g., Graphis, CIadonia, Parmelia, Usnea, etc.)* or sometimes basidiomycetes (Basidiolichens - *e.g., Corella, Cora, etc.).*
- **Phycobiont** is mostly a member of Chlorophyceae *(e.g., Chlorella, Trebouxia, Protococcus, Palmella,* etc.) or can be a BGA *(e.g., Nostoc, Chlorococcus, Scytonema,* etc.).
- The term lichen was coined by **Theophrastus** (370 -285 B.C.), also **called Father of Botany.**
- Lichens often grow in most inhospitable and uninhabited places like barren rocks (saxicolous), soil (terricolous), icy tundra or alpines, sand dunes, roofs, walls, wood (Iignicolous), tree bark (corticolous), *leaves,* etc.
- They commonly live under humid and exposed conditions but can tolerate extreme desiccation. However, **lichens, cannot tolerate air pollution, especially due to sulphur dioxide** (so are considered indicators of SO_2 pollution).
- Lichens are perennial. Their growth is slow. Lichens *have* greyish, yellowish, greenish, orange, dark brown or blackish colouration.

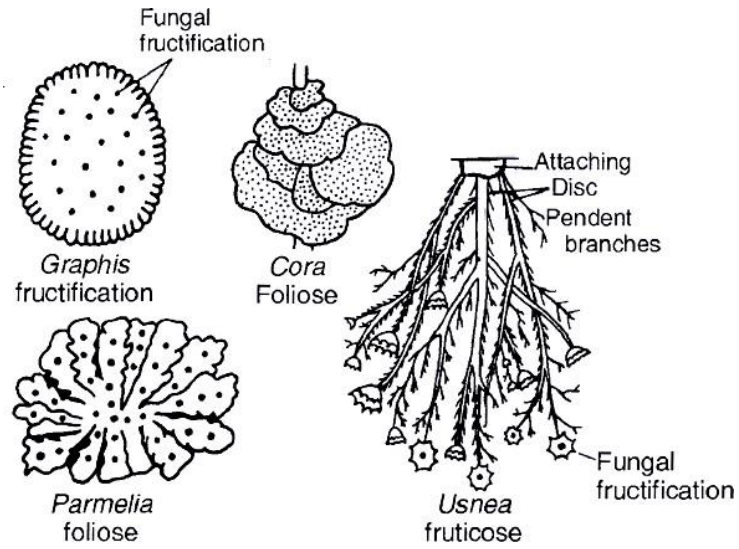
Structure :

- Based upon external morphology, the lichens are of three types :

(i) **Crustose.** Crust like, closely appressed to the substratum and attached to it at several places, *e.g., Graphis, Lecanora, Rhizocarpon.*

(ii) **Foliose:** The body of the lichen is flat, broad, lobed and leaf-like, which is attached to the substratum at one or a few places with the help of rhizoid like structures called **rhizines,** *e.g., Parmelia, Peltigera.*

(iii) **Fruticose** : The lichen is branched like a bush and attached to the substratum by means of a disc, *e.g., CIadonia, Usnea, Evernia, Bryonia.*

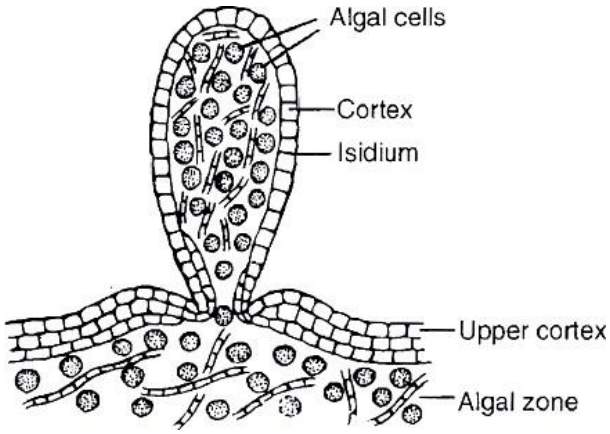


Forms of Lichens

- The bulk of lichen body is formed by fungal partner called **mycobiont.** It includes the surface, medulla (or interior) and rhizines (attaching devices).
- The algal partner or **phycobiont** constitutes hardly 5% of the lichens body.
- It is generally restricted to a narrow zone (algal zone) below the surface.

Relationship :

- The fungus performs following functions:
  (i) Body structure and covering (ii) Anchoring (iii) Absorption of water and minerals. It can absorb water from wet air (atmosphere), dew and rain. Minerals are picked up both from substratum and atmosphere. Special chemicals are excreted by the fungal partner of the lichen to dissolve minerals from the substratum. (iv) Sex organs and fruitifications are of fungal origin.
- **The major function of alga is photosynthesis.**
- The cyanobacterial alga additionally takes part in nitrogen fixation. The alga picks up water and mineral salts from the fungus while the fungus obtains part of the food manufactured by the alga.
- Therefore, in a lichen the association between alga and fungus is that of mutual benefit (mutualism) popularly called **symbiosis.**
- However, at times the fungus is found to (i) send haustoria into algal cells (ii) induce alga to secrete organic substances and (iii) prevent alga to develop pectic covering. Therefore, some workers believe that the fungus is a **controlled parasite** over the alga. The phenomenon is **called helotism.**



V.S. of lichen showing an isidium and algal zone

- **Reproduction:** Lichens multiply by four methods:

(i) **Progressive death and decay** resulting in the separation of a lichen thallus into two or more parts.

(ii) **Fragmentation** caused by mechanical injury, due to wind or animal bites.

(iii) **Isidia** are superficial outgrowths of the lichens which are primarily meant for increasing surface area and photosynthetic activity. At time, they are broken off. Each isidium is capable of forming a new lichen because it has a core of a few algal cells surrounded by a sheath of fungal hyphae.

(iv) **Soredia.** These are **most efficient means of asexual reproduction.** They are microscopic lichen propagules which are produced in large numbers inside sori called pustules. Soredia are dispersed by air currents. After falling on a suitable substratum each soredium gives rise to a lichen, because it has a few algal cells surrounded incompletely by a weft of fungus.

Concept Builder

- **Special structures in the thallus of lichen:**

(i) **Cyphellae** help in exchange of gases, present in lower cortex.

(ii) **Cephalodia** help to retain moisture and its algal partner fix nitrogen also.

(iii) Breathing pores for aeration, present in upper cortex of thallus.

- **Early Colonisers :** Lichens are early or **pioneer colonisers** of barren rocks, cliffs, mountains and new terrains. During their growth, lichens stick to the rocks and cliffs by secreting acids. It produces minute crevices where organic matter accumulates. It paves the way for growth of mosses.
- **Food:** In tundra, Cladonia rangifera **(Reindeer Moss)** constitutes the staple food of reindeer, caribou, musk ox, etc. Cetraria islandica **(Iceland Moss)** is used as a food article in Iceland, Sweden and Norway Lecanora esculenta is regarded as **bread of heaven** by Jews. Parmelia **(Rock Flower)** is also a table delicacy Dermatocarpon miniatum **(Stone Mushroom)** is a vegetable in Japan.
- **Dyes :** Orchil is obtained from Rocella tinctoria. The latter was also the source of litmus (R.montagnei) before the advent of synthetic products. Litmus is a pH indicator.
- **Perfumes:** Scented incense is got from species of Ramalina and Evernia.
- **Medicines:** Usnic acid got from Usnea **(Old Man's Beard)** and Cladonia has antibiotic properties. It is used in preparation of ointment for burns and wounds.
- **Air Pollution :** Decrease in lichen population of an area is indicative of SO_2 pollution.
- **Fires:** In hot season, Usnea may produce forest fires.

Conceptual Questions

Fill in the blanks:

(a) In ectomycorrhiza, fungal partner commonly belongs to_____.

(b) _____are mutually useful associations between algae and_____.

(c) _____are superficial outgrowths of the lichens which are primarily meant for increasing surface area and photosynthetic activity.

(d) In tundra,_____constitutes the staple food of reindeer, caribou etc.

(e) _____are most efficient means of asexual reproduction in lichens.

Ans. (a) Basidiomycetes, (b) Uchens, fungi, (c) Isidia.
(d) Cfaoonia rangifera (Reindeer moss), (e) Soredia

VIRUS

Term virus was coined **by Pasteur.**

Viruses are **obligate intracellular parasites.** They are intermediate between living and non living entities.

Non living nature of virus

- Lacking protoplast.
- Ability to get crystallized, *e.g.*, TMV, poliomyelitis virus.

- Inability to live independent of a living cell. (Lack functional autonomy)
- High specific gravity which is found only in non living objects
- Absence of respiration.
- Absence of energy storing system.
- Absence of growth and division.

Living nature of virus

- Being formed of organic macromolecules.
- Presence of genetic material.
- Ability to multiply.
- Occurrence of mutations.
- Occurrence of certain enzymes like, neuraminidase (first discovered), transcriptase and lysozyme in certain viruses.
- Infectivity and host specificity.
- Viruses can be 'killed' by autoclaving and ultraviolet rays.
- They take over biosynthetic machinery of the host cell and produce chemicals required for their multiplication.
- Viruses are responsible for a number of infectious disease like common cold, epidemic influenza, chicken pox, mumps, poliomyelitis, rabies, herpes, AIDS, SARS etc.

Concept Builder

- **Mayer** described Tobacco Mosaic disease in 1886.
- **Iwanowsky** is credited with the discovery of virus in 1892. **TMV** was the first virus to be discovered.
- **Beijerinck** called **virus** as "Contagium vivum fluidum " (living infectious fluid).
- In 1935, **Stanley** crystallised TMV.
- **Twort and d'Herelle** discovered bacteriophage.
- **Lwoff and Wollmann** discovered temperate viruses.
- **Shafferman and Morris** discovered cyanophage, *e.g.*, LPP-1.
- **Bawden and Pirie** studied the chemical nature (nucleoproteins) of TMV.
- **Sinsheimer** discovered single stranded DNA in bacteriophage $\phi \times 174$
- **Issac and Lindemann** discovered interferon
- **Delbruck** (1938), found viruses to undergo mutations.
- Reverse transcription in Retroviruses was discovered by **Temin and Baltimore,** so the phenomenon is called **teminism.** The enzyme **reverse transcriptase** is RNA dependent DNA polymerase.

Structural Components of Viruses

(i) **Envelope** is the outer thin loose covering composed of proteins (from virus), lipids and carbohydrates (both from host). It has smaller subunits known as **peplomers,** *e.g.*, Herpes

virus, HIV, Vaccinia virus etc. If it is not present the virus is said to be naked.

(ii) **Capsid :** It is the outer protein coat made up of subunits called **capsomeres,** their number is virus specific. These possess antigenic properties.

(iii) **Nucleoid :** Viruses contain either DNA or RNA. No virus contains both DNA and RNA.

(a) DNA containing viruses are called deoxyviruses.

These are of two types:

(i) Double stranded DNA (dsDNA) virus, *e.g.*, Pox virus, Cauliflower mosaic virus.

(ii) Single stranded DNA (ssDNA) virus, *e.g.*, Coliphage $\phi \times 174$, M 13 phage.

(b) RNA containing viruses or riboviruses are of two types.

(i) Double stranded RNA (ds RNA) virus, *e.g.*, Reo virus, Wound Tumour Virus.

(ii) Single stranded RNA (ss RNA) virus, *e.g.*, TMV, Influenza virus, Foot and Mouth disease virus, Retroviruses (HIV).

Classification of Virus

Holmes (1948) has divided viruses into three groups on the basis of specific hosts.

(a) **Phytophagineae** are plant viruses. They generally have ssRNA, *e.g.*, TMV, Potato Mosaic Virus, Yellow Vein Mosaic virus, Cauliflower Mosaic virus.

(b) **Zoophagineae** are animal viruses. They commonly have ssRNA or dsRNA or dsDNA. *e.g.*, Poliomyelitis virus, Influenza viruses, Small pox virus, Mumps virus, Rabies virus.

(c) **Phagineae** attack lower organisms

(i) **Bacteriophages** are bacterial viruses and they usually possess dsDNA, *e.g.*, T_2, T_4, lambda (λ) phage.

(ii) **Coliphages** are viruses of *E.coli*, *e.g.*, Coliphage fd.

(iii) **Cyanophages** attack blue green algae, *e.g.*, LPP-1, SM-1 .

(iv) **Phycophages** attack algae.

(v) **Mycophages** attack fungi.

(vi) **Zymophages** attack yeast.

Reproduction

It is of two main types: **Phagic** and **Pinocytic**

(a) **Phagic Reproduction** : It is further of two types :

(i) **Lytic cycle :** Occurs in virulent phages, *e.g.*, T_4 bacteriophages.

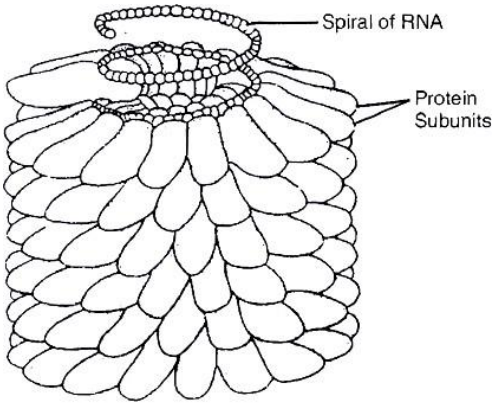
(ii) **Lysogenic cycle :** Occurs in temperate viruses such as λ phage.

(b) **Pinocytic Reproduction:** It is found in viruses like TMV, HIV, Hepatitis B etc., in which whole of virus particle enters host cell except envelope (if present).

Structural details of some viruses

(1) **Tobacco Mosaic Virus (TMV)** is elongated rod like, 3000 Å long, 180 Å in diameter with molecular weight Protein 39.4×10^6 dalton. 2130 capsomeres are arranged helically to form the capsid. RNA strand is helical. ssRNA consists of 6400 nucleotides. Thus, the ratio of

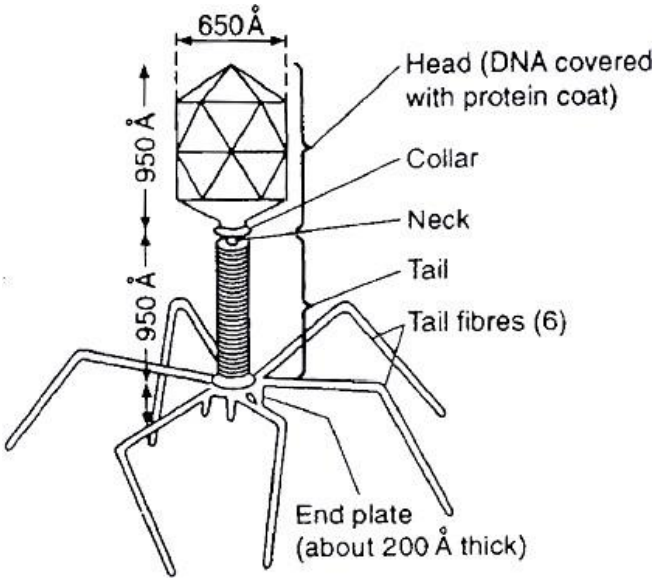
nucleotides : capsomeres = 3 : 1



Tobacco Mosaic Virus

(2) **Pox virus / variola** is the causal agent of small pox. These are among the largest of animal viruses, are rectangular (brick shaped), 300 × 230 nm in size. Genome is dumbell shaped with central core of dsDNA. The core has two enzymes RNA polymerase and ATP phosphohydrolase.

(3) **AIDS virus** consists of single stranded RNA. It has 2 copies of ssRNA. Outer cover has 5 layers, *i.e.*, outer most glycoprotein, followed by double lipid layer and the innermost has two protein layers.



Structure of T_4 bacteriophage

(4) **T_4 Bacteriophage** has a tadpole like structure with polyhedral head connected to a helical tail (binal). The head consists of nucleic acid surrounded by a protein coat or capsid. Nucleic acid is double stranded DNA. Tail is proteinaceous tube-like, core surrounded by sheath. At one end, tube is joined to the head by thin collar. At the other end, it has a hexagonal base plate with six small tail pins and six tail fibres which help in attachment of the phage to the host cell.

- **Sub Viral Agents:** These are viruses which lack one of the essential component, *e.g.*, viroids, virusoids, prions

(1) **Viroids** (L. *virus* -poison, *eidos* -diminutive)

- They are the smallest self replicating particles which were discovered by **Diener** (1971). Viroids are infectious RNA particles which are devoid of protein coat.

- They are obligate parasites. Molecular weight of a viroid is low.
- The RNA is tightly folded to form circular or linear structures. Viroids are known to cause diseases (some 20) in plants only, *e.g.*, Potato spindle tuber disease (PSTD), *Chrysanthemum* stunt and *Citrus* exocortis.

(2) Virusoids

- Discovered by **Randle** *et. al.*, these are RNA viruses but inside the capsid of other larger virus. They replicate within the host and do not cause any infection.

(3) Prions

Discovered by **Alper *et al.***

Proteinaceous infectious particles, causing certain diseases like

(i) Kuru disease (laughing death disease in humans)

(ii) Bovine spongiform encephalopathy (BSE or Mad cow disease)

(iii) Scrapie disease in sheep

(iv) Creutz Feldt Jakob disease

Table 5 : Viral diseases of Plants

Disease	Causal agent
Tobacco mosaic	Tobacco Mosaicvirus
Cucumber mosaic	Cucumber mosaic virus
Bunchy top of Banana	Banana bunchy top virus
Sugarcane mosaic	Sugarcane (or Saccharum) Virus I

Table 6 : Viral diseases of Man

Name of the disease	Causal Virus
Common cold	Rhinoviruses
Influenza	Influenza virus
German measles (Rubella)	Rubella virus
Measles	Measles virus
POliomyelitis	Polio virus
Small pox	Variola virus
Yeilowfever	Arbovirus

- **Animal viral diseases** -Foot and mouth disease, Rinderpest, Ranikhet, Bird flu etc.

Concept Builder

Nomenclature of viruses :

International committee of virus nomenclature has given a system of naming the virus. The system consists of two parts. First part is common name of the virus and second part has the coded information about the virus. This is called as **Cryptogram**.

In a cryptogram

(1) First pair Represents type of nucleic acid / no. of strands in nucleic acid.

(2) Second pair Represents molecular weight of nucleic acid / amount of nucleic acid expressed as percentage.

(3) Third pair Denotes shape of virus / shape of nucleoprotein.

(4) Fourth pair Denotes type of host / carrier used in the transmission of virus.

(a) Cryptogram of TMV **(Tobacco Mosaic Virus)**

R/1 : 2/5 : E/E : S/A

- It can be explained as –

(1) **First pair** Nucleic acid RNA (R) is single stranded (1)

(2) **Second pair** -Mol. wt. of nucleic acid is two (2) hundred thousands / amount of nucleic acid (5%)

(3) **Third pair** Shape of virus -elongated (E) / shape of nucleoprotein -elongated (E)

(4) **Fourth pair** Host is seed plants or spermatophytes (S) / carrier of transmission air (A) orsap(S)

(b) Cryptogram of Polio virus

R/1, 2.5 / 30, S/S, V/O [O means no vector is needed]

(c) Cryptogram of T_4 bacteriophage

D/2, 130 / 40, X/X, B/O [X means complex shape and B for bacteria]

Conceptual Questions

What type of nucleic acid is present in most of the plant viruses?

Fill in the blanks

(a) Reproduction in temperate viruses occurs by _____ cycle.

(b) Number of capsomeres and nucleotides in TMV is respectively_____and _____

(c) Nucleic acid in Reo virus is _____

(d) Shape of virus is represented in_____pair of cryptogram.

(e) The chemical nature of infectious particle causing Kuru disease is _____

Bunchy top of Banana is a viral disease (true/false).

Ans. **Q.1.** ssRNA; **Q.2.** (a) Lysogenic, (b) 2130 and 6400, (c) dsRNA, (d) Third, (e) Proteinaceous ; **Q.3.** True

Self Assessment

Lichens growing on tree bark are called

(1) Lignicolous (2) Terricolous (3) Corticolous (4) Saxicolous

Common mycobionts and phycobionts of lichen body are respectively

(1) Ascomycetes, Chlorophyceae (2) Ascomycetes, Cyanophyceae

(3) Basidiomycetes, Chlorophyceae (4) Basidiomycetes, Cyanophyceae

Foliose lichens are attached to the substratum at one or few places with the help of

(1) Branched, multicellular rhizoids (2) Holdfast

(3) Rhizines (4) Rhizomorph

Specialised structure in the thallus of lichen for nitrogen fixation and retaining moisture is

(1) Cyphellae (2) Isidia (3) Cephalodia (4) Soredia

Select correct statement w.r.t. mycorrhizal roots

(1) They do not differ in shape from normal roots

(2) Often show a wooly covering

(3) Possess root cap but lack root hairs

(4) Fungal partner is commonly a member of Ascomycetes

Which of the following feature is not related with virus?

(1) Infectivity and host specificity (2) Presence of genetic material

(3) Occurrence of certain enzymes (4) Presence of respiration

Most of the viruses are/have

(1) Enveloped nucleo-protein structure (2) Non-enveloped nucleo-protein structure

(3) Infectious protein particles (4) Double stranded DNA as well as dsRNA

Infectious RNA particles without protein coat

(1) Have high molecular weight (2) Were discovered by Alper

(3) Known to cause disease in plants only (4) More than one option is correct

Select incorrect statement w.r.t. T_4 bacteriophages

(1) Have polygonal prismatic head (2) Contractile tail without tail-sheath

(3) Six tail fibres (4) ds-DNA as the genetic material

TMV is

(1) ds Ribovirus (2) ds Deoxyvirus

(3) ss Ribovirus (4) Ribovirus with 6400 capsomeres

Ans. Q.56 (3), Q.57 (1), Q.58 (3), Q.59 (3), Q.60 (2), Q.61 (4), Q.62 (2), Q.63 (3), Q.64 (2), Q.65 (3)

SUMMARY

1. Biological classification of plants and animals was first proposed by Aristotle on the basis of simple morphological characters.
2. Linnaeus later classified all living organisms into two kingdoms -Plantae and Animalia.
3. Whittaker proposed an elaborate five kingdom classificatlon -Monera, Protista, Fungi, Plantae and Animalia. The main criteria of the five kingdom classification were cell structure, body organisation, mode of nutrition, reproduction and phylogenetic relationship out of which mode of nutrition was most important.
4. In the five kingdom classification, bacteria are included in Kingdom Monera.
5. Bacteria are cosmopolitan in distribution.
6. These organisms show the most extensive metabolic diversity, although they have a simple structure.
7. Bacteria may be autotrophic or heterotrophic in their mode of nutrition.
8. Kingdom Protista includes all single-celled eukaryotes such as Chrysophytes, Dinoflagellates, Euglenoids, Slime moulds and Protozoans.
9. Protists have defined nucleus and other membrane bound organelles. They reproduce both asexually and sexually.
10. Members of Kingdom Fungi show a great diversity in structures and habitat.
11. Most fungi are saprophytic in their mode of nutrition.
12. They show asexual and sexual reproduction.
13. Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes are the four classes under this kingdom.
14. The plantae includes all eukaryotic chlorophyll-containing organisms. Algae, bryophytes, pteridophytes, gymnosperms and angiosperms are included in this group.
15. The life cycle of plants exhibit alternation of generations-gametophytic and sporophytic generations.
16. The heterotrophic eukaryotic, multicellular organisms lacking a cell wall are included in the Kingdom Animalia. The mode of nutrition of these organisms is holozoic.
17. They reproduce mostly by the sexual mode.
18. Some acellular organisms like viruses and viroids as well as the lichens are not included in the five kingdom system of classification.

EXERCISE – 1

SECTION – A

Two kingdom system classification was given by

(1) Linnaeus (2) John Ray (3) Copeland (4) Whittaker

Which kingdom was introduced in 4 kingdom classification and who proposed it?

(1) Protista and Copeland (2) Plantae and linnaeus

(3) Monera and Whittaker (4) Monera and Copeland

Which of the following is the major group in Monera?

(1) Eubacteria (2) Cyanobacteria (3) Archaebacteria (4) All of these

Term bacteria was given by

(1) Koch (2) Pasteur (3) Ehrenberg (4) Stanley

70S ribosomes, chromatophores, circular DNA, mesosomes are found in

(1) All eukaryotes (2) All prokaryotes

(3) Some prokaryotes (4) Some eukaryotes and some prokaryotes

A bacterium that bears flagella all over the surface is called

(1) Lophotrichous (2) Cephalotrichous (3) Peritrichous (4) Amphitrichous

A distinct lipo-polysaccharide layer is found in

(1) Gram (+) bacteria (2) Gram (-) bacteria (3) All bacteria (4) Mycoplasma

In bacteria, the respiratory enzymes are situated in the

(1) Cytoplasm (2) Cell membrane (3) Ribosomes (4) Mitochondria

Cell wall in Gram positive bacteria is composed of

(1) Lipid and protein (2) Murein (3) Proteins only (4) Cellulose and pectin

One of the following is a filamentous bacteria

(1) Pseudomonas (2) Clostridium (3) Actinomyces (4) Azotobacter

Pili represent

(1) Extra chromosomal genetic elements (2) Protoplasmic outgrowths of donor cells

(3) Small flagella (4) Special bacterial cilia

Plasmids represent

(1) A group of monerans (2) Small parasitic organisms

(3) Genetic elements (4) Extra chromosomal genetic elements

The resting spores produced by bacteria in unfavourable conditions are called

(1) Oidia (2) Endospores (3) Exospores (4) Chlamydospores

Conjugation in bacteria was discovered by

(1) Beadle and Tatum (2) Zinder and Lederberg

(3) Griffith (4) Lederberg and Tatum

Genophore is the name of

(1) DNA of eukaryoles (2) DNA of bacteria

(3) Genes of Drosophila

(4) Genes of Neurospora

There is no alternation of generation in Escherichia coli because of the absence of

(1) Syngamy (2) Reduction diviSion

(3) Conjugation (4) Both (1) & (2)

The following bacterium is associated with denitrification

(1) Azotobacter (2) Rhodospirillum (3) Pseudomonas (4) Rhizobium

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

(1) Obligate anaerobes (2) Facultative anaerobes

(3) Obligate aerobes (4) Facultative aerobes

Streptomycin is produced by

(1) Streptomyces venezuelae (2) *Streptomyces griseus*

(3) *Streptomyces arythreus* (4) *Streptomyces aureofaciens*

Food poisoning is caused by

(1) Clostridium tetani (2) *Clostnaium botulinum*

(3) *Salmonella typhi* (4) *Mycobacterium tuberculosis*

Rhizobium is

(1) Symbiotic and Gram negative bacterium (2) Symbiotic and Gram positive bacterium

(3) Free living nitrogen fixing bacterium (4) Parasitic and nitrogen fixing bacteria

Syphilis is caused by

(1) Neisseria gonorrhoeae (2) *Treponema pallidum*

(3) *Hemophilous pertusis* (4) *Pasteurella pestis*

Jacob and Wollman coined the term

(1) Plasmid (2) Episome (3) Circular DNA (4) Chromosome

Branched chain lipids occur in the cell membranes of

(1) Archaebacteria (2) Mycoplasma (3) Actinomycetes (4) Streptomyces

Monerans producing conidia for reproduction belong to

(1) Eubacteria (2) Archaebacteria (3) Actinomycetes (4) Mycoplasma

Smallest known moneran lacking cell wall are

(1) Spirochaete (2) Mycoplasma (3) Cyanobacteria (4) Archaebacteria

Cyanobacteria do not possess

(1) Gene recombinations (2) Flagella

(3) Plasmids (4) Lamellasomes

Heterocyst present in Nostoc is specialised for

(1) Fragmentation (2) Nitrogen fixation (3) Storage (4) Photosynthesis

'Contagium vivum fluidium (*i.e.*, living fluid infectant) term has been given by

(1) Mayer (2) lvanowsky (3) Beijerinck (4) Bawden and Pirie

Anaerobic monerans which are endosymbiotically associated with cattles rumen are

(1) Bacillus (2) Methanobacterium

(3) Halococcus (4) Thermoacidophiles

Gange's water purity is maintained by

(1) Bdellovibrio (2) Clostridium (3) Ferrobaciflus (4) Tolypothrix

Bivalved siliceous shell or frustule occur in

(1) Diatoms (3) Zooflagellates (2) Radiolarians (4) Archaebacteria

Diatomaceous earth is due to

(1) Silicon (2) Zinc (3) Phosphorus (4) Calcium

Reserve food in Euglena is

(1) Paramylum (2) Starch (3) Glycogen (4) Mannitol

Special type of red pigment present in the eye-spot of Euglena and Crustacea is called

(1) Phycoerythrin (2) Astaxanthin (3) carotene (4) Xanthphyll

Mixotrophic nutrition occurs in

(1) Paramecium (2) Euglena (3) Plasmodium (4) Amoeba

The structure formed in the life cycle of cellular slime-mould due to chemotactic movement is

(1) Pseudoplasmodium (2) Swarm cells

(3) Macrocyst (4) Capillitia

Myxamoeba are formed in the life cycle of

(1) Physarum (3) Entamoeba (2) Amoeba (4) Diatoms

De Bary considered slime moulds to be closely related to animals and called them

(1) Protozoa (3) Mycetozoa (2) Metazoa (4) Mycotina

De Bary was a leading

(1) Phycologist (3) Bryologist (2) Mycologist (4) Pteridologist

Asexual spores of fungi (thallophytes) are commonly known as

(1) Oospores (2) Mitospores (3) Meiospores (4) Zygospores

Oidia resemble yeasts in

(1) Fermentation (2) Budding (3) Unicellular nalure (4) All of these

Which one of the following shows haplodiplontic life cycle with four ascospores in the ascus?

(1) Budding yeast (2) Fission yeast (3) Helobial yeast (4) False yeast

Gametangial copulation (conjugation) is common in

(1) Ascomycetes (2) Zygomycetes (3) Basidiomycetes (4) Deuleromyceles

Molile sperms (or motile sperm cells) are absent in

(1) Rhizopus (2) Funarla (3) Fem (4) Cycas

If the thallus of an organism like a fungus is entirely converted into one or more reproductive structures it is called as

(1) Eucarpic (2) Holocarpic (3) Holozoic (4) Hornothallic

Subterranean masses of hyphae which pass the unfavourable periods in donnant stage are known as

(1) Sclerotia (2) Mycelium (3) Rhizomorph (4) Puff balls

Asexual reproduction by aplanospore formation is the feature of

(1) Sac fungi (2) Fungi impertect (3) Conjugating fungi (4) Club fungi

Haploid sexual spore produced exogenously is

(1) Ascospore (2) Oospcre (3) Basidiospore (4) Zygospore

White rust of crucifers is caused by

(1) Albugo candida (2) *Sclerospora*

(3) *Phytophthora infestans* (4) *Pythium debaryanum*

Coenocytic mycelium occurs in

(1) Zygomycetes (2) Phycomycetes (3) Both (1) & (2) (4) Deuteromycetes

Ascomycetes are known as

(1) Club fungi (2) Sac fungi (3) Fungi imperfecti (4) Fission fungi

One of the following is helobial yeast

(1) Saccharomyces (2) *Schizosaccharomyces*

(3) *Saccharomycokies* (4) *Schizomycetes*

One of the following is a true yeast

(1) Canedida (2) Myoodenna (3) Cryptococcus (4) Saccharomyces

Fungi differs from bacteria in

(1) Mode of nutrition (2) Having NAG in cell wall

(3) Flagella structure (4) Reserve food material as glycogen

Penicillin is obtained from

(1) Penicillium griseofulvum (2) *Penicillium chrysogenum*

(3) *Penicillium camemberti* (4) *Penicillium roqueforti*

Branched conidiophores are found in

(1) Penicillium (2) Rhizopus (3) Uslifago (4) Saccharomyces

Fruiting body in Aspergillus (or Penicillium) is known as

(1) Cleistothecium (2) Apothecium (3) Perithecium (4) Hysterothecium

A mushroom having hallucinating properties similar to LS.D. is

(1) Morchella (2) Psaliota (3) Psilocybe (4) Armillaria

Powdery mildew of cereals is due to

(1) Puccinia graminis (2) *Claviceps purpurea*

(3) *Ustilago tritici* (4) *Erysiphe graminicola*

Ergot is a product of

(1) Rhizopus (2) *Claviceps purpurea*

(3) *Aspergillus* (4) *Sclerospora*

The famous Irish famine is related to a disease of potato known as

(1) Late blight of potato (2) Early blight of potato

(3) Dry rot of potato (4) Potato scab

A fungus, which grows on rotting wood, is

(1) Rhizopus (2) Pythium (3) Peziza (4) Aspergilfus

A dolipore septum is a characteristic feature of

(1) Phycomycetes (2) Ascomycetes (3) Basidiomycetes (4) Zygomycetes

Fertile layer of gills is known as

(1) Hymenium (2) Trama (3) Paraphyses (4) Basidia

An edible part at mushroom is

(1) Primary mycelium (2) Secondary mycelium

(3) Rhizomorph (4) Basidiocarp

Pioneer work on wheat rust was done by

(1) Mundkur (2) Tutsane (3) KG. Mehta (4) Subramaniam

The soredium is a reproductive structure of

(1) Ascomycetes (2) Zygomycetes (3) Basidiomycetes (4) Lichens

Symptom not seen in plants due to viruses is

(1) Mosaic formation (2) Leaf rolling and curling

(3) Yellowing, vein clearing (4) Root knot

Viroids were discovered by

(1) Alper (2) Randle (3) Diener (4) lvanowsky

Section – B

Five kingdom system of classification is mainly based on

(1) Complexity of cell structure (2) Mode of nutrition

(3) Complexity of body organisation (4) Ecological role

Bacteria are considered primitive organisms becauselhey

(1) Possess incipient nucleus

(2) Are small, microscopic plants, which are not seen by the naked eyes

(3) Cause serious diseases to human being, domesticated animals and crop plants

(4) Produce endospores which are very resistant to adverse conditions

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

(1) Exogenote (2) Endogenote (3) Dysgenic (4) Eugenic

Broad spectrum antibiotic is that which

(1) Acts on both pathogens and hosts

(2) Acts on all bacteria and viruses

(3) Acts on a variety of pathogenic microorganisms

(4) Is effective in very small amounts

A cyanelie is

(1) A BGA associated with human intestine (2) A BGA associated with protists

(3) A free living 8GA (4) Any symbiotic 6GA

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?

(1) 30 minutes (2) 45 minutes (3) 60 minutes (4) 17 minutes

Highly resistance nature of endospore is due to the presence of

(1) Dipicolinic acid and peptidoglycan in spore coat

(2) Peptidoglycan in exosporium

(3) Dipicolinic acid and Ca in cortex

(4) Dipicolinic acid and Ca in cell membrane

Find the correct match

	Column I	**Column II**
a.	Streptomycin	(i) *Streptomyces griseus*
b.	Terramycin	(ii) *S. venezuelae*
c.	Chloramphenicol	(iii) *S. rimosus*
d.	Bacitracin	(IV) *Bacillus licheniformis*

(1) a(i), b(iii), c(ii), d(iv) (2) a(ii), b(i), c(iii), d(iv)

(3) a(iii), b(ii), c(i), d(iv) (4) a(i), b(ii), c(iii), d(iv)

The photosynthetic protists are

(1) Diatoms, euglenoids and slime moulds (2) Sacrodines, dinoflagellates and diatoms

(3) Euglenoids, diatoms and dinoflagellates (4) Ciliates, zooflagellates and dinoflagellates

Sea water glows during night mainly due to occurrence of

(1) Gonyaulax (3) Euglena (2) Noctiluca (4) Cyetoletta

Rejuvenescent spore of diatom is

(1) Haploid and exospore (2) Diploid and statospore

(3) Haploid and statospore (4) Diploid and auxospore

Leucosin (Chrysolaminarin) is a carbohydrate which is stored as reserve food in case of

(1) Diatom (2) Euglena (3) Dinoflagellates (4) Paramecium

Flagellation in Euglena is

(1) Uniflagellation and stichonematic (2) Isakon! and whiplash type

(3) Heterokont and whiplash type (4) Heterokont and stichonematic

Paraflagellar body of Euglena helps in

(1) Locomotion (2) Photoreception (3) Reproduction (4) Osmoregulation

Difference between a red sea and red tide is

(1) Red tide takes place in red sea

(2) Associated with a cyanobacteria and protist respectively

(3) One is by virus and other by bacteria

(4) Associated with Rhodophyceae and diatoms respectively

Find the correct match

	Column I	**Column II**
a.	Gill fungi	(i) Salmon disease
b.	Cup fungi	(ii) Trama
c.	Black mould	(iii) Penicillin
d.	Blue I green mould	(iv) Zygophore
		(v) Apothecium

(1) a(ii), b(iii), e(i), d(v) (2) a(ii), b(v), e(iv), d(i)

(3) a(ii), b(v), e(iv), d(iii) (4) a(ii), b(iii), e(i), d(iv)

Select incorrectly matched pair

(1) Mucor mucedo – Coprophilous (2) Albugo candida – Facultative parasite

(3) Agaricus bisporus – Edible basidiocarp (4) Puccinia graminis – Heteroecious fungi

When two host species are required for completion of a parasitic fungus life cycle, th is condition is described as

(1) Autoecious (2) Heteroecious (3) Autotrophic (4) Heterokaryotic

The most common chlorophycobionl in a lichen is

(1) ChIarella (2) Trebouxia (3) Gonium (4) Chlamydomonas

Viruses possess all the following properties, except

(1) They are non-cetlular organisms

(2) Possess both DNA and RNA

(3) Capsid protects nucleic acid

(4) Have inert crystalline structure outside living cells

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

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

(2) Protista : Unicellular, eukaryotic, photoautotrophs and chemoautolrophs

(3) Fungi : Multicellular/l oose tissue , eukaryotic, osmotrophs, chitinous wall

(4) Anirnalia : Multicellular, eukaryotic, organ or organ system, holozoic, no saprobic

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

a. LPS layer present b. Dlazotroph c. Peritrichous e. Obligate anaerobes

d. Sewage disposal f. Chemoautotrophs g. L-Lysine absent h. Aerobic

(1) Clostridium - a, c, d , e (2) Rhizobium - a, b, g

(3) Azotobacter - a, b, g, h (4) Methanogens - e, f, a, g

Endospores formed by certain bacteria are actually the means for

(1) Reproduction (2) Perennation (3) Bioluminescence (4) Red snow formation

Pyrrophytes ·are similar to Euglenophytes but differ from chrysophytes in

(1) Mode of nutrition

(2) Motility and nature of flagella

(3) Presence of primary photosynthetic pigments

(4) Occurrence and cell wall composition

Consider the following statements and select correct set of features W.r.t. the life cycle of Physarum

a. Haploid vegetative stage as myxamoebae

b. Diploid vegetative stage as plasmodium

c. Holocarplc and polycentric

d. Holocarpic and monocentric

e. Sporeic meiosis

f. Isogamous sexual reproduction

g. Anisogamous sexual reproduction with zygotic meiosis

(1) a, c, g (2) b, c, g (3) b, d, e, f (4) b, c, e, f

Mycelium with compact mass of hyphae as pseudo parenchymatous structure can be observed in the

(1) Fructification stage of slime moulds

(2) Gill of mushroom

(3) Asexual stage of bread mould

(4) Uredia stage of rust fungi

Which one of the following combination of characters is correct for the given fungal group?

(1) Algal fungi : Coenocylic, cellulosic wall, zoospore, zygospore, dikaryophase present

(2) Conjugating fungi : Septate mycelium, chitinous wall, sporangiospore, shorter (n + n) phase

(3) Sac fungi : Septate mycelium, Ascogonium, Crozier stage, meiospores as ascospores, shorter dikaryophase

(4) Club fungi : Shorter primary mycelium stage, No sex organs , dominant dikaryophase, zygosporic meiosis

Read the statements carefully

a. Hartig net is the network of intracellular mycelium of Boletus

b. Ectomycorrhiza forms ten percent of total mycorrhiza

c. Fungal partner of VAM belongs to zygomycetes or phycomycetes

(1) Only a & c are correct (2) Only b & c are correct

(3) Only c is correct (4) All are correct

Identify A, Band C given below

A B C

(1) A - DNA virus - Cauliflower mosaic virus
B - RNA virus - Pox virus
C - Relerovirus - HIV

(2) A - RNAvirus - T.M.V
B - DNA virus - T_4 bacteriophage
C - Retero virus - HIV

(3) A - RNA virus - Hepatitis B virus
B - Reterovirus - T.M.V
C - DNA virus - $\phi \times 174$

(4) A - Reterovirus - Hepatitis B virus
B - RNA virus - T_4 bacterophage
C - DNA virus - Pox virus

Read the following statements carefully and identify correct statements w.r.t. Lichens

a. The association cannot tolerate air pollution, especially due to sulphur dioxide

b. lichens are annuals and their growth is slow

c. The fungal partner shows controiled parasitism

d. $oredia are most efficient means of asexual reproduction

e. Orchids seldom occur without this association

f. Foliose lichens are pioneers of succession on bare rock

(1) c, d, F (2) a, c, d, f (3) a, b, e (4) a, c, d

ANSWER KEY

Section–A

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

Section – B

Q.1	2	Q.2	1	Q.3	2	Q.4	3	Q.5	2	Q.6	4	Q.7	3
Q.8	1	Q.9	3	Q.10	2	Q.11	4	Q.12	1	Q.13	4	Q.14	2
Q.15	2	Q.16	3	Q.17	2	Q.18	2	Q.19	2	Q.20	2	Q.21	3
Q.22	1	Q.23	2	Q.24	2	Q.25	4	Q.26	2	Q.27	3	Q.28	2
Q.29	2	Q.30	4										

The five kingdom classification was given by : **[HP PMT 2006]**

(1) Whittaker (1969) (2) Linnaeus (1758)

(3) Copeland (1966) (4) Haeckel (1866)

Which one of the following is common to multicellular fungi, filamentous algae and protonema of mosses? **[AIPMT Pre 2012]**

(1) Members of kingdom Plantae (2) Mode of Nutrition

(3) Multiplication by fragmentation (4) Diplontic life cycle

The two bacteria found to be very useful in genetic engineering experiments are : **[AIPMT 2006]**

(1) Nitrosomonas and Klebsiella (2) Escherichia and Agrobacterium

(3) Nitrobacter and Azotobacter (4) Rhizobium and Diplococcus

The bacterium (Clostridium botulinum) that causes botulism is : **[AIPMT 2006]**

(1) an obligate aerobe (2) a fecultative anaerobe

(3) an obligate anaerobe (4) a fecultative aerobe

Curing of ten leaves is brought about by the activity of : **[AIPMT 2006]**

(1) fungi (2) bacteria (3) micorrhizae (4) viruses

In prokaryotes, chromatophores are : **[AIIMS 2006]**

(1) specialized granules responsible for colouration of cells.

(2) structures responsible for organizing the shape of the organism.

(3) inclusion bodies lying free inside the cells for carrying out various metabolic activities.

(4) internal membrane systems that may beocme extensive and complex in phtosythesis bacteria.

Which one of the following statements about mycoplasma is wrong? **[AIPMT 2007]**

(1) They are pleomophic (2) They are sensitive to penicillin

(3) They cause diseases in plants (4) They are called PPLO

Thermococcus, Methanococcus and *Methanobacterium* exemplify : **[AIPMT 2008]**

(1) archaebacteria that contain protein homologous to eukaryotic core histones.

(2) archaebacteria that lack any histones resembling those found in eukaryotes but whose DNA is negatively supercoiled.

(3) bacteria whose DNA is relaxed or positively supercoiled but which have a cytoskeleton as well as mitochondria.

(4) bacteria that contain a cytoskeleton and ribosomes.

Bacterial leaf blight of rice is caused by a species of : **[AIPMT 2008]**

(1) Xanthomonas (2) *Pseudomonas* (3) *Alternaria* (4) *Erwinia*

Total parasites belongs to protozoan group **[CPMT 2001]**

(1) Sporozoa (2) Ciliata (3) Sarcodina (4) Zooflagellata

Beedle and Tatum gave 'one gene and one enzyme' hypothesis while working on **[AIPMT 2007]**

(1) Salmonelly typhimurium (2) *Neurospora crassa*

(3) *Eschericlia coli*

(4) *Diplococcus pneumoniae*

Which of the following pair belongs to basidiomycetes? **[AIPMT 2007]**

(1) Puffballs and Claviceps (2) Morchella and mushrooms

(3) Peziza and stink horns (4) Bird's nest fungi and puffballs

'Ergot of rye' is caused by **[AIPMT 2007]**

(1) Claviceps purpurea (2) Sclerospora graminicola

(3) Cannabis sativa (4) Algae and fungi

Cellulose is a major component of cell walls of **[AIPMT 2008]**

(1) Pythium (2) Xanthomonas (3) Pseudomonas (4) Saccharomyces

Trichoderma harziahum has proved a useful microorganism for **[AIPMT 2008]**

(1) bioremediation of contaminated soils

(2) reclamation of wastelands

(3) gene transfer in higher plants

(4) biological control of soil-borne plant pathogens

Which one is the wrong pairing for the disease and its causal organism? **[AIPMT 2009]**

(1) Loose smut of wheat – Ustilago nuda

(2) Root know of vegetables – Meloidogyne sp

(3) Late blight of potato – Alternaria solani

(4) Black rust of wheat – Puccinia graminis

Which one of the following has haplontic life cycle? **[AIPMT 2009]**

(1) Ustilago (2) Wheat (3) Funaria (4) Polytrichum

Yeast is used in the production of : **[AIPMT Pre 2012]**

(1) Lipase and pectinase (2) Bread and beer

(3) Cheese and butter (4) Citric acid and lactic acid

Which one of the following microbes forms symbiotic association with plants and helps them in their nutrition? **[AIPMT Pre 2012]**

(1) Aspergillus (2) Glomus (3) Trichodrma (4) Azoiobacter

Which statement is wrong for viruses ? **[AIPMT Pre 2012]**

(1) All of them have helical symmetry.

(2) They have ability to synthesize nucleic acids and proteins

(3) Antibiotic have no effect on them.

(4) All are parasites.

There exist a close association between the alga and fungus within a lichen. The fungus : **[AIPMT 2005]**

(1) fixes the atmospheric nitrogen for the alga

(2) provides protection, anchorage and absorption for the alga

(3) provides food for the alga

(4) release oxygen for the alga

Which of the following fungus can cause diseases in humans? **[CMC Ludhiana 2006]**

(1) Penicillium (2) Ustilago (3) Puccinia (4) Smut

Red rot of sugarcane and white rust of radish are respectively caused by **[Kerla PMT 2005]**

(1) Albugo candida and Cerospora (2) Colletotrichum and Fusarium

(3) Pythium and Phytopthora (4) Colletotrichum and Albugo candida

The fungi in which sexual reproduction is absent or is under abnormal conditions is **[Pb.PMT 2006]**

(1) phycomycetes (2) asomycetes (3) basidiomycetes (4) deuteromycetes

Edible part of mushroom is **[CPMT 2003]**

(1) basidiocarp (2) primary mucelium

(3) secondary mycelium (4) tertiary mycelium

VAM stands for **[PIMS–AICET 2006]**

(1) Vascular Arbuscular Mycorrihizae (2) Vesicle Arbuscular Mycorrihizae

(3) Veremicular Arbuscular Mycorrihizae (4) Vacuolar Arbuscular Mycorrihizae

Ascomycetes are **[GGSIPU 2006]**

(1) club fungi (2) algal fungi (3) pin moulds (4) sac fungi

Genus Aspergillus and Claviceps belongs to **[BVP Pune 2006]**

(1) phycomycetes (2) ascomycetes

(3) basidiomycetes (4) deuteromycetes

Among rust, smut and mushroom all the three **[AIIMS 2006]**

(1) all pathogens (2) are saprobes (3) bear ascocarbs (4) bear basidiocarps

In the following table identify the correct matching of the crop, its disease and the corresponding pathogen **[AIIMS 2006]**

Crop -	Disease	Pathogen
(1) Citrus	Canker	A. Pseudomonas rubrilineans
(2) Potato	Late Blight	B. Fusarium udum
(3) Root	know	C. Meoidogyn injection
(4) Pigeon pee	See gall	D. Phytophthora infestans

Cell wall of fungi consists of **[AMU 2007]**

(1) cellulose (2) hemicellulose (3) chitin (4) both a and c

Asperigillus niger is used for the manufacture of **[Manipal PMT 2007]**

(1) citric acid and gluconic acid (2) HCl and HNO_3

(3) fumaric and malic acid (4) succinic and fumaric acid

An organism with eukaryotic multicellular nature obtains its nutrition through its cell wall. It should be placed under **[Manipal PMT 2007]**

(1) Mycota (2) Plantae (3) Animalia (4) Monera

The toxins released by plants to save themselves from fungal attack are **[BHU 2007]**

(1) phytotoxins (2) phytoalexins (3) calmodulins (4) aquaporins

LSD is extracted from **[Manipal PMT 2007]**

(1) Claviceps (2) Cannabis (3) Agaricus (4) Amanita

The pathoens for leaf spot disease in Arachis hypogea is **[KCET 2007]**

(1) Fusarium (2) Cercosporia (3) Alternaria (4) Heminthosphorium

Which of these is follose lichen **[Pb. PMT 2008]**

(1) Cladonia (2) Graphs (3) Parmeia (4) Lecanora

The athlete's foot disease in humans is caused due to **[AMU 2009]**

(1) bacteria (2) fungi (3) virus (4) none of the above

Sexual reproduction in fungi may occur by means of **[AMU 2009]**

(1) sporangiospore, oospore and ascospore

(2) zoospore, oospore and ascospore

(3) sporangiospore, ascospore and basidiospore

(4) oospore, ascospore, basidiospore

Lichens growing on tree bark are called

(1) Lignicolour (2) Terricolous (3) Corticolous (4) Saxicolous

Common mycobionts and phycobionts of lichen body are respectively

(1) Ascomycetes, Chlorophyceae (2) Ascomycetes, Cyanophyceae

(3) Basidiomycetes, Chlorophyceae (4) Basidiomycetes, Cyanophyceae

Foliose lichhens are attached to the substratum at one or few places with the help of

(1) Branched, multicellular rhizoids (2) Holdfast

(3) Rhizines (4) Rhizomorph

Specialised structure in the thallus of lichen for nitrogen fixation and retaining moisture is

(1) Cyphellae (2) Isidia (3) Cephalodia (4) Soredia

Which of the following feature is not related with virus ?

(1) Infectivity and host specificity (2) Presence of genetic material

(3) Occurrence of certain enzymes (4) Presence of respiration

Most of the viruses are/ have

(1) Enveloped nucleo-protein structure

(2) Non-enveloped nucleo-protein structure

(3) Infectious protein particles

(4) Double stranded DNA as well as dsRNA

Infectious RNA particles without protein coat

(1) Have high molecular weight

(2) Were discovered by Alper

(3) Known to cause disease in plants only

(4) More than one option is correct

Pigment-containing membranous extensions in some cyanobacteria are : **[AIPMT 2013]**

(1) Basal bodies (2) Pneumatophores (3) Chromatophores (4) Heterocysts

Select the wrong statement: **[AIPMT 2013]**

(1) Anisogametes differ either in structure, function or behaviour

(2) In Oomycetes female gamete is smaller and motile, while male gamete is larger and non-motile

(3) Chlamydomonas exhibits both isogamy and anisogamy and Fucus shows oogamy

(4) Isogametes are similar in structure, function and behaviour

Read the following statements (A-E) and answer the question which follows them.

(A) In liverworts, mosses, and ferns gametophytes are free-living

(B) Gymnosperms and some ferns are heterosporous.

(C) Sexual reproduction in Fucus, Volvox and Albugo is oogamous

(D) The sporophyte in liverworts is more elaborate than that in mosses '

(E) Both, Pinus and Marchantia are dioecious

How many of the above statements are correct? **[AIPMT 2013]**

(1) Two (2) Three (3) Four (4) One

Which of the following are likely to be present in deep sea water? **[AIPMT 2013]**

(1) Eubacteria (2) Blue-green algae

(3) Saprophytic fungi (4) Archaebacteria

ANSWER KEY

Q.1	1	Q.2	3	Q.3	2	Q.4	3	Q.5	2	Q.6	4	Q.7	2
Q.8	1	Q.9		Q.10	1	Q.11	2	Q.12	4	Q.13	1	Q.14	1
Q.15	4	Q.16	3	Q.17	1	Q.18	2	Q.19	2	Q.20	1	Q.21	2
Q.22	1	Q.23	5	Q.24	4	Q.25	1	Q.26	1	Q.27	4	Q.28	2
Q.29	4	Q.30	2	Q.31	4	Q.32	1	Q.33	1	Q.34	2	Q.35	1
Q.36	2	Q.37	3	Q.38	2	Q.39	4	Q.40	3	Q.41	1	Q.42	3
Q.43	3	Q.44	4	Q.45	2	Q.46	3	Q.47	3	Q.48	2	Q.49	2

Q.50 4

Assertion–Reason Type Questions

In the following questions, a statement of assertion (A) is followed by a statement of reason (R).

(1) If both Assertion & Reason are true and the reason is the correct explanation of the assertion, then mark (1).

(2) If both Assertion & Reason are true but the reason is not the correct explanation of the assertion, then mark (2).

(3) If Assertion is true statement but Reason is false, then mark (3).

(4) If both Assertion and Reason are false statements, then mark (4).

A : Cellular slime moulds have the characters of both plants and animals.

R : Reproductive phase is animal like and vegetative phase is plant like.

A : Outer membrane is present in Rhizobium.

R : Outer membrane contains lipopolysaccharides.

A : Lichens do not grow in polluted area having SO_2.

R : Lichens secrete carbonic acid and oxalic acid on barren rocks.

A : Secondary mycelium of Agaricus is binuclealed.

R : Secondary mycelium is formed by somatogamy of primary mycelium.

A : CypheUae help to retain moisture in lichens.

R : It contains large number of hyaline cells.

A : Unicellular eukaryoles are included in Monera.

R : Unicellular eukaryotes have 70S cytoribosomes.

A : Lamellasome connects nucleoid to cell membrane. hR :

Lamellasome is present in oxyphotobacteria.

A : Pseudomonas fluorescense is cephalotrichous bacteria.

R : It is helpful in retting of fibres.

A : MLOs are pleomorphic and non-motile monerans.

R : They are resistant to antibiotics like penicillin.

A : Gram positive bacteria detect and respond to chemicals by lipopolysaccharides.

R : They have high amount of porins and lipidS which act as antigen.

A : Holophytic protistans are important phytoplanktons and they contribute 80% of the total photosynthesis.

R : They lack chemosynthetic nutrition and utilize non sulphur organic compound as the source of electron and proton in carbon assimilation.

A : Sexual spores in pink mould are meiospores produced endogenously.

R : They develop flask shaped fruiting txx:ty in sexual life cycle.

A : Azotodesmic lichens are biofertilisers enriching nitrogen contents in soil.

R : This ability is due to the presence of heterocystous blue-green algae as phycobiont

component.

A : Viroids are not included in five kingdom system.

R : They are acellular.

A : Viruses which infect animals generally possess ssRNA or dsRNA or dsDNA.

R : Phytophagineae generally contain dsDNA.

ANSWER KEY

Q.1	(3)	Q.2	(2)	Q.3	(2)	Q.4	(1)	Q.5	(4)	Q.6	(4)	Q.7	(2)
Q.8	(2)	Q.9	(2)	Q.10	(4)	Q.11	(3)	Q.12	(2)	Q.13	(1)	Q.14	(1)
Q.15	(3)												