Biological Classification

Introduction

Classification is the arrangement of organisms into groups (taxa) based upon their distinctive characteristics reflecting their similarities and dissimilarities. Classification of living organisms is essential because:

- It makes the study of all living organisms easy and convenient. The study of one or two organisms can help us to understand distinctive features of entire group.
- It makes the study systematic.
- It helps in understanding relationships between different groups of organisms.
- It helps in studying the evolutionary relationships between organisms.

HISTORY OF CLASSIFICATION

First attempt at classification was made by a Greek philosopher, Aristotle, also known as the "Father of Zoology". He classified animals-

- In two main groups- Anaima (Invertebrates) and Enaima (vertebrates), lacking red blood cells and having red blood cells respectively.
- Classified organisms on the basis of their habitat into aquatic, aerial and terrestrial.
- Classified plants on the basis of stem and life duration into herbs, shrubs and trees.

Definition

Classification: Systematic arrangement of organisms into categories according to their similarities and differences.

Demerits of the Classification

His classification could not be accepted as-

- It was an artificial system of classification.
- Certain animals lived in two different habitats like amphibians and thus their placement was confusing.

Theophrastus is known as the "Father of Botany". He classified plants. Based upon habitat, form and texture, he grouped plants into herbs, shrubs, undershrubs and trees.

- He talked about 480 plants in his book "Historia Plantarum."
- This book "De Historia plantarum" (enquiry into plants) is in ten volumes, where in Theophrastus described plants, by their uses and attempted biological classification of plants based on how plants reproduce. This attempt was the first of its kind in the history of Botany.
- In volume nine of Historia Plantarum, medicinal uses of plants is described.
- This book is one of the first books to contain a description of plant juices, gums and resins/their extractions.

Candolle or Augustin Pyramus de Candolle or Pyrame de Candolle (Swiss Botanists) introduced the term 'TAXONOMY' in his book Théorie Élémentaire de La botanique (Elementary Theory of Botany), in the year 1813.

John Ray, a naturalist, was the first to apply the concept of "species" to classification. He introduced and defined the term species. His book

"Historia Generalis Plantarum" contains description of more than 18,000 plants and animals. He divided plants into two divisions –Imperfect and Perfect. He further divided Plantae perfecta into different life forms like trees, shrubs, sub-shrubs and herbaceous plants.
Carolus Linnaeus a Swedish naturalist, known as the "Father of Taxonomy".
He gave the sexual system of classification in 1758.

- He listed all animals known to him in his book "Systema Naturae." He characterized and named over 4400 species of animals.
- Similarly, he named over 8,000 species of plants in his book "Species Plantarum."
- He also gave taxonomical hierarchy.

George Bentham and Joseph Dalton Hooker (1862- 1883) gave the Natural system of classification of seeded plants. Their book "Genera Plantarum" have a description of 202 families of Angiosperms.
Adolf Engler and Karl Prantl gave phylogenetic system of classification of plants in their book 'Die Naturlichen Pflanzenfamilien'.

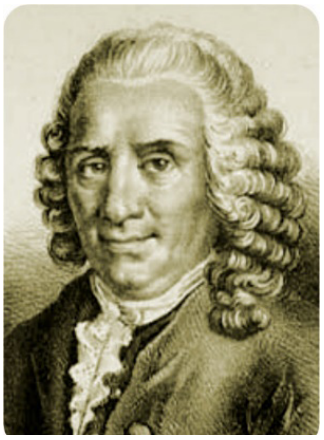
SYSTEMS OF CLASSIFICATION

Types of Classification

1 Artificial System of Classification
2. Natural System of Classification
3. Phylogenetic System of Classification

1. Artificial System of Classification

This type of classification is based on habitat, external features, i.e., morphology or on the numeric number of the sex organs. Linnaeus also put forward an artificial system of plant classification on the basis of numerical strength of sex organs into 24 classes like monandria, diandria, polyandria, didynamia, monoecia, cryptogamia, etc.



Carolus Linnaeus

Demerits of Artificial System of Classification

It could not be accepted as-

- It was based on superficial characteristics.
- It did not take into account the relationship between the different organisms.
- Organisms belonging to different groups were placed together e.g., birds and bats were placed in the same group due to their ability to flight.
- Separated the closely related species.

2. Natural System of Classification

It was based on natural affinities among the organisms. It was based on considering the morphology, ultrastructure, anatomy, embryology and physiochemistry.

Merits of Natural System of Classification

It is better than the artificial system of classification as -

- It does not consider habit and habitat as characteristics for classifying organisms.
- It considered characteristics of each and every organism.
- It helped the related organisms to be placed in one group only.
- The system prevents placing together the non-related organisms.
- The system indicates phylogenetic relationships and the origin of different taxa.

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Molecular homology: It is the study of similarities and differences between DNA, RNA and proteins of different organisms.

Demerit of Natural System of Classification

- It does not consider habit and habitat as characteristics for classification.

3. Phylogenetic System of Classification

It is based on evolutionary relationship between different organisms. This classification assumes that the organisms belonging to the same taxa may have a common ancestor. In such a system, organisms belonging to the same group are believed to have a common ancestry and maybe represented in form of a family tree, called a cladogram.

Information from Numerical Taxonomy, Cytotaxonomy, Chemotaxonomy helps in resolving difficulties in classification.

- **Cytotaxonomy-** It is based on the study of Chromosome number, structure, behaviour during cell division and the banding pattern of chromosomes. It helps in finding the lineage and similarity among the organisms.
- **Chemotaxonomy-** It is based on the different chemical constituents of the organisms like amino acids, alkaloids, proteins, etc. The chemical constituents of the plants are specific and stable, thus help in classification.
- **Numerical Taxonomy-** Number and codes are assigned to all the characters and the data is then processed. Each character under consideration is given a certain number and codes. Then these characters are used to establish a numerical degree of relationship between the organisms. Computers make numerical taxonomic studies easier.

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Alpha Taxonomy: Based on morphological features.
Beta Taxonomy: Based on morphological, anatomical, cytological, embryological features and biochemistry.
Gamma Taxonomy: Based on experimental, genetic and evolutionary evidences.

Two Kingdom Classification System

- It was given by Linnaeus in 1758.
- Based upon
  - Mode of nutrition
  - Presence or absence of cell wall
  - Locomotion
  - Response to stimuli
  - Divided all living organisms into two kingdoms: Plantae and Animalia.
- Kingdom Plantae was characterized.
  - By the presence of cell wall and central vacuole
  - Autotrophic nutrition
  - absence of nervous system, sense organs and locomotion
  - Starch as reserve food material
  - Well defined growing points with unlimited growth.
- He placed bacteria, fungi, algae, bryophyte, pteridophyte, gymnosperms and angiosperms in plant kingdom.
- Kingdom Animalia on the other hand:
  - Showed absence of cell wall and central vacuole.
  - Demonstrates heterotrophic nutrition, presence of nervous system, sense organs and locomotion.
  - Glycogen as reserve food material and absence of well-defined growing points and limited growth.

Merits of Two Kingdom Classification System

- The advantage of two kingdom classification was that it initiated the first systematic way of classifying organisms.
- This system was adopted by the biologists all over the world for a long time but it showed many inconsistencies.

Demerits of Two Kingdom Classification System

- First formed organisms as reported, were neither plants nor animals.
- It did not distinguish between prokaryotes and eukaryotes and placed bacteria along with eukaryotic groups in the plants.
- Fungi were placed in kingdom Plantae, whereas structurally, physiologically and reproductively, they differed from plants.
- Lower organisms like *Euglena*, *Chlamydomonas*, Slime mould have been considered by both zoologists and botanists. Their placement in this system was ambiguous.

  In order to address these discrepancies, two kingdom classification system was modified to three kingdom classification system.

Three Kingdom Classification System

- Ernst Haeckel added a new kingdom Protista and gave us three kingdom system.
- This system classified all the living organisms into three kingdoms-
  - Protista
  - Plantae
  - Animalia
- Protists comprised of bacteria, blue green algae, mycoplasma, unicellular Protozoa, some simple unicellular green algae, whole group of Charophyceae and Bacillariophyceae algae, fungi and slime moulds. All these organisms lacked the capability of tissue differentiation.

Ernst Haeckel

Merit of Three Kingdom Classification System

- The advantage of three-kingdom classification was placing the unicellular organisms in a different group called Protista.

Demerits of Three Kingdom Classification System

The drawbacks of this classification was-

- All Prokaryotic and Eukaryotic unicellular organisms were placed in one group. Fungi were not classified properly.
- No mention of the Virus
  Both unicellular and multicellular organisms were placed under Protista
  Heterotrophic bacteria and fungi that cannot prepare their own food but still were placed along with autotrophic algae.

Four Kingdom Classification System

- In 1956, Lynn Margulis and Copeland added a new kingdom Monera.
- Based upon the simple cell structure -Without true nucleus and membrane bound organelles.
- Mycoplasma and prokaryotic forms of primitive organisms were placed in this group.
- Kingdom Monera consisted of all the Prokaryotic forms. Kingdom Monera was initially called Mycota. Thus, four kingdoms comprised of Kingdom Monera, Protista, Metaphyta and Metazoa.

Merit of Four Kingdom Classification System

It created the kingdom Monera.

Demerits of Four Kingdom Classification System

- Prokaryotes and Eukaryotes were placed together.
- Both unicellular and multicellular organisms are placed under Protista.
- Heterotrophic bacteria and fungi cannot prepare their own food but still were placed along with autotrophic algae.

Five Kingdom Classification System

- In 1969 Robert Harding Whittaker proposed this system of classification and added kingdom Fungi. He argued that fungi, which had been previously placed along with plants, had a unique method of obtaining food. So, he proposed Kingdom Fungi and separated it from plants.
- Living organisms are divided into five kingdoms; Monera, Protista, Fungi, Plantae and Animalia.

Robert Whittaker

Criteria used by Whittaker for his classification scheme was:

- Cell structure
- Body organization
- Mode of nutrition
- Reproduction
- Phylogenetic relationships

This classification system placed all prokaryotes in the Kingdom Monera and unicellular eukaryotes were placed in the kingdom Protista. Fungi were elevated to the level of kingdom.

Merits of Five Kingdom Classification System

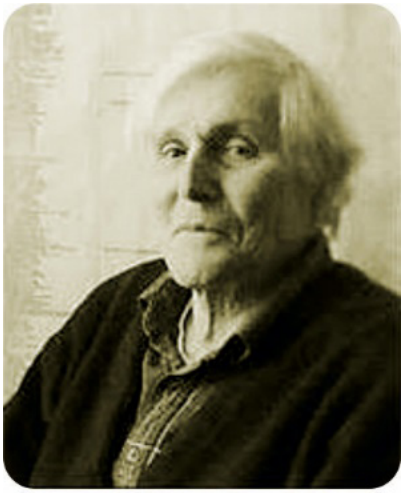
- It removed most of the confusions of the kingdom system.
- It gave just treatment to all groups of organisms.
  It reflected phylogenetic relationships amongst groups.

Demerit of Five Kingdom Classification System

- Though it led to a better arrangement of taxa, still it lacked the systematic position of viruses and lichens.

Three Domains of Life or Six Kingdom Classification System

- It was introduced by Carl Woese that divides different life forms into three domains-
  - Archaea
  - Bacteria
  - Eukarya
- He proposed that on the basis of differences in 16S rRNA genes, each domain arose separately from an ancestor called as progenote.
- Domain Archaea contains the kingdom Archaebacteria.
- Domain Bacteria contains the kingdom Eubacteria
- Domain Eukarya consists of Protista, Fungi, Plantae and Animalia.



Carl Woese

Merits of Six Kingdom Classification System

- Prokaryotes are separated into two groups on the basis of basic differences and this helps in determining the genetic similarities between organisms.
  They are grouped in such a way that their features can indicate a common ancestor

Demerits of Six Kingdom Classification System

- It is time consuming and the scientists have to study minute details in order to place the animals in different domains specially the Domain Archaebacteria and Domain Bacteria.
- Viruses and lichens do not have any position in this classification also.

KINGDOM MONERA

It comprises of most primitive and simplest organisms. All prokaryotes such as bacteria, Mycoplasma and blue green algae are placed in this group.

Characteristics

- Unicellular, organisms having prokaryotic cell structure.
- Cell wall is made of peptidoglycan. Cellulose is absent.
- Naked DNA lies in the cytoplasm in a coiled form. It is called a nucleoid.
- Nutrition is autotrophic, saprophytic, parasitic and symbiotic.
- Asexual mode of reproduction. Gametes are absent.
- Kingdom Monera includes Archaebacteria, Eubacteria, Cyanobacteria and Mycoplasma

Archaebacteria (Archaea – ancient: bact – rod)

- These are most simple and ancient bacteria which were probably the first to evolve.
- Archaebacteria are popularly known as the "Oldest of living fossils".
- It is a most unusual group of bacteria which are capable of growing under extreme conditions.
- Structurally, they resemble prokaryotes (except for cell wall which is not made of peptidoglycan) but metabolically they differ from them. The cell wall is composed of non–cellulosic polysaccharide and proteins. This cell wall gives them ability to survive under conditions of extremely high pH, temperature and salinity.
- Most of them are chemoautotrophs.
- Types of archaebacteria:
  (i) Methanogens
  (ii) Halophiles
  (iii) Thermoacidophiles

Methanogens

- These are strictly anaerobes.
- Generally present in marshy areas or gut of several ruminants like goat, cows and buffaloes. They ferment the cellulose, which forms the main food of these ruminants.
- They are responsible for the production of about 65% of atmospheric methane. This property of Methanogens is used in biogas plants.
  Example: *Methanobacterium, Methanococcus, Methanogenium, Methanospirillum*

Halophiles

- Mostly anaerobes, they are found in extremely salty environments like marshes, salt lakes etc.
- No photosynthetic activity has been found. They can convert light energy to ATP.
- Halophiles contain 'Halorhodospin'. This chemical pumps in chloride into the cell and prevents cellular dehydration.
  Example: *Halobacterium, Halococcus, Haloferax*

Thermoacidophiles

- These are temperature and acid loving bacteria. They occur in hot Sulphur springs They can live in extreme temperature and acidic pH.
- Thermoacidophiles survive in extreme temperature and acidic pH due to:
  - Presence of special branched chain lipids in their cell membrane which reduces cell fluidity.
  - Ability of enzymes to work at low pH.
  - Resistance of enzymes to high temperature.

Under anaerobic conditions they oxidise sulphur to sulphuric acid.

$2S + 2H_2O + 3O_2 \rightarrow 2H_2SO_4 + Energy$

Example: *Sulpholobus, Desulphurolobus*

Eubacteria (True bacteria)

Antonie van Leeuwenhoek (1683) observed small animalcules in decaying tooth scum, under his self made microscope. Ehrenberg (1829) gave the term "Bacteria."

Bacteria are omnipresent and can be found in water, air, soil, in and on other organisms and in all environments where life can exist.

Bacteria are classified into different types using different criteria:-

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Largest Bacterium: *Thiomargarita namibiensis* – Ocean shelf of Namibia.

Based upon the shape, they are of four types:

- **Coccus:** These are spherical shaped bacteria that lack flagella. Spheres can occur singly (*Monococcus*), in pair (*Diplococcus*), in clusters (*Staphylococcus*) or change chains (*Streptococcus*).
- **Bacillus:** These are rod shaped bacteria. They may occur singly (*Monobacillus*), in pair (*Diplobacillus*), in clusters (*Staphylobacillus*) or in chains (*Streptobacillus*).
- **Spirillum:** These are bacteria that are screw shaped or are twisted. They occur as single cells.
- **Vibrio:** These are comma shaped bacteria. They occur as single cells.

Based upon Gram staining, they are of two types:

- Gram positive Example: *Bacillus, Clostridium*
  Gram negative Example: *Pseudomonas, Salmonella*

Technique of Gram Staining

The differential staining technique was introduced by Hans Christian Gram (1884), hence it is called Gram stain. The

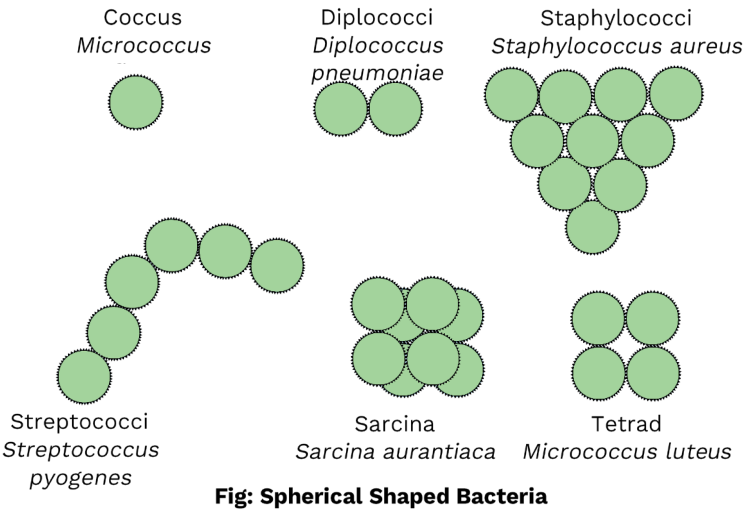


Fig: Spherical Shaped Bacteria

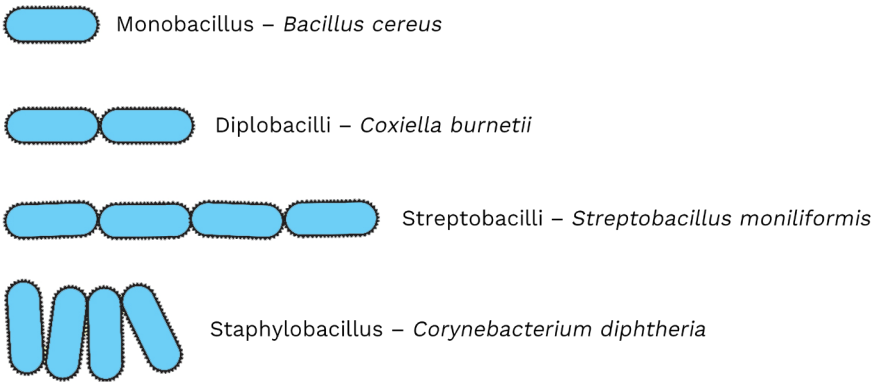


Fig: Rod Shaped Bacteria

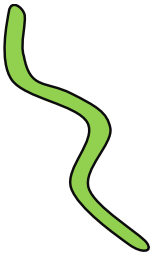


Fig: Spirillum Shaped Bacteria
Spirochaete

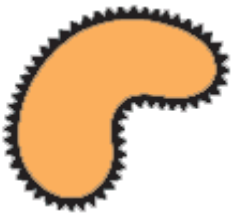
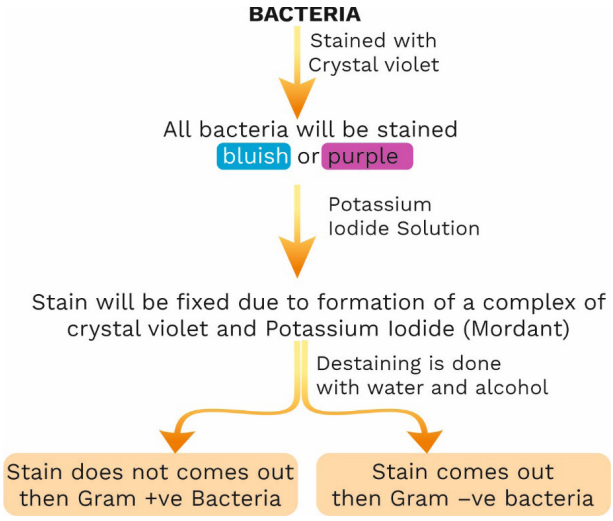


Fig: Comma Shaped Bacteria
Vibrio cholerae

main stain used is 1% solution of crystal violet or gentian violet.

- Heat treated bacteria is stained with an aqueous solution of crystal violet for 1-2 minutes. Then it is transferred to iodine solution (iodine dissolved in potassium iodide solution). Iodine solution acts as mordant and makes the cell wall accept the Gram stain easily.
- Then it is washed with alcohol. If the cells retain the colour, they are gram positive and if the cells do not retain the colour, they are gram negative.
- Gram negative bacteria are then stained with a counterstain like eosin or safranin to make them visible under microscope.



The difference in the ability to retain colour is because of different structures of the bacterial cell wall.

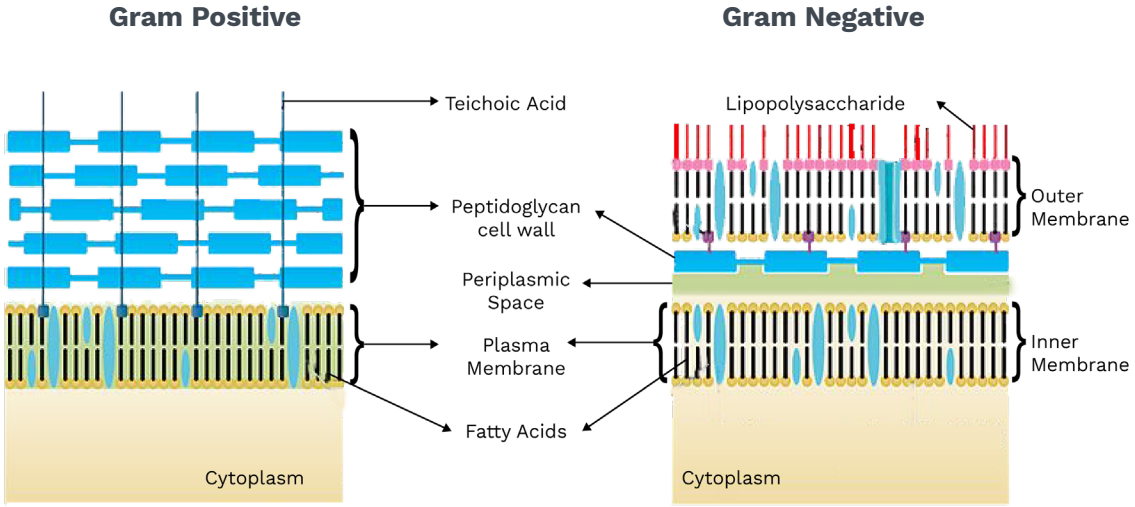


Fig: Cell Wall of Gram Positive and Gram Negative Bacteria

Difference between Gram positive and Gram negative Bacteria.

CHARACTER	GRAM POSITIVE	GRAM NEGATIVE
Number of layers	One	Two
Thickness	Thick (20-80 nm)	Thin (8-10 nm)
Chemical composition	Peptidoglycan, Teichoic acid and lipoteichoic acid	Lipopolysaccharide, Lipoproteins and peptidoglycan
Lipid	Less	More
Peptidoglycan	More	Less

Based Upon Flagellation, they are of two types:

- **Atrichous:** These are bacteria without flagella. All coccus forms are atrichous.
- **Trichous:** These are the bacteria that do have flagella. Depending upon number of flagella, they may be-
  - **Monotrichous:** Bacteria having a single flagellum attached at one end. Example: *Vibrio cholerae.*
  - **Lophotrichous:** Bacterial cell having tuft of flagella attached at one end. Example: *Spirillum volutans.*
  - **Amphitrichous:** Bacteria having one or more flagella attached at both ends. Example: *Nitrosomonas.*
  - **Peritrichous:** Bacteria having flagella evenly distributed throughout the surface of bacterial cells. Example *E. Coli*.

General Structure Of Bacterial Cell

Cell Structure: Bacteria have typical prokaryotic cell structure. Cell is surrounded by a rigid cell wall which is made of peptidoglycan. Cell wall is further surrounded by mucilaginous sheath. Inside cell wall, cell membrane is present. Membrane bound organelles and a well-defined nucleus is absent. Genetic material consists of single circular naked segment of DNA which is known as nucleoid or genophore or incipient nucleus. It is rich in Guanine and Cytosine. Extra chromosomal material Plasmid is present in the cell which provide antibiotic resistance to the bacteria.

Cell Membrane: It is a living, elastic, semi-permeable membrane which

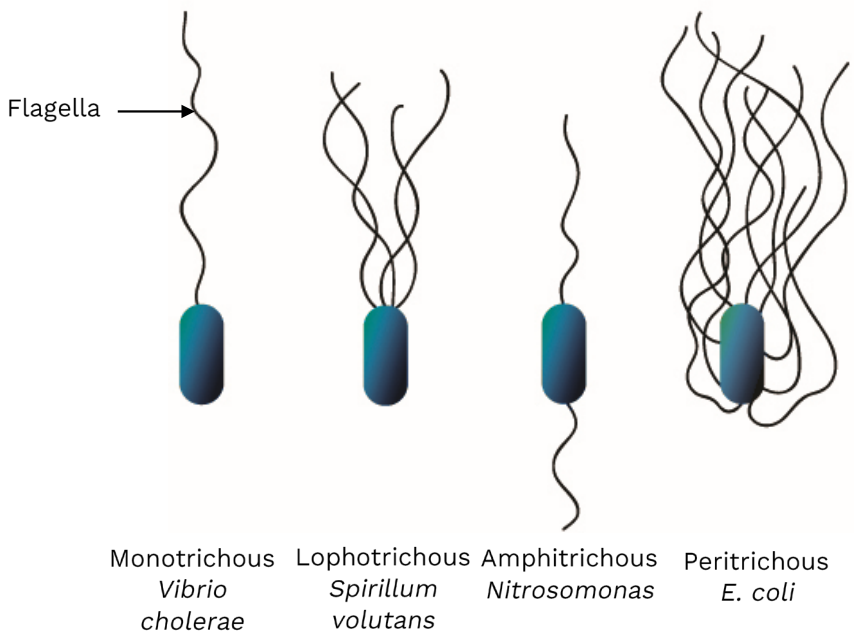


Fig: Flagella in Bacteria

regulates the flow of material in and out of the cell. It shows invaginations to form mesosomes.

Cytoplasm: It is a colorless, colloidal, homogenous material which lacks any membrane bound cell organelle. It does not show streaming movement and appears granular due to the presence of 70S ribosomes. These ribosomes generally lie scattered in cytoplasm. Sometimes, they may form a small chain of 4 – 6 ribosomes attached to mRNA. This structure is called polyribosome. Some bacteria living in aquatic conditions may show sap or gas vacuoles, otherwise these vacuoles are absent.

Rack your Brain

Which is the most essential unit for a living cell to sustain limited life span?

Respiration in Bacteria

Respiration: Based upon the mode of respiration, bacteria are of two types:-

- Aerobes and Anaerobes.
- Each group is further subdivided into facultative and obligate types.

Definition

Facultative Aerobes: Organisms that are chiefly anaerobic but can respire in the presence of oxygen also.

Obligate aerobes: These are the bacteria that respire only in the presence of oxygen. Example: *Bacillus subtilis*

Facultative aerobes: These are the bacteria that normally respire in absence of oxygen but can respire in it's presence also. Example: *Chlorobium.*

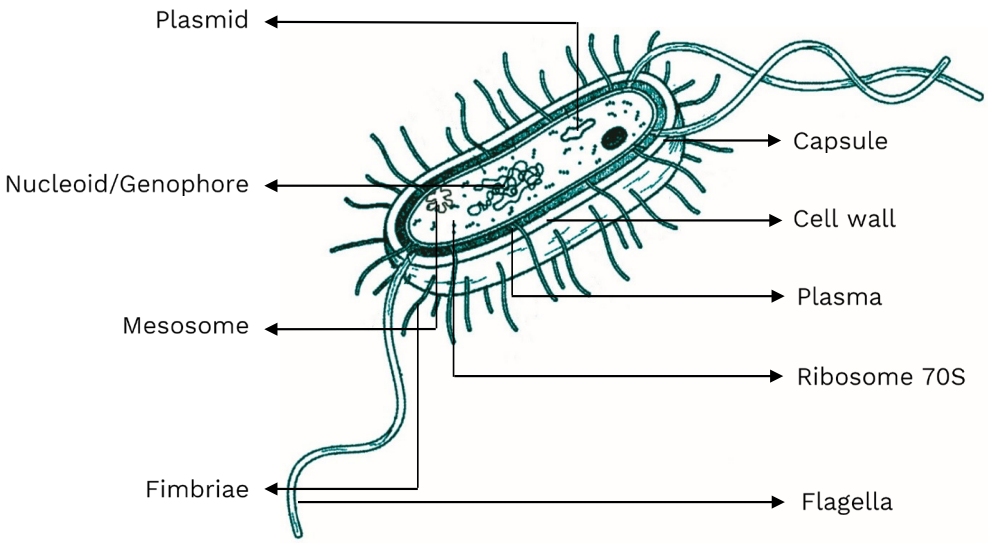


Fig: Structure of Bacteria

Definition

Facultative Anaerobes: Organisms that are chiefly aerobic but can respire in the absence of oxygen.

Facultative anaerobes: These are the bacteria that normally respire in the presence of oxygen. However, if sufficient oxygen is not available, they can switch over to anaerobic respiration to get energy. Example: *Pseudomonas.*

Obligate anaerobes: These are the bacteria that respire only in the absence of oxygen. Since the amount of energy liberated during anaerobic respiration is less, the rate of growth of these anaerobic bacteria is slow. Example: *Clostridium botulinum*.

Photosynthetic bacteria, Green Sulphur bacteria or Purple Sulphur bacteria are obligate anaerobes. Thus, their photosynthesis is anoxygenic. They use H_2S as hydrogen donor instead of H_2O. Most of the pathogenic forms are anaerobes.

Nutrition in Bacteria

Nutrition: Bacteria show both the modes of nutrition:

- Autotrophic
- Heterotrophic

Autotrophic Nutrition

- It is shown by less than 1% of bacteria. Bacteria showing this mode maybe photoautotrophic or chemoheterotrophic.

Photoautotrophic bacteria

- These bacteria have a photosynthetic pigments like bacteriochlorophyll

(found in purple bacteria), bacteriopheophytin, chlorophyll (found in green sulphur bacteria).

- By using these pigments, they trap the solar energy and synthesize food for themselves. These pigments occur in membranes of thylakoids.
- The photosynthesis shown by these bacteria is anoxygenic. No oxygen is evolved during this photosynthesis as they do not use water as a reducing agent. Therefore, these monerans are commonly found near the bottom of pond or lake. At the bottom of these water bodies, reduced sulphur and other compounds are easily available.
- Hydrogen is obtained either directly or from various inorganic or organic compounds like H_2S (Green bacteria).
- Bacteriochlorophyll, bacteriopurpurin and Bacterioviridin are pigments that are found in different bacteria. These pigments are present in the chromatophores.

Chemoautotrophic bacteria

- These bacteria are able to manufacture their own organic food from inorganic raw materials. The energy needed is obtained from the oxidation of inorganic materials.
- The energy used is ATP. Different types of chemoautotrophic bacteria are-
- Nitrifying bacteria
- Sulfur oxidizing bacteria
- Iron bacteria

Definition

Chemoautotrophs: Organisms that are able to manufacture their own organic food from inorganic raw materials.

Nitrifying bacteria – *Nitrosomonas* and *Nitrosococcus* oxidize ammonia to nitrite and release energy.

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H^+ + \text{Energy}$$

Nitrobacter oxidizes nitrites into nitrates.

$$2NO_2^- + O_2 \rightarrow 2NO_3^- + \text{Energy}$$

Sulfur oxidizing bacteria- A colourless sulfur bacteria oxidizes hydrogen sulphide into Sulphur to obtain energy

$$2H_2S + O_2 \rightarrow 2S + 2H_2O + \text{Energy}$$

Iron bacteria- The bacteria *Ferrobacillus ferrooxidans* obtain energy by the oxidation of oxidized ferrous ions into ferric form.

$$4FeCO_3 + 6H_2O + 3O_2 \rightarrow 4Fe(OH)_3 + 4CO_2 + \text{Energy}$$

Heterotrophic bacteria

These obtain energy from the external source as they cannot manufacture their own food.

They are:

Saprophytic

Symbiotic

Parasitic

Saprophytic bacteria

- These are the free-living bacteria which obtain their energy from the dead and decayed organic matter like fallen leaves, vegetable and fruit leaves,

animal excreta and corpses of animals. Breakdown of organic compounds aerobically is known as decay.
- They break the complex organic matter into soluble form.
- Anaerobic breakdown of carbohydrates is known as fermentation.
- While the anaerobic breakdown of proteins is known as putrefaction.
- The bacteria play an important role in the environment by decomposing the dead organic matter. They can be called as nature's scavengers or cleaners of the environment.

Symbiotic bacteria
- They live in an association with other living organisms where both are benefitted.
- One of the most important examples is the association of *Rhizobium* in the root nodules of leguminous plants. *Rhizobium* fixes atmospheric nitrogen in the form of nitrates in the soil. In return the bacteria get shelter and food from the plants.
- *Escherichia coli* lives in human intestine, where it produces vitamin B and K and prevents the growth of putrefying bacteria.

Parasitic bacteria
- They live in contact with other living organisms.
- They cause diseases due to the breakdown of the host cells or due to the secretion of toxic substances.

NAME OF DISEASE (IN ANIMALS)	CAUSATIVE BACTERIA
Pneumonia	*Diplococcus pneumoniae*
Typhoid	*Salmonella typhii*
Cholera	*Vibrio cholerae*
Plague	*Pasteurella pestis*
Gonorrhea	*Neisseria gonorrhoeae*
Gastroenteritis	*E. coli*

NAME OF DISEASE (IN PLANTS)	CAUSATIVE BACTERIA
Soft rot of potato	*Pseudomonas solanacearum*
Citrus canker	*Xanthomonas citri*
Bacterial blight of paddy	*Xanthomonas oryzae*
Tundu disease in wheat	*Corynebacterium tritici*
Potato wilt	*Pseudomonas solanacearum*
Fire blight of apple and peach	*Erwinia amylovora*
Crown gall of sugar beet	*Agrobacterium tumefaciens*

Reproduction in Bacteria

Reproduction: These reproduce asexually by binary fission and tide over unfavorable conditions through endospore and perinate. Sexual reproduction is absent, but the exchange of genetic material takes place.

Binary Fission: Mature bacterium divides into two equal daughters. Similar to amitosis, it does not involve the formation of a spindle. The DNA uncoils and replicates attached to the Mesosome. A new Mesosome is formed which gets attached to the newly replicated DNA. Formation of a membrane takes place between the two Mesosomes leading to the formation of two daughter cells, thus pushing the DNA towards the two poles. The cytoplasm divides finally and forms two daughter cells.

Endospore

Endospores are thick-walled resting spores that are formed in adverse environmental conditions. Dehydration and drying separate a part of the protoplasm with the nuclear material known as the endospore primordium. Walls get deposited over this primordium and form the endospore. The parent cell undergoes lysis and the liberated endospore germinates under favorable conditions to form one bacterium.

There is no multiplication taking place, but the survival of the individual takes place. Hence cannot be considered as a method of reproduction. It is formed in *Bacillus* and *Clostridium*.

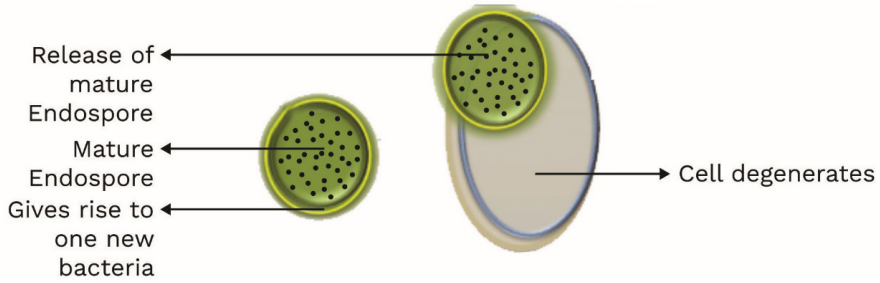


Fig: Endospore of Bacteria

Advantages of endospore formation

1. Resistant to high temperature (100^0C).
2. Tolerate toxic substances.
3. Produce anticoagulant chemical – Dipicolinic acid.

Genetic Recombination

It is of the following types-

- Conjugation
- Transformation
- Transduction

(a) **Conjugation-** Lederberg and Tatum, first observed Conjugation in *Escherichia coli*. Bacteria are dimorphic i.e., have male or donor (F^+) and female or recipient (F^-). Male/Donor have sex pili on their surface and fertility factor in their plasmid. Fertility factor is responsible for producing the sex pili and for the other factors needed for gene transfer. Both sex pili and fertility factors are absent in the female. Sex pili form a protoplasmic bridge or conjugation tube with the female recipient. Genetic material can be exchanged by-

- **Sterile Male Method:** The bacteria having a plasmid with a fertility factor will replicate and get transferred to the recipient cell. The recipient becomes a donor.
- **Fertile Male Method:** The fertility factor gets integrated with the genome of the male and F^+ male becomes Hfr male that is high fertility male or super male. When the F factor is detached from Hfr, it converts back to F^+ male. The Hfr and F^- female connects with the sex pilus. The integrated DNA with the Hfr breaks and replicates. This replicated DNA moves to the female cell.The segment replaces a homologous segment in the F^- cell. Thus a new recombinant is formed.

(b) **Transformation-**Griffith in the year 1928, conducted an experiment on *Diplococcus pneumoniae*. It has two strains-

- R type i.e a non-virulent strain, cannot cause disease.

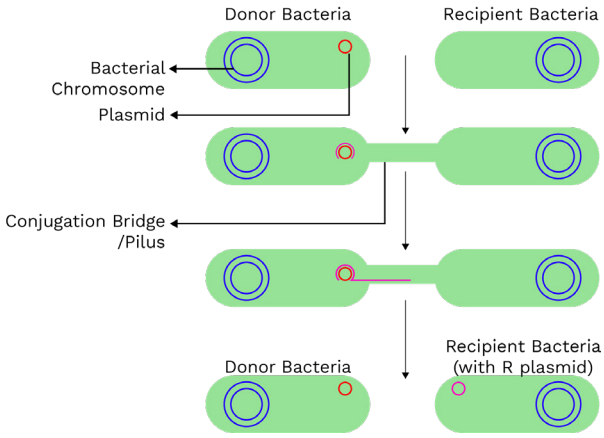


Fig: Conjugation in Bacteria

- S type i.e virulent type, can cause a disease as it has a polysaccharide coat.
- He took both the different types of strains and injected them into mice and saw the results.
- R type injected into the mice → Mice lived.
- S type injected into the mice →The mice died.
- S type strain was heat killed and inserted into the mice → The mice lived.
- R strain and heat killed S strain injected into the mice → The mice died.

Through this Griffith arrived at a conclusion with a transformation principle that transforms the non-virulent strain into the virulent one. Later Avery, MacLeod and McCarty separated the carbohydrates, DNA and proteins from the dead mice and through the addition of proteases, DNAase and RNAase respectively, showed that DNA is the transforming principle.

Transformation has also been reported in *Bacillus, Haemophilus and Neisseria*

(c) Transduction-Discovered first time in *Salmonella typhimurium* by Zinder and Lederberg.

A process of genetic recombination in bacteria in which genes from a bacterium are incorporated into the genome of a bacteriophage and then carried to another host cell, when the bacteriophage initiates another cycle of infection.

It is of three types:

- Generalized transduction
- Restricted/Specialized transduction
- Abortive transduction

Generalized transduction –It is the transfer of any gene of the donor bacterium e.g., T4 - bacteriophage.

Restricted/Specialized transduction –It can carry only a specific region of the bacterial DNA to a recipient e.g., Bacteriophage.

Abortive transduction –In this, the donor bacterium gene is not integrated into the genome of the recipient bacterium and is lost after a few generations.

Economic Importance of Eubacteria

Useful effects

(a) **In Agriculture:**

- In soil fertility: Bacteria convert atmospheric free nitrogen into nitrogenous compounds.
  Example: *Azotobacter and Clostridium, Nitrosomonas, Nitrosococcus.*
- Decay and decomposition of dead plants and animals and converts

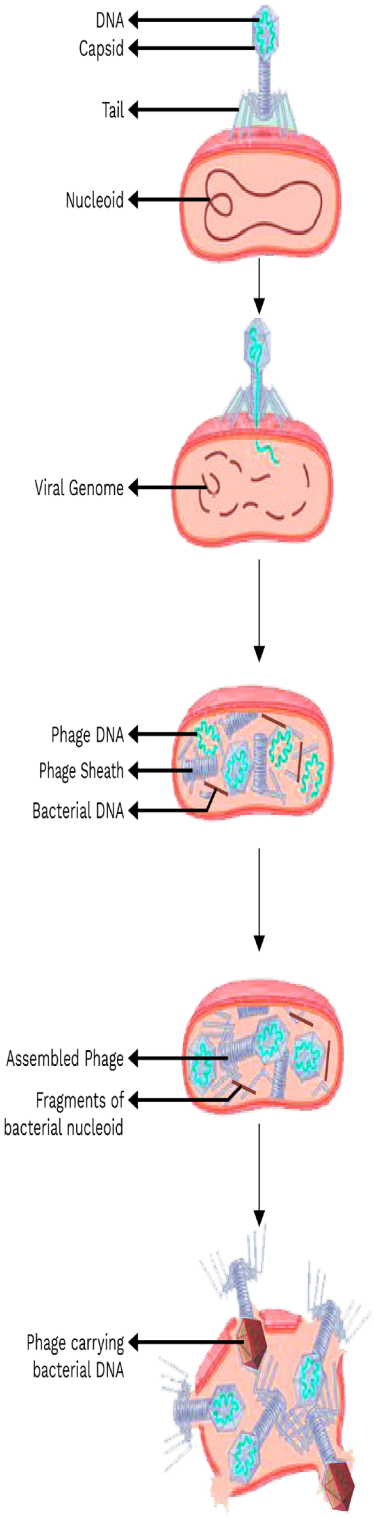


Fig: Transduction in Bacteria

their complex compounds into simpler substances.

(b) **In dairy:**

- *Lactobacillus* converts milk into curd. It converts lactose sugar found in milk to form lactic acid.
- Formation of cheese.

Rack your Brain

Which bacteria help to maintain the purity of the Ganges?

(c) **In industry:**

- Alcoholic Beverages are prepared from different raw materials using the bacteria.
- Vinegar is produced by *Acetobacter aceti.*
- *Linum usitatissimum*, *Cannabis sativa* and *Corchorus capsularis* (Jute) are retted by the bacteria.
- *Micrococcus candidans* is used for curing the tea leaves which helps in developing the taste in the leaves.
- Leather is tanned by bacteria.

(d) **In medicines:**

- Manufacture of antibiotics. Antibiotics are chemical substances produced by living microorganisms and are capable of inhibiting or destroying other microbes.

Harmful effects

(a) Food poisoning (Botulism): It is caused by *Clostridium botulinum*. The main symptoms are vomiting,

followed by paralysis and even death in some cases.

(b) Biological warfare: Bacteria that cause diseases like anthrax, blackleg are used for biological warfare.

(c) Putrefaction: It is the spoilage of protein, anaerobically by the putrefying bacteria e.g., *Proteus, Mycoides.*

Cyanobacteria (Blue green algae)

- These are gram positive, photosynthetic prokaryotes.
- They are found in fresh water, sea water, moist rocks, moist soil, hot springs and frozen waters. They live under many different types of environments and thus are considered the colonizers of the barren land.
- They are unicellular, colonial or filamentous. Each filament consists of mucilage sheath. The cells have nucleoid and lack membrane bound organelles.
- The photosynthetic pigments present are chlorophyll a, beta carotene, C–phycocyanin and C–phycoerythrin. C–phycocyanin gives blue and C–phycoerythrin gives red colour.
- They have special structures known as heterocyst which are present in the intercalary or lateral position. Heterocyst has an enzyme nitrogenase, which helps in fixing the atmospheric nitrogen in the form of nitrates in the soil.
- Cyanobacteria reproduce asexually by fragmentation, binary fission, endospores and hormogonia.

Hormogonia- Hormogonia are formed by some Cyanobacteria, the filament may break into a number of pieces by the decay of the vegetative cell which forms a separation disc and thus separating the pieces. Each separated piece is known as a hormogonium which develops into a new Cyanobacteria.

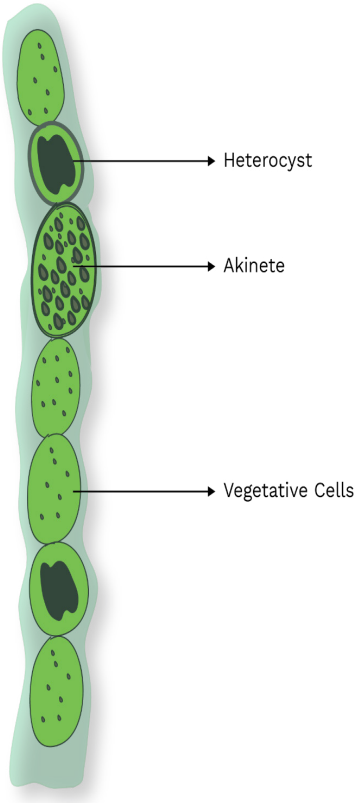


Fig: A Filament of *Anabaena* bearing Heterocyst and Akinete

Resting spore or Akinetes- An akinete is an enveloped, thick-walled, non-motile, dormant cell that is formed by filamentous, heterocyst-forming cyanobacteria. They can tide over unfavorable conditions and once favorable conditions return, on absorbing moisture germinates into a new filament.

Economic Importance of Cyanobacteria

Useful activities

- Production of oxygen through photosynthesis.
- Used as biofertilizers. *Nostoc* is important for their nitrogen-fixing ability. It is used in paddy fields.
- *Anabaena* and *Aulosira* prevent mosquitoes from breeding.
- *Nostoc commune*, *Cylindrospermum muscicola* are used in the reclamation of 'usar' land that is sterile alkaline soil.

Harmful activities

- They cause algal bloom, causing the deterioration of the water bodies. Produce an odour in the water and block the water supply system.
- They produce toxic chemicals which is harmful to humans and animals.

Mycoplasma (P.P.L.O. - PleuroPneumonia Like Organisms)

- These are the simplest of all the living forms. They were discovered by Nocard and Roux in 1898, in cattle suffering from pleuropneumonia.
- They do not have a regular shape and hence are known as the 'Joker of the microbial world'. The plasma membrane is present while cell wall is absent.
- Membrane bound organelles are absent. They are resistant to Penicillin but not against Tetracyclines.
- It has a double helix DNA. It has RNA and ribosomes that help in protein synthesis.
- It multiplies by budding off minute elementary bodies.
- Mycoplasma are heterotrophic. They are saprophytic and most of them

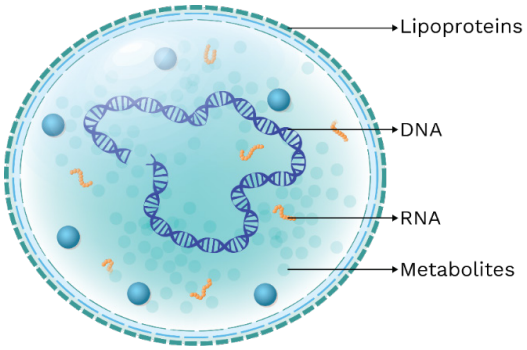


Fig: Mycoplasma

are parasitic. They cause diseases in plants and animals. They cause pleuropneumonia in domestic animals, little leaf disease of Brinjal, Witches' broom, Papaya bunchy top, Potato purple top in plants.

Rack your Brain

DNA of which organism possesses a replicating disc?

Actinomycetes

- These are generally gram positive and anaerobic. They are found in soil and decaying organic matter and also in humans and animals.
- Streptomycin, Actinomycin are antibiotics isolated from Actinomycetes bacteria.

Spirochaetes

- Coiled aflagellate bacteria. They cause diseases like Syphilis in human.

Rickettsia

- First discovered by Ricketts in 1909 and described by Rocha Lima in 1916.

- Rod or circular obligate parasites.
- They have a mucopeptide cell wall and DNA as their genetic material.
- Asexual reproduction occurs by fragmentation, conidia and oidia formation.
- The endospores are not formed.
- They are sensitive to antibiotics like Chloramphenicol, Tetracycline. They cause Q fever, rock mountain spotted fever, rickettsial pox in humans.

KINGDOM PROTISTA

Characteristics

- These are unicellular, eukaryotes that can be solitary and colonial.
- They are surrounded by a cell membrane which may be covered by the pellicle, shell or cellulosic wall. They have membrane bound organelles.
- Locomotion is brought about by the pseudopodia, flagella and cilia.
- Nutrition may be photosynthetic, holozoic, parasitic and mixotrophic. Mixotrophic nutrition is a mixed nutrition where the organism can perform two different modes of nutrition depending on the environmental conditions. Example: *Euglena* is both photosynthetic and parasitic.
- Reproduction by asexual and sexual methods.
- The kingdom Protista is broadly divided into three groups namely-
- Photosynthetic Protists or Protistan Algae
- Consumer – Decomposer Protists-Slime Moulds
- Protozoan Protists

Photosynthetic Protists or Protistan Algae

They are photosynthetic and are divided into three groups- Dinoflagellates, Chrysophytes and Euglenoids

Dinoflagellates

Characteristics:

- Most of these are marine and are photosynthetic. Unicellular, motile with two flagella. One flagellum projecting from one end and the other lies in the transverse groove between the wall plates. They appear green, yellow, blue or red depending on the pigments present in high concentration in their cells.

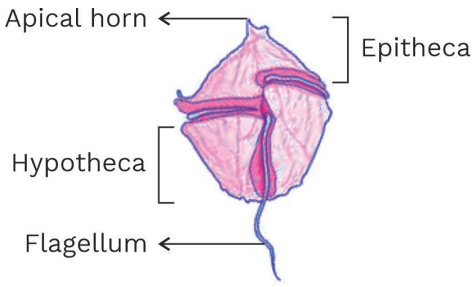


Fig: Dinoflagellates

- They are surrounded by a cell wall made up of cellulose, which is composed up of two plates interlocking each other. This gives them an appearance of armoured dinoflagellates.
  Reproduces asexually. Sexual reproduction is absent in them except *Ceratium*.
- *Gymnodinium* and *Gonyaulax* grow in large numbers in the sea, giving it a red colour and thus causes the red tide.

Gonyaulax catenella when present in large numbers produces a toxin saxitoxin which is poisonous to the fishes and marine animals.

- Examples: *Ceratium, Noctiluca, Peridinium*

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Bioluminescence: Ability of the organism to produce light.*Noctiluca*, *Peridinium* emit light due to luciferin-luciferase reaction.

Chrysophytes

Characteristics

- It includes diatoms and desmids (golden algae). Diatoms are microscopic and single celled. They do not have flagella and float in water.
- Cell is called frustules. The cell wall is made up of two halves fitting each other like a soap box and hence known as diatom. The cell wall is made up of silica.
- Diatoms are the main producers in the oceans. The cell wall of the desmids does not decay easily, they accumulate at the bottom of the water bodies leading to the formation of the diatomaceous earth.
- Desmids are present in large numbers in non-polluted water. They are unicellular. Examples: *Navicula, Cymbella, Triceratium.*

Euglenoids

Characteristics

- Unicellular, found in freshwater body. *Euglena* is an example.
  Cell wall is absent. They are covered by a layer of protein known as pellicle which makes them flexible.
- They consist of two flagella. One is short and other is long.

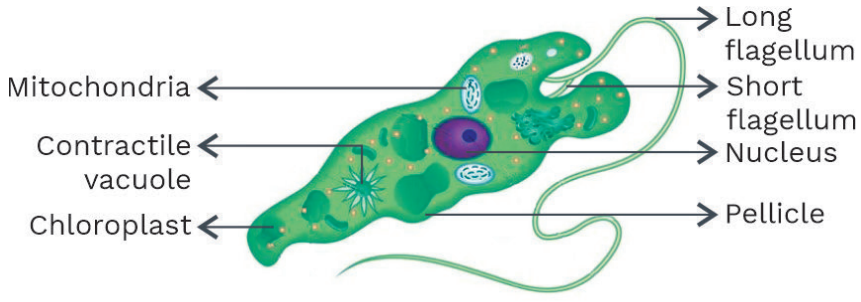

Fig: *Euglena*

- *Euglena* shows mixotrophic nutrition. In the presence of sunlight, they are autotrophic while in the absence of sunlight they obtain their food by feeding on other organisms.
- They reproduce asexually.
  Examples: *Euglena, Astasia.*

Rack your Brain

What is hologamy? Which group of organisms shows it?

Consumer – decomposer protists – slime moulds
Characteristics

- They are found in shady and damp places.
- The vegetative phase of the thallus is free living. It consists of the protoplasm in which the nuclei are suspended.
- Mode of nutrition is saprophytic.
- They reproduce by the formation of spores on special structures known as sporangia. The spores germinate to form myxamoebae which form the gametes. These gametes fuse together to reproduce sexually.
- Examples: *Physarium, Stemonitis.*

Protozoan Protista
Characteristics

- They are unicellular and heterotrophic.
- They are divided into the following-

Flagellated Protozoan

- Commonly known as Zooflagellates.
- They are unicellular, heterotrophic.
- They consist of flagella for locomotion. They only show asexual reproduction.
  Examples: *Trypanosoma gambiense, Leishmania, Giardia*.

Amoeboid Protozoans

- Also known as Sarcodina.
- They are found in fresh water or marine water.
- They show locomotion by finger like projections known as pseudopodia.
- Reproduction is usually asexual by binary fission and some forms show sexual reproduction.
  Examples: *Amoeba, Entamoeba histolytica*

Ciliated Protozoans

- Also known as Ciliata, one of the most advanced groups.
- They are usually found in fresh water and show locomotion because of the presence of thousands of hair like structures all over the body, known as cilia.
- They consist of cytostome by which the intake of food takes place.
- The nucleus shows dimorphism. There is a micronucleus and a macronucleus. Micronucleus controls the reproduction while macronucleus is vegetative.
  Examples: *Paramecium, Podophyra.*

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Hemixis:
Reorganisation process where the macronucleus breaks and forms new macronuclei. It is observed in *Paramoecium caudatum, Paramoecium aurelia.*

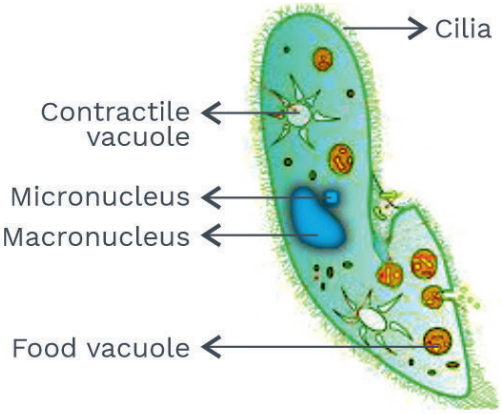

Fig: *Paramoecium*

Sporozoans

- Simple body design.
- They have a parasitic mode of nutrition.
- They lack any organelle for locomotion.
- They produce spores in their life cycle which causes infection.
  Example: Malaria causing *Plasmodium* and *Monocystis*.

KINGDOM FUNGI

- It comprises eukaryotic organisms.
- It is divided into Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes.

Characteristics

- They are mostly filamentous, multicellular except *Yeast* which is unicellular.
- Body is not composed of stem, leaves and roots. It is composed of fine tubular structures known as hyphae which form a network known as Mycelium. The mycelium may be septate or non-septate. When aseptate, the nuclei lie in a common mass and this condition is known as coenocytic.
- Chitin is present in their cell walls. It is a polymer of N-Acetyl Glucosamine. Exception- Oomycetes, in which cellulose occurs.
- The mode of nutrition is heterotrophic as they lack chlorophyll. Food is stored in the form of glycogen.
- They are saprophytic, parasitic and symbiotic.

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Smallest Fungi – *Yeast*
Largest Fungi – Mycelium of *Armillaria ostoyae* or Honey fungus.

Saprophytic Fungi

Saprophytic means they obtain their nutrition from dead decaying organic matter.

Parasitic Fungi

- Parasitic means they obtain food from living hosts.
- Parasitic fungi may be obligate or facultative.
  - Obligate parasitic fungi depend on a living host throughout their life.
  - Facultative parasitic fungi are the one who are actually saprophytes and have secondarily become parasites.
  - Parasitic fungi form the structure appressoria to adhere to the host and for absorption of food haustoria are produced by obligate parasitic fungi.

Symbiotic Fungi

- Fungi show a symbiotic association with the algae and with the roots of higher

plants. Symbiotic association with the algae is known as Lichens.

- In lichens, the fungi absorb water and minerals and algae synthesize food. The association of fungi with the roots of higher plants is known as mycorrhiza.

Reproduction in Fungi

- Reproduction in fungi is vegetative, asexual and sexual.
- In *Yeast,* the whole cell is converted into a reproductive structure known as Holocarpic.
- In *Rhizopus,* only a part of the thallus is converted into a reproductive structure, known as Eucarpic.
- Fungi reproduces vegetatively by fragmentation, budding, oidia and fission.

Asexual Reproductive Units in Fungi

Fungi reproduces asexually by-

Zoospores

- These are thin-walled spores that are motile due to the presence of flagella. The zoospore may be uniflagellate or biflagellate.

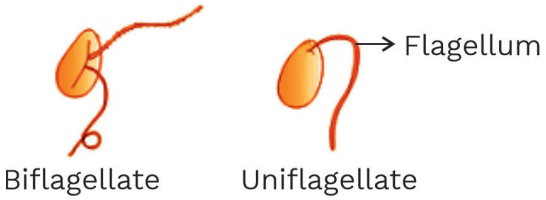


Fig: Asexually Produced Zoospore

Sporangiospores

- These are thin walled, non–motile spores produced in sporangium.
- They are also called aplanospores. They are formed endogenously.

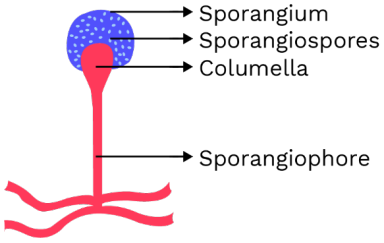


Fig: Sporangiophore

Conidiospores or Conidia

- In some fungi, the spores are not produced in sporangium but at the tip of specialized branches known as conidiophores.
- Such spores are known as conidiospores or conidia. They are single celled, double celled or multi celled.
- They are formed exogenously.

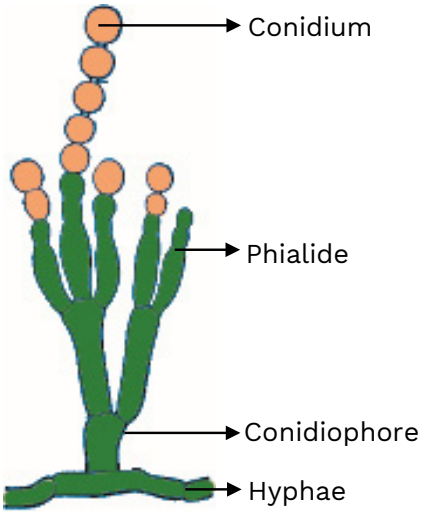


Fig: Conidiophore

- Fungi reproduces sexually by the following three phases-

Plasmogamy- The fusion of the two motile or non-motile gametes leads to

the fusion of their protoplast. The nuclei do not fuse and the mycelium formed is dikaryotic.

Karyogamy- The fusion of the two haploid nuclei from two different parents results in the formation of a diploid nucleus.

Meiosis- Reductional division in the zygote leads to the formation of haploid spores.

Karyogamy and meiosis occur in fungi but sometimes not at a specific time or point in the life cycle. Such a cycle is known as the parasexual cycle and the phenomenon is known as parasexuality. It is seen in some of the Deuteromycetes. The fungi reproduce sexually by the following methods-

Gametangial Contact

- The fusion of two gametangia occurs.
- The male gametangium is antheridium and the female gametangium is oogonium.
- The male nucleus is transferred to the female directly or through a tube.

Gametangial Copulation

- In some cases, the whole thallus acts as gametangium and in others, the dissolution of the cell wall between the two gametangia is known as gametangial copulation.

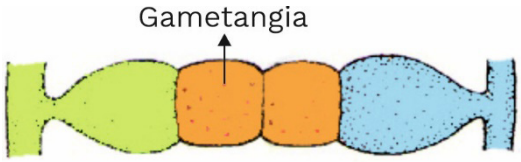


Fig: Gametangial Copulation

Spermatization

- The male gametes called Spermatia are formed in Spermogonia.
- The female gametangium is called Ascogonium.
- The spermatium attaches itself to the trichogyne and the male nucleus is transferred and thus causing dikaryotization.

Somatogamy

- It occurs in higher fungi. Hyphae of two different strains fuse together and bring about dikaryotization.

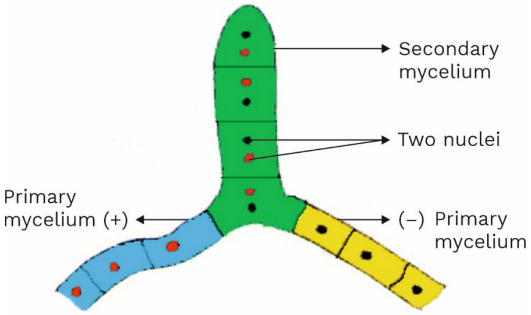


Fig: Somatogamy

Mycorrhiza

- The term 'mycorrhizae' was coined by Frank (1885).
- It is an example of symbiosis or mutualism.
- Association between a fungus and the root of the higher plants e.g., Pine, Birch, Ficus etc. Roots of higher plants get infected by fungi. The root cells and fungi directly transmit nutrients to each other.

Definition

Mycorrhiza: It is a symbiotic association between a fungus and the roots of a green plant.

Mycorrhiza is classified into two categories:

- **Ectotrophic mycorrhiza:**
  - The fungus partner is commonly a Basidiomycetes.
  - In this type of mycorrhiza, the fungus completely encloses the rootlet and penetrates into the cells of root cortex.
  - The hyphae in intercellular space form a network called Hartig Net.

  Ectotrophic mycorrhiza is found in *Pines, Spurs, Firs, Oaks, Beeches, Birches, Eucalyptus*.
- **Endotrophic mycorrhiza:**
  - The fungal partner is commonly Zygomycetes.
  - In this kind of mycorrhiza, the fungus does not form an external mantle but lives within the root both intracellularly as well as intercellularly.
  - The fungal hyphae develop some special organs, called vesicles within the root cortical cells and are called Vesicular-Arbuscular Mycorrhiza (VAM). VAM helps in the absorption of phosphate from soil.

  Endotrophic mycorrhiza is found in *Orchid.*

Advantages of mycorrhizal association

- The fungal hyphae increase the plant's uptake of phosphorus from the soil.
- Helps the host to absorb water efficiently.
- The fungi produce various growth promoting substances which help the plants to grow efficiently.
- Due to phytotoxins released by fungi in mycorrhizal association, the higher plants develop resistance to soil borne diseases, drought resistance and pH and temperature extremes.

On the basis of the mycelium, spore formation and reproduction, the fungi are divided into the following divisions:

Phycomycetes: Commonly known as Algal fungi because of their aquatic habitat and form of the thallus.

Characteristics:

- Mycelium is coenocytic.
- Asexual reproduction takes place by the formation of sporangia which in aquatic conditions form zoospores.

Zygomycetes: Commonly known as conjugation Fungi.

Characteristics

- These are terrestrial fungi, which are usually saprophytic.
- The mycelium is aseptate and thus coenocytic. The hyphae are made up of chitin.
- Motile spores are absent, and they reproduce asexually by producing sporangiospores. Sporangiospores are produced in specialized structures known as sporangia, developed on the tip of special hyphae called sporangiophores.
- Sexually they reproduce by the special structures called gametangium. Male and female gametangium is formed. The male and the female gametangium form gametes which are multinucleate and known as coenogametes. Sexual reproduction occurs by gametangial copulation or conjugation. Thus, they are known as conjugation fungi.

- After conjugation, a diploid spore known as zygospores is formed. Due to the formation of Zygospore, the class is known as Zygomycetes. Zygospore does not form the new mycelium but forms germ sporangium. Germ sporangium forms the meiospores called germ spores which germinate to give rise to the mycelium.
  Examples: *Rhizopus, Mucor.*

Ascomycetes (Commonly known as Sac fungi)

Characteristics

- Unicellular (*Yeast*) to multicellular (*Penicillium*).
- They are saprophytic (Yeast), parasitic (Penicillium) and those growing on dung known as coprophilous (*Mucor mucedo*).
- Mycelium is branched and is septate.
- They reproduce asexually by conidia produced on the conidiophores.
- They reproduce sexually by the formation of ascospores, which are produced in specially formed fruiting bodies called the ascus. Usually, eight ascospores are produced in the ascus. There are four types of ascus-
- Cleistothecium is a closed, globose ascocarp from which the ascospores are released, only by its rupture or decay.
- Gymnothecium is a completely enclosed structure containing globose or pear-shaped, asci. The wall of the gymnothecium has loosely interwoven hyphae.
- Perithecium- These are flask shaped structures opening by a pore or ostiole through which the ascospores escape.
- Asexual reproduction takes place by the formation of conidia. Examples: *Neurospora*, *Peziza*

Basidiomycetes (Commonly known as Club fungi)

Characteristics

- Large group, which are the best decomposers of wood. They are able to degrade both lignin and cellulose.
- Mycelium is of two types-primary and secondary.
- Primary mycelium consists of haploid cells while secondary mycelium consists of diploid cells. Septum has central pores with barrel shaped outgrowths. Such a structure is known as dolipore. Clamp connections are also present.
- Mycelium of different mating strains come together to form a dikaryotic mycelium. This secondary mycelium bears the basidiocarp which produces sexual spores (basidiospores) on a club-shaped structure called a basidium.
- Each basidium produces four spores on the tips of minute stalks called sterigmata. It is this reproductive structure (basidium) that gives the group its name.
  Examples: *Agaricus campestris, Ustilago tritici*

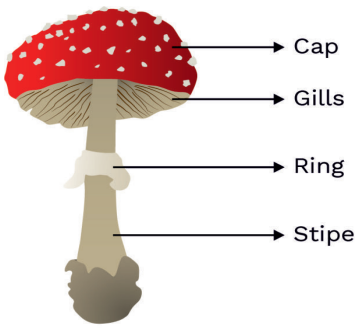


Fig: *Agaricus*

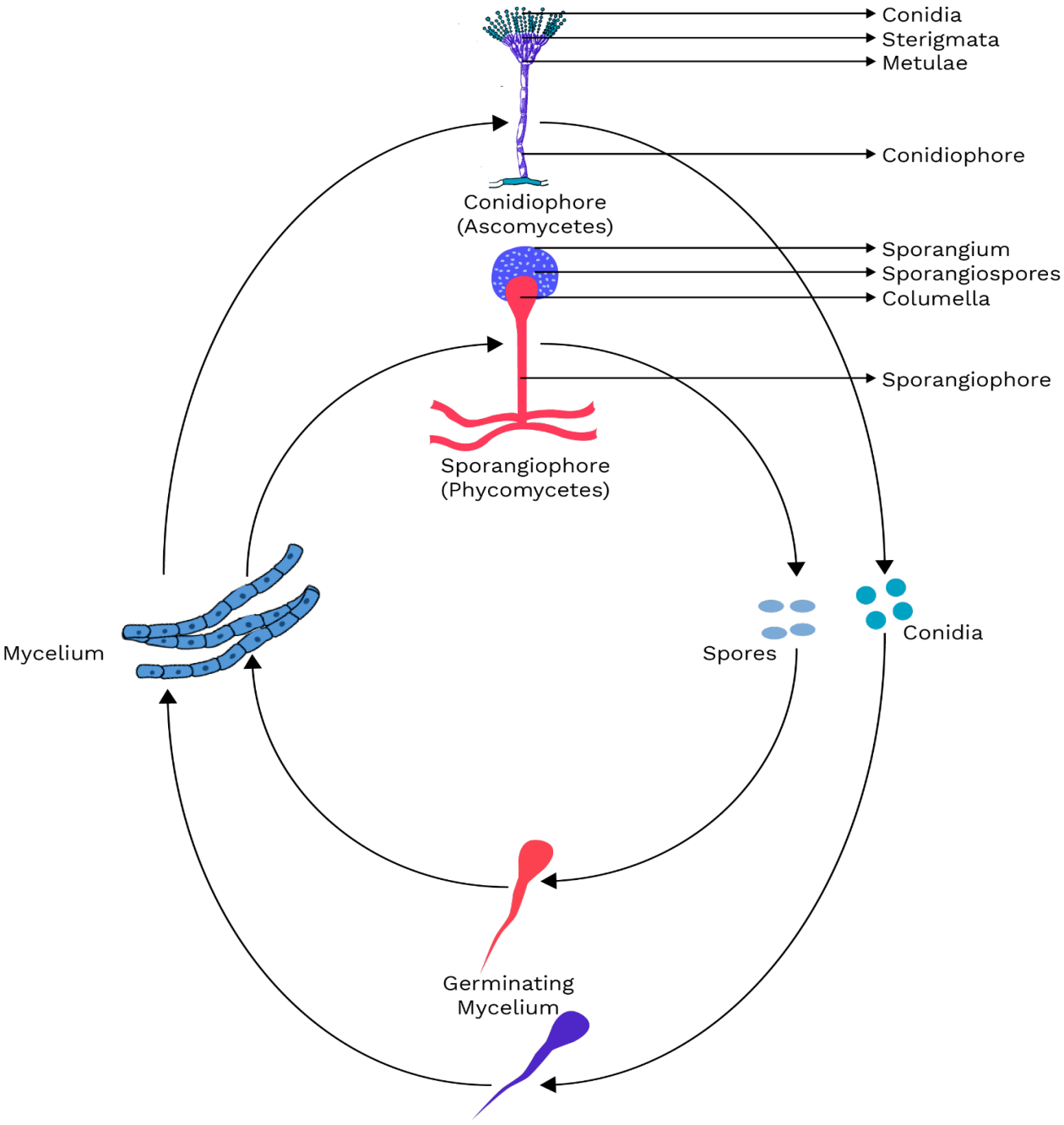


Fig: Asexual Cycle of Ascomycetes and Phycomycetes

Rack your Brain

What is the role of clamp connection in Fungi?

Deuteromycetes: Commonly known as 'Fungi Imperfecti'

Characteristics

- The group consists of all the fungi in which the sexual reproduction is not reported.
- Mycelium is septate and thus is not coenocytic. Clamp connections are absent.
- Asexual reproduction takes place by spores like conidia.

Examples: *Alternaria solani*, *Colletotrichum, Helminthosporium oryzae*

Economic Importance of Fungi

Useful activities

- Yeasts are commonly used for fermentation and in preparation of alcoholic beverages e.g., beer, wine, cider, toddy etc. Two common yeasts used in the brewing industry are *Saccharomyces cerevisiae* (Brewer's yeast) and *S. ellipsoideus* (Wine Yeast).
- Morels i.e., *Morchella esculenta* (Guchhi) has edible ascocarp.
- First antibiotic Penicillin, was discovered from *P. notatum*.
- *Neurospora crassa* is often employed in studies conducted in experimental genetics. Hence it is called 'Drosophila of Plant Kingdom.'
- Mushroom (*Agaricus)* is an edible fungus.

Harmful activities

- *Aspergillus* contaminates laboratory cultures thus known as 'weed of laboratory'. It produces Aflatoxins that are carcinogenic.
- *Rhizopus* and *Mucor* are the common saprotrophic fungi that attack a large number of foodstuffs.
- Hallucination drug LSD i.e., Lysergic Acid Diethylamide is extracted from *Claviceps purpurea*.
- They cause a number of diseases in the plants-
  - Early Blight of Potato caused by *Alternaria solani*.
  - Red Rot of Sugarcane caused by *Colletotrichum falcatum*.
  - Tikka Disease of Ground Nut caused by *Cercospora personata*.
  - Wilt of Arhar caused by *Fusarium*.
  - Ringworm/Athlete's Foot caused by *Trichophyton interdigitale*.

Rusts

- These are characterized by the formation of rusty pustules containing the spores. A basidiocarp is absent. (i) *Puccinia graminis tritici* causes black rust of wheat.
- *Puccinia glumarum* causes yellow rust of wheat.

Smuts

- These produce thick-walled, black-coloured, rusting spores called smut spores (teliospores).
- *Ustilago maydis* causes Smut of corn, *Tilletia tritici* causes bunt or stinking smut of wheat.

- *Clavic*eps *purpurea* causes 'Ergot of rye' while *C. microcephala* causes Ergot of Bajra. Eating infected cereals produces ergotism. It produces an alkaloid called 'ergotine' which can cause abortion.

Gray Matter Alert!!!

Fungal infection of plants can be treated with Bordeaux mixture: ($CuSO_4$: Ca $(OH)_2$: H_2O).
It was the first fungicide discovered by PMA Millardet.

KINGDOM PLANTAE

It comprises multicellular organisms which are commonly known as plants.

Characteristics

- These are eukaryotic and have the photosynthetic pigment chlorophyll. This pigment is present in the organelle-chloroplast. Their chloroplasts contain chlorophylls a and b.
- They obtain their energy from the sun through photosynthesis.
- The cell wall of the plants is composed of cellulose. Cellulose is composed of many glucose units combined together.
- They reproduce both asexually and sexually. Life cycle of plants show alteration of generation i.e., it has two distinct phases – the diploid sporophytic and the haploid gametophytic phase.
- Nearly all of the plants are autotrophic with some exceptions. *Cuscuta* is a plant parasite that depends on the other plants for its nutrition. Insectivorous plants like Bladderwort and Venus fly trap are partially heterotrophic.
- Plantae includes Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms.

KINGDOM ANIMALIA

The word 'Animal' is derived from the Latin word 'animalis' which means 'having breath'. A vast variety of organisms right from the sponges to the humans are included in this category.

Characteristics

- These are multicellular, eukaryotic and heterotrophic organisms and cell lacks cell wall.
- Most animals show movement and show locomotion from one place to another.
- Their mode of nutrition is Holozoic, in which the food is digested in a cavity inside the body. The extra digested food is stored in the body in the form of Glycogen.
- They respire through different organs like lungs, gills, book lungs and skin also.
- Complex animals show neuromotor mechanisms through which electric impulses pass through the body and control and coordination are taken care of.
- The sexual reproduction is by fusion of the male and female gametes followed by the embryological developments.
- Animalia includes vertebrates and invertebrates.

Viruses, Viroids, Prions and Lichens

Viruses, Virons and Lichens do not find a place in any of the classifications of the world.

Discoveries related to Viruses

- The term 'virus' meaning poison was given by Pasteur who studied canine rabies.
- D.J Ivanowsky (1892) showed that the causal organism of Tobacco Mosaic disease could pass through a bacterial filter and remained effective.
- M.W. Beijerinck (1898) ruled out the possibility of bacteria that infected the plants of tobacco. He called the fluid as "Contagium vivum fluidum" (infectious living fluid).
- W.M. Stanley (1935) isolated and crystallized Tobacco Mosaic Virus. The crystals were of proteins.

Gray Matter Alert!!!

Satellite Virus/Incomplete Virus/ Virusoids

Single stranded RNA that lacks genes required for replication. The replication of such viruses is dependent on the co-infection of the second helper virus.

- Hershey and Chase (1952) discovered that the virus proteins are non-infectious and it is the nucleic acid that carries the hereditary information.
- Twort and d'Herelle discovered Bacteriophage virus that infects bacteria.
- Viruses are considered to be at the border line of the living and the nonliving because virus can grow and multiply within the living host only and thus are considered to be living. They enter the host body and overtake the host machinery to replicate and slowly affecting the host and killing it.
- They are made up of macromolecules like protein, D.N.A or R.N.A. They are inactivated by ultraviolet rays.
- They cause disease in other living organisms.
- Some of them have the enzyme reverse transcriptase and neuraminidase. Neuraminidase is present on the surface of influenza viruses that enables the virus to be released from the host cell.

Virus lacks protoplasm and can be crystallized. There is no respiration, lack of energy and storage system. Growth and division are absent, They are inert outside the host body.

These properties show us that they have the features of both living and nonliving things. Thus they are considered to be at the borderline of the living and the nonliving.

Characteristics

- These are non-cellular and can pass through the bacterial filters.
- They cannot be grown on artificial media.
- They behave as a living host within a host body.
- They can mutate and forms new strains in nature.
- They are obligate parasites.
- The nucleic acid is enclosed by the protein coat called as capsid which protects it. The capsid is made up of many small units called as capsomeres. The capsomeres are arranged in a helix or polyhedron. The nucleic acid can be RNA or DNA. Plant viruses usually have single stranded RNA and animal viruses

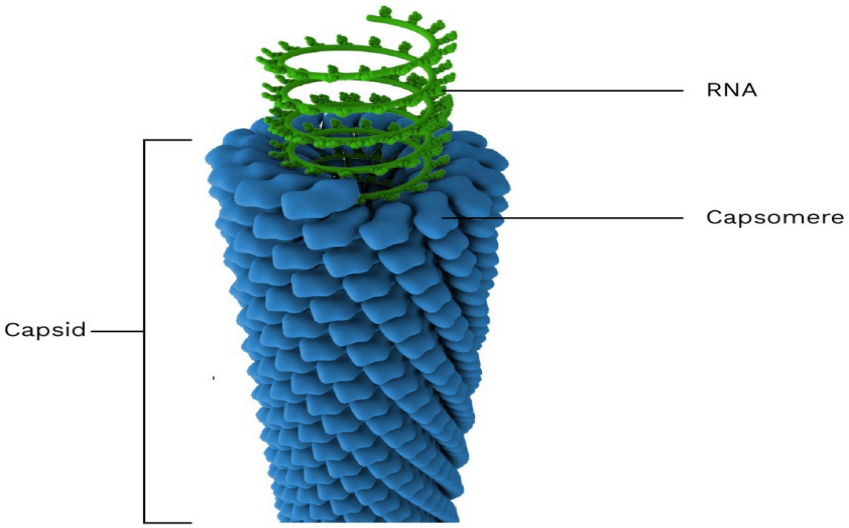


Fig: Tobacco Mosaic Virus

Definition

Obligate parasite: Organism that cannot live without a host.

have single and double stranded RNA or double stranded DNA.

Examples:

- Double stranded DNA-Poxvirus, Herpes simplex (animal)
- Double stranded RNA-Reovirus (animal)
- Single stranded RNA-Poliovirus (animal)

Exceptions:

- Single stranded DNA- Parvovirus, S-13 (animal)
- Double stranded RNA-Wound Tumour Virus (plant)
- Viruses that infect the bacteria are known as bacteriophages. They are generally double stranded DNA viruses. The bacteriophage shows lytic and lysogenic cycle.

Rack your Brain

Some viruses get surrounded by a membranous envelope. Where does this envelope originate from?

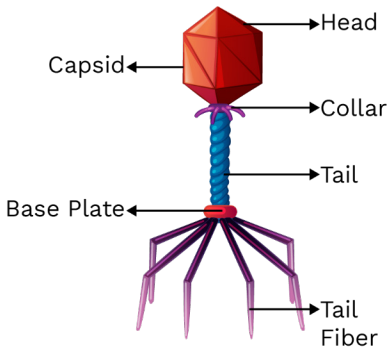


Fig: Bacteriophage

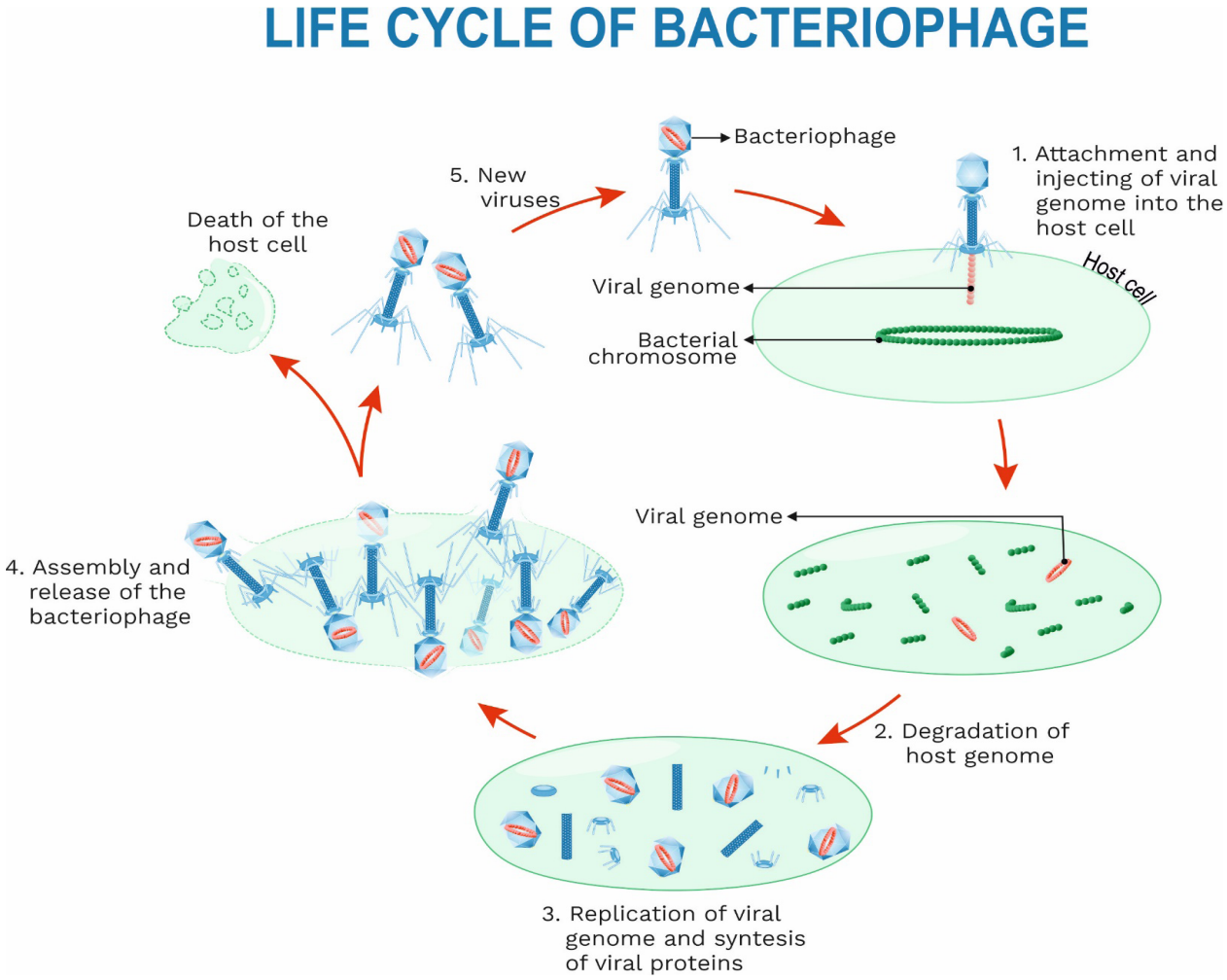


Fig: Lytic cycle of Bacteriophage

LYTIC CYCLE

- It occurs in T phage. The phage adsorbs on the specific receptor sites on the wall of the host bacterial cell with the help of tail fibres.
- The lysozyme secreted by the phage lyses the cell wall, the tail sheath contracts and the phage DNA is inserted into the bacterial cell. After this, the protein shell of the phage is discarded.
- The phage DNA replicates inside the bacterial cell. The phage DNA also controls the protein synthesis machinery of the bacterial cell. This process requires a number of enzymes which are synthesised and later protein coat of the phage is formed.
- The DNA of the phage is also synthesised and then both protein and DNA are assembled. The head is assembled first and then the tail is added.

- The phenomenon of assembling the viral components is known as maturation.
- The enzyme of the phage acts on the host cell wall causing its lyses, releasing a large number of phages.

Lysogenic Cycle

- It occurs in the Lambda phage attacking the *E. coli*. In this cycle, the phage does not multiply and the cell does not lyse.
- The phage adsorbs to the receptor sites of the bacterial cell and its DNA is transmitted into the host cell.
- The phage DNA integrates with the bacterial DNA and this integrated state is known as Prophage. The phage replicates and multiplies. This is known as lysogeny.
- The phage DNA may break away from the host genome and this dissociation is known as induction. This separated phage shows the lytic cycle and the bacterial cell lyses releasing the phage.

Virus causes diseases in plants and animals. In plants, symptoms of viral diseases are stunting, reduction in leaf size, leaf curling, leaf rolling, yellowing and ring spots. E.g., In plants, it causes Bunchy top of Banana, Leaf curl of Papaya, Tobacco Mosaic, Vein clearing in ladyfinger, Potato leaf roll.
In animals, the virus causes Pneumonia in Pigs, Rabies in dogs, Foot and mouth disease. In humans it causes Mumps, Dengue fever, Herpes, Influenza, AIDS.

Rack your Brain

There is no vaccination for common cold. What is the reason for it?

Viroid

The term Viroid was given by Diener (1971) for the organisms that are the smallest known disease causing agent. They cause potato spindle tuber disease. They usually infect higher plants only. The protein coat is absent and hence the name viroid. The RNA is free and has a low molecular weight.

Prions

It was first discovered by Prusiner (1982). It is an infectious, proteinaceous particle. There is no nucleic acid. It causes the Mad cow disease and Kuru and Creutzfeldt –Jakob disease in humans.

Lichens

Theophrastus was the first person to use the word 'Lichen'. Lichens are a symbiotic association between algae and fungi. Both the individuals are benefited from the association. The fungi provide shelter, absorbs water and nutrients for the algae and algae in return prepares food. The algal component is known as Phycobiont or photobiont and the fungal component is known as Mycobiont. The algae present in the association can be Myxophyceae or Chlorophyceae and the fungi present can be Ascomycetes, Basidiomycetes or Deuteromycetes.
Fungi provide structure and help in absorbing water and nutrients while algae due to the presence of chlorophyll help in the production of food by photosynthesis.
They are the pioneer of vegetation on a rocky surface. They are the bioindicators of air pollution especially of Sulphur

Dioxide. Sulphur dioxide affects the structure of the chlorophyll molecule and thus preventing photosynthesis and killing the algae and affecting the lichens.

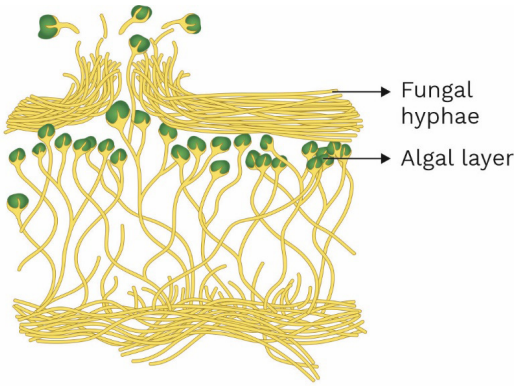


Fig: Symbiotic Association – Lichen

Types of Lichens

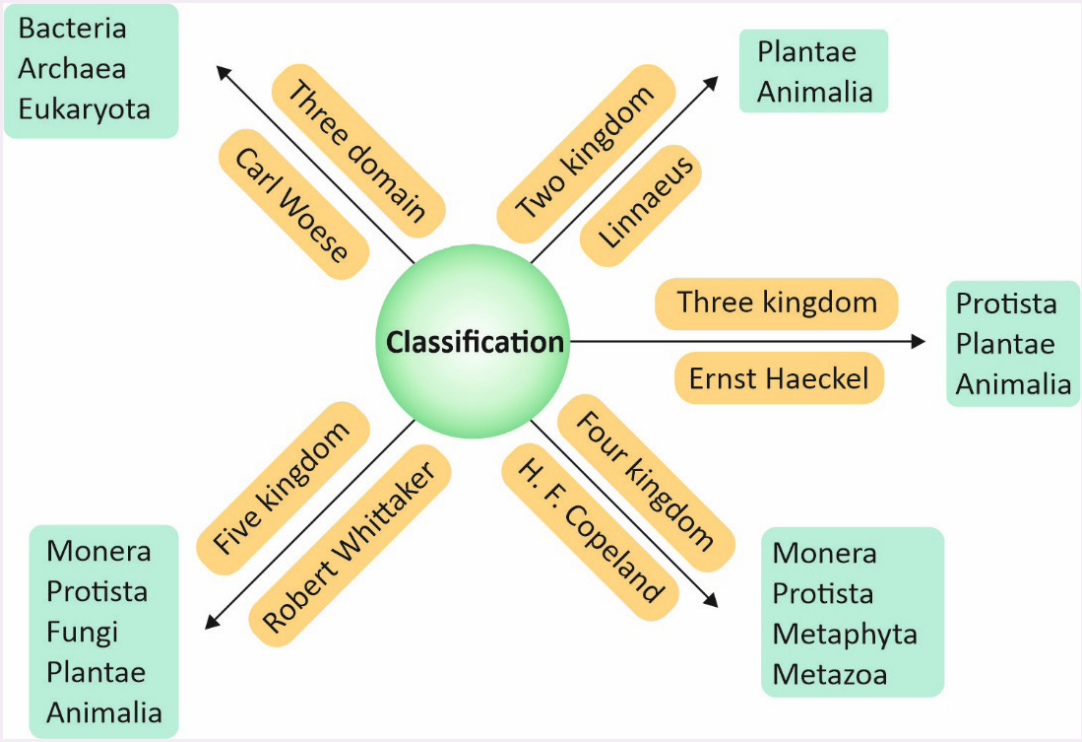
These are of the following types on the basis of thallus organisation-

- **Crustose-** These are thin and flat lichens occurring on the rock or bark. Example: *Rhizocarpa, Lecanora*
- **Foliose-** These are leafy, lobed and dorsoventrally flattened lichens. Example: *Parmelia, Peltigera*
- **Fruticose-** These are branched with upright organization. Example: *Cladonia, Usnea*
- On the basis of the distribution of algal component, the lichens are divided into two types-
- **Homoiomerous-** The algal and fungal partners are uniformly distributed. They are also known as endogenous. Example: *Collema*
- **Heteromerous-** The algal component is present on the upper side. They are also known as exogenous. Example: *Parmelia*

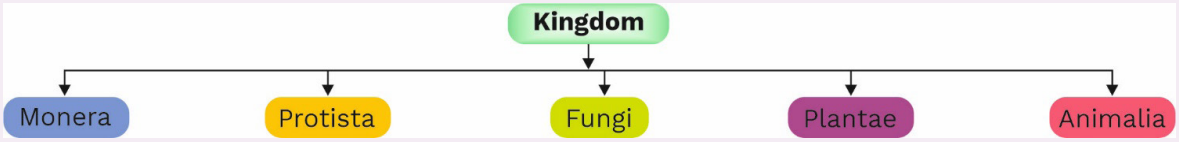
Economic Importance of Lichens

- These are pioneer species on barren rocks and help in the weathering of rocks to form soil.
- Some lichens like *Cladonia* (Reindeer moss) and *Cetraria* (Iceland moss) are used as food. *Evernia* and *Parmelia* are also edible. *Parmelia* and *Lecanora* are used as fodder.
- *Cetraria islandica* is used to cure respiratory diseases. *Usnea barbata* is used to treat urinary problems Usnic acid present in *Usnea* is a broad spectrum antibiotic.
- Lichens contain lichenin and are used for preparing alcoholic drinks.
- *Evernia* and *Ramalina* contain essential oils and thus are used to make soaps and perfumes.
- Litmus used as an acid base indicator is obtained from *Roccella montagnei* and *Lasallia pustulata*.
- Lichens form an important component of hawan samagri and scented stick.

Summary

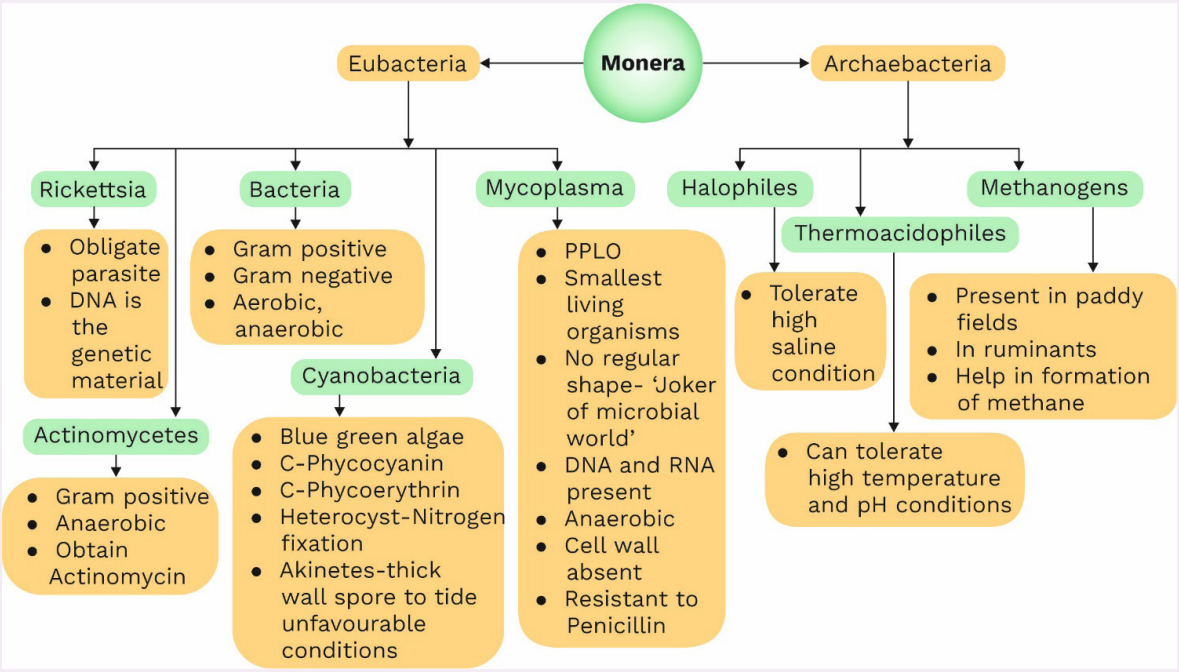


Classification of Organisms



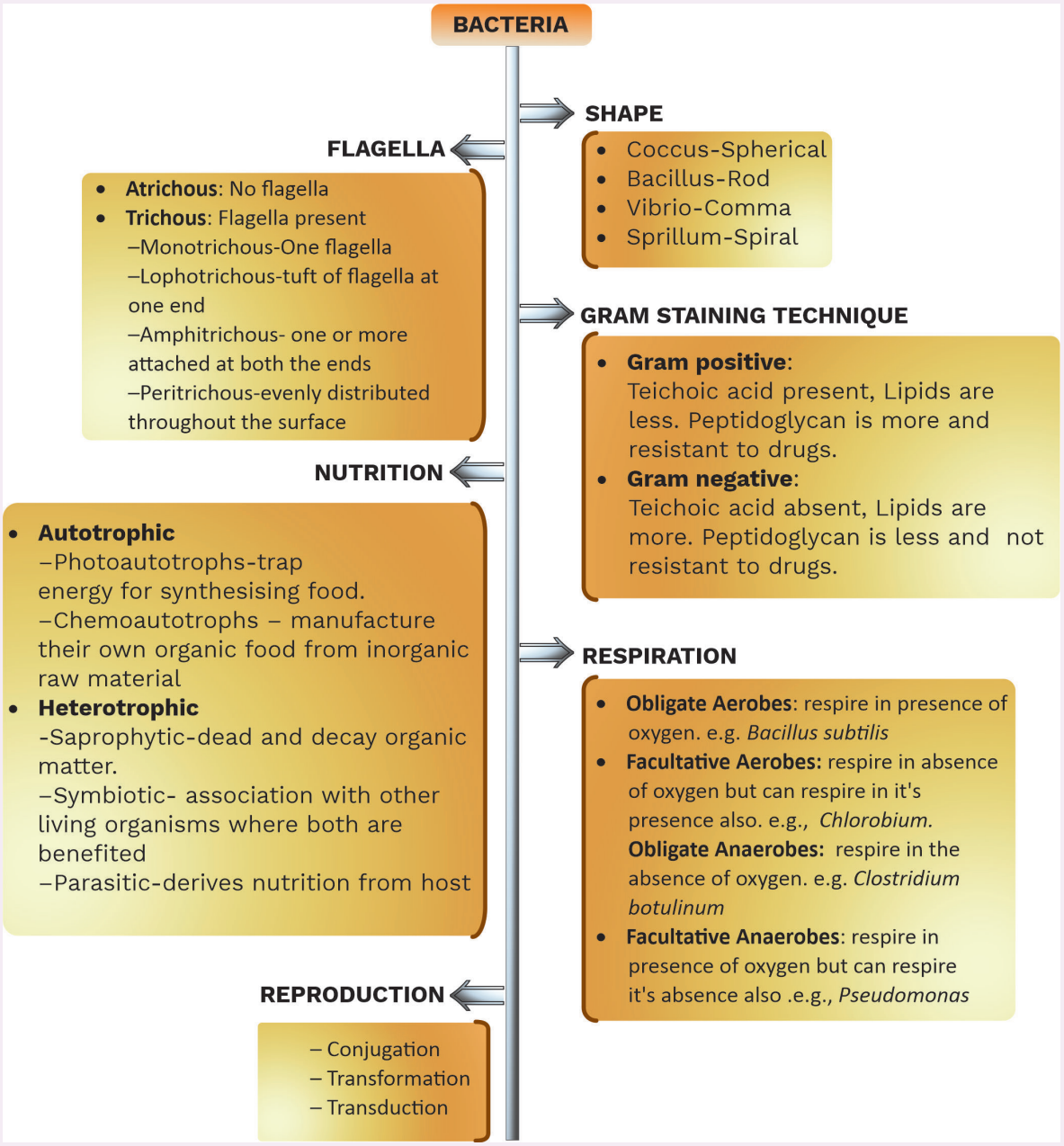
Five Kingdom Classification

Summary



Kingdom Monera

Summary



Characteristics of Bacteria

Summary

Protista

Chrysophyta

- Diatoms – Diatomaceous earth made up of silica.
- Chief producers in the ocean.

Dinoflagellate

- Flagella – 1 groove, 1 transverse
- *Gonyaulax* – causes red tides, secretes toxins that kill marine life.

Euglenoids

- Flagella – one short, one long
- Pellicle layer – proteinaceous
- Mixotrophic

Slime mould

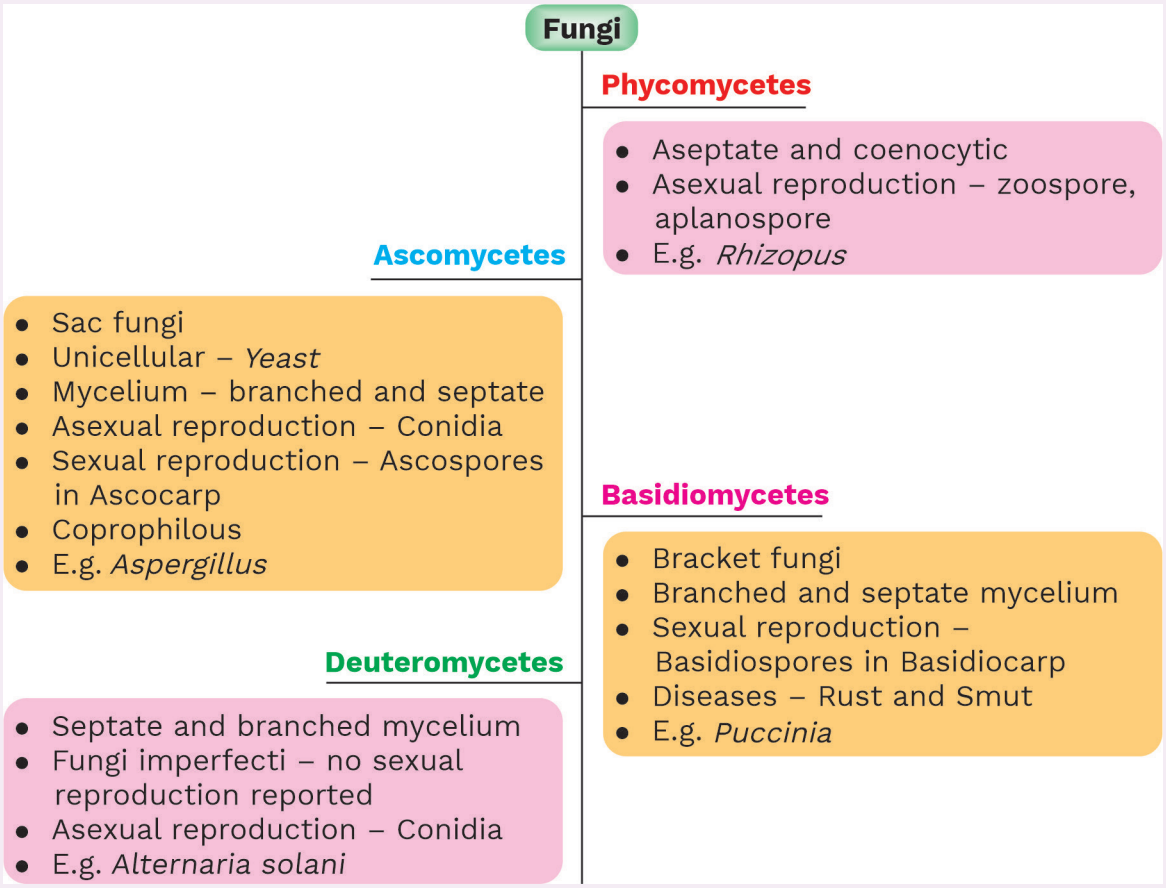
- *Plasmodium* – favorable conditions
- Fruiting bodies produce spores in unfavorable conditions

Protozoan

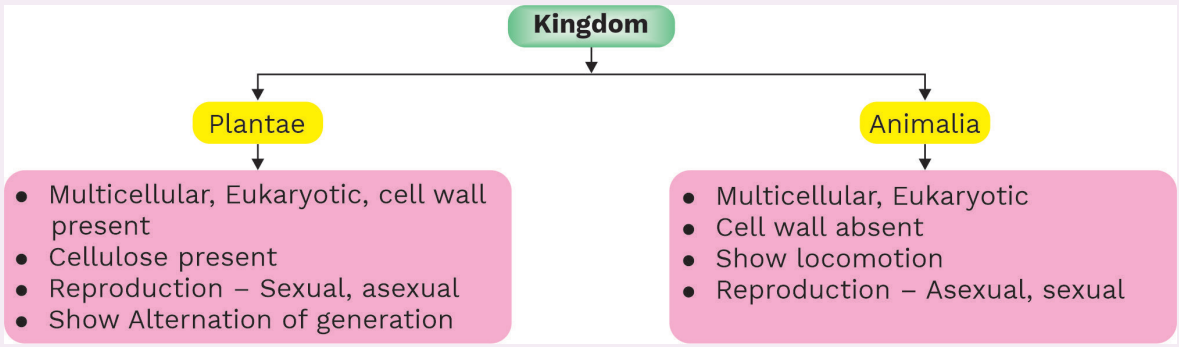
- Unicellular
- Amoeboid – *Amoeba*
- Flagellated – *Trypanosoma*
- Ciliated – *Paramoecium*
- Sporozoan – *Plasmodium*

Kingdom Protista

Summary



Kingdom Fungi



Kingdom Plantae and Animalia

SOLVED EXERCISE

Q1 **The causal organism for African sleeping sickness is-**
(1) *Entamoeba histolytica* (2) *Giardia* (3) *Leishmania* (4) *T. gambiense*

A1 (4)
Trypanosoma gambiense was first observed by Forde in 1901.

Q2 **Lichens indicate SO_2 pollution because they**
(1) show association between algae and fungi
(2) grow faster than others
(3) are sensitive to SO_2
(4) flourish in SO_2 rich environment

A2 **(3)**
As the algal component dies and thus the components of lichens dissociate.

Q3 **Which nucleus is vegetative in nature in *paramecium*?**
(1) micronucleus (2) macronucleus (3) both micronucleus (4) none of these

A3 **(2)**
Macronucleus is vegetative in *paramecium*.

Q4 ***Escherichia coli* is used extensively in biological research as it is-**
(1) easily cultured (2) easily available (3) easy to handle (4) easily multiplied in host

A4 **(1)**
It can multiply easily in the laboratory conditions.

Q5 **Non-photosynthetic, aerobic nitrogen fixing soil bacterium is-**
(1) *Rhizobium* (2) *Clostridium* (3) *Azotobacter* (4) *Klebsiella*

A5 **(3)**
A non photosynthetic, aerobic nitrogen fixing soil bacterium is *Azotobacter*.

Q6 **Mycorrhiza exhibits the phenomenon of**
(1) parasitism (2) symbiosis (3) antagonism (4) endemism

A6 **(2)**
Association between roots of higher plants and fungi, where both are benefitted, thus it is a symbiotic association.

Q7 **Columella is a specialized structure found in the sporangium of**
(1) *Spirogyra* (2) *Ulothrix* (3) *Rhizopus* (4) None of these

A7 (3)
Dome shaped, sterile portion in the sporangia. It helps in the dispersal of spores.

Q8 **The site of respiration in bacteria is-**
(1) ribosome (2) microsome (3) episome (4) mesosome

A8 (4)
Mesosomes are formed by the infoldings of the membrane and have enzymes for respiration.

Q9 **Viruses possess**
(1) ribosomes to synthesize protein (2) organelle for its vital mechanism
(3) either DNA or RNA (4) none of these

A9 **(3)**
Viruses always contain only a single kind of nucleic acid. It can be either DNA or RNA.

Q10 **An important criterion for modern day classification is-**
(1) resemblances in morphology (2) anatomical and physiological traits
(3) breeding habits (4) presence or absence of notochord

A10 **(2)**
With the advancement of microscopes, the anatomical details were well understood that helped in classification.