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rapid BIOLOGY

Crash Course for Peak Performance

- HIGH YIELD FACTS
- EASY TO GRASP
- ESSENTIAL BIOLOGY FOR COMPETITIVE EXAMS

Contents

Nature & Scope of BIOLOGY

WHAT IS BIOLOGY

Biology, the word comes from Greek *bios* meaning life and *logos* meaning thought or science of, can be defined as the study of various aspects of living beings (plants and animals). Biology is the study of life from the simplest forms of plants and animals (including one-celled animals and algae) to highly complex structures of the human being. It includes the study of how organisms are structured as well as how they function and relate to each other. Biology is also called **life science** as it makes to understand how living things perform their life activities and interacts with the other living and non-living things. Main branches of biology are **botany, zoology** and **microbiology. Pure biology** is concerned with gaining fundamental knowledge of the subject and studied only for better understanding of natural phenomenon. It has no direct practical application in human welfare, eg. taxonomy, physiology etc. **Applied biology** is related to well being of mankind and is directly beneficial economically. Some of the main branches of applied biology are agriculture, animal husbandary, sericulture, poultry, genetic engineering, breeding, biotechnology, bioinformatics etc.

Table : Branches of biology

Branch of Biology	Definitions
Agriculture	The study of how best to grow and improve crops.
Horticulture	Development and management of orchards and gardens.
Apiculture	The rearing of bees especially for commercial purpose.
Sericulture	The breeding and treatment of silkworms for raw silk.
Anthropology	The study of physical and mental constitution of man with social conditions exhibited both in the present and the past.
Entomology	The study of insects.
Medicine	The study of structure and functioning of the human body and mind in sickness and health.
Agronomy	Branch of agricultural science which deals with the study of crops and soils.
Soil Science	Study of structure, types and dynamics of the soil.
Breeding	To produce or procreate improved varieties by selective mating.
Veterinary Medicine	Deals with the diseases of domesticated animals and their health care.
Fishery	Occupation or industry of catching fish or other products of the sea, lakes or rivers.
Poultry Science	Deals with study of domestic fowls such as chickens, ducks and geese.
Forestry	Science of developing, cultivation and conserving forests.
Dairy Technology	Application of science for the manufacture of milk products.
Microbiology	Science that deals with the structure, function, uses etc. of microscopic organisms.
Pharmacy	Science that deals with preparing and compounding medicines and dispensing them according to the medical prescriptions.
Pharmacology	Science that deals with the knowledge of drugs and preparation of medicines.

Forensic Science	Application of scientific knowledge to questions of civil and criminal law (includes use of finger-prints, blood typing, identification of narcotics etc).
Surgery	Surgery involves physical operations to cure diseases or injuries to the body.
Human Reproductive Biology	Science of understanding and regulating reproduction.
Nutrition	Study of the nourishment of human beings or other organisms.
Physiotherapy	Science of treatment of diseases, bodily weaknesses or defects by physical remedies such as massage and exercise.
Occupational Therapy	A method of treatment of convalescents and the physically handicapped utilising light work for diversion, physical exercise or vocational training.
Genetic Engineering	Science that involves manipulations at gene level so as to produce an organism with a new combination of inherited properties.
Biomedical Engineering	Science for production of spare parts for man, implants, artificial limbs, heart lung machines etc.
Food Technology	Application of science for processing and preservation of foods.
Silviculture	Management of useful forest.
Olericulture	Cultivation of vegetables.
Anatomy	Internal structures of living organisms.
Biochemistry	Science connected with chemistry (composition, chemical nature, mode of formation, functioning) of living matter.
Biogeography	Distribution of organisms on various parts of earth.
Cytology	Structure and functions of cells and their organelles.
Ecology	Relationship between organisms and environment.
Embryology	Development stages of organisms up to hatching or birth.
Endocrinology	Endocrine glands and hormones.
Evolution	Origin of life and the gradual differentiation or descent of species.
Eugenics	Factors related to improvement of human race.
Exobiology	Life on other planets.
Genetics	Heredity and variations.
Histology	Tissues by microscopy.
Immunology	Resistance of organisms to infection.
Limnobiology	Fresh water lakes, ponds and streams.
Morphology	External shape of living organisms in contrast to function.
Molecular biology	Physio-chemical organization of biomolecules.
Palaeontology	Fossils and their distribution in time.
Palaeozoology/Palaeobotany	Fossil animals/fossil plants.
Physiology	Functions of various organs within the organisms.
Psychology	Behaviour and working of mind.
Parasitology	Parasitic organisms.
Pathology	Diseases and their control.
Radiobiology	Effects of radioactivity on life.
Taxonomy	Classification of organisms and their evolutionary relationship with other organisms.
Teratology	Malformation or birth defects.
Zoogeography	Distribution of animals over the earth.
Zoopathology	Diseases of animals.

RELATIONSHIP OF BIOLOGY TO OTHER SCIENCE

In order of study biology one has to understand and know other sciences like physics and chemistry as well. Because our present knowledge of biology has reached to such an extent that it has become a multidisciplinary branch of science involving participation of the fundamental knowledge of all the basic sciences.

Structure/ Mechanism Studied	Example	Related Science	Knowledge of other sciences is required because
Cell membrane	Structure of lipids, and proteins	Chemistry	Living organisms are made up of inorganic and organic compounds.
Transportation of O_2 in body	Formation of oxyhaemoglobin	Chemistry	All metabolic pathways involve chemical changes.
Excretory system	Absorption and elimination of salts	Chemistry	Homeostasis involves acid-base equilibrium to maintain pH of living organism.
Absorption of food/water	Absorption of sugars amino acids, fatty acids, water or salts	Chemistry	During diffusion and osmosis molecules move in and out of cells.
Transportation of water in plants	Conduction of water from root to leaves	Physics	Liquids have certain properties like cohesion and adhesion that result in surface tension and capillary action which help in certain processes.
Release of energy during respiration	Electron transport chain	Chemistry	Energy transfer and transformation are important in all the living cells.
Effect of light on flowering	Absorption of different wave lengths of light	Physics	Light induces definite pattern of responses in plants and animals.

Similarly other branches also have relationship with Biology in their particular characters like –

- Geography – Required for studying the distribution of organisms.
- Climatology – There is an intimate relationship between distribution and adaptations of organisms with the climate of the area.
- Geology – Study of palaeobiology and soil types cannot be carried out without the knowledge of geology etc.

UTILITY OF STUDY OF BIOLOGY

The scope and application of biology is quite vast. Its study provides a necessary knowledge and perfect understanding about almost all the spheres of life, its requirements and the various ways by which they can be fulfilled.

Study of biology is connected with the following objectives.

- To help us to understand ourselves better. It explains the basic concepts like structure and functions of cells, organs and organ systems. It explains about heredity *i.e.*, why do we resemble our parents and why are we different. It helps us to answer the basic questions about ourselves like what happens during sleep, when we eat food, when we get hurt, and how do we remember things etc.
- To help us to meet our needs by utilising the sources available. The knowledge of medicine, surgery, crops rotation, animal husbandry help us to cure diseases and improve the quality of plants and animals. Meeting our basic requirements of food, clothing and shelter.
- To acquaint us with the fundamentals of nutrition, health and population control. To have a scientific approach while solving problems.
- To enlighten us about our place in the universe. It helps us to understand that man is only a small part of the living system and we have a responsibility to protect and respect other living things on earth.

- To increase the awareness of the inter-relationships of organism with the environment. It makes us aware about the threat that lies before us if the natural resources are not taken care of. It helps us to identify measures to overcome them.
- To warn us about health hazards due to indiscriminate use of pesticides, fertilizers, cutting of forests, depletion of the ozone layer, dumping of radioactive wastes in water, discharge of pollutants in air and water and wastage of our natural resources.
- To help us overcome the superstitions and to remove the biases of sex, race and colour.
- To enable us to enjoy nature and appreciate the rich, varied life of living things on earth.

BIOLOGY : SCIENCE OF EXCEPTIONS

Physical sciences are governed by a set of laws, such as the laws of gravity, magnetism, thermodynamics and so on. Biology, however, is a science which have many exceptions. This is due to the fact that it deals with living organisms which show enormous variations and are capable of change. **Some of the common exceptions** are given below.

- DNA is the hereditary material in all living organisms except in some plant viruses such as Tobacco mosaic virus where RNA is the hereditary material.
- RNA is usually single stranded but in Rheovirus it is double stranded.
- DNA is normally double stranded except in some viruses in which it is single stranded.
- Most roots grow towards the centre of gravity but in mangrove plants (*Rhizophora*) the roots are negatively geotropic.
- *Cuscuta* (Amerbel) is classified as dicotyledonous plant but lacks cotyledons.
- Normally the roots lack chlorophyll and are non-green but the assimilatory roots of Tinospora (Gilo) contain chlorophyll, are green and perform the function of photosynthesis.
- The venation in monocot leaf is as a rule parallel but in *Smilax* (a monocot plant) the leaf show reticulate venation.
- Stem is the part of plant above the ground but potato, corn and ginger are underground stems.
- Most plants follow Calvin cycle during dark phase of photosynthesis but sugarcane follows Hatch Slack cycle.
- All living cells have a nucleus except red blood cells (RBC) of mammals.
- RBCs of mammals are without nucleus excepts those of camel.
- Blood of all vertebrates is red due to the presence of a pigment-haemoglobin but in a shark (*Carcharhinus*) it is colourless.
- The heart of all reptiles is three chambered but in crocodile it is four chambered.
- Birds fly, but some birds like Kiwi and Ostrich are unable to do so.
- Lungs, as a rule are absent in fishes, but some fishes the *Protopterus* possess lungs as well as gills.
- Larval stage in the life history of an animal is not capable of sexual reproduction sexually before they change into adults.
- All mammals give birth to young ones (viviparous) but some primitive mammals like Duck billed platypus and spiny ant earter (*Echidna*) lay eggs (oviparous).
- All land inhabiting animals drink water but Kangaroo rat never drinks water.
- *Lacerta saxicola*, a kind of lizard found in Caucasian region of Soviet Union has only females but no males.

A student of biology must be prepared to accept exceptions. Some exceptions has been explained. In other cases the reasons for the exceptions are still no known. It is worth noting that the quantum of unexplained phenomena in biology is much larger than in any other natural science.

SERENDIPITY

Discoveries of important facts by chance unexpectedely, intuition and thoughts without making well planned conscious effect are called serendipity.

Some of the examples of serendipity are –

- **Discovery of antibiotic – Penicillin : Alexander Fleming** (1881-1955) was culturing the bacterium – *Staphylococcus* (the causal organism infection) in Petri dishes on agar medium. He found that one of his culture plate was contaminated by blue-green mould – *Penicillium notatum*. Such a contamination in laboratories was not new. Normally such contaminated cultures are discarded but Fleming retained it and observed minutely. To his surprise, he noticed that fungal growth inhibited in those areas where fungus was growing. By flash idea Fleming poured the extract of fungus over fresh bacterial cultures and found that even the extract inhibited the bacterial growth. This curious observation **led the discovery of the most important antibiotic – Penicillin**.
- **Law of Gravitation : Newton** was simply sitting in the garden when an apple fell on the ground. He started thinking about the cause of its fall and came to a conclusion that some force is present in the earth which attracts everything towards it. This observation led the formation of **Newton's law of gravitation**.
- **Structure of Benzene ring :** Chance observation of snake licking its tail led the discovery of ring – structure of benzene by **Kekule**.
- **Archimede's Principle :** While taking bath he came to the conclusion that a body which is immersed partially or completely in a liquid, experiences an up thrust equal to the weight of the liquid displaced by it. This led to the discovery of principle of floatation by Archimedes.

Table : Fathers of Biology

Antibiotics	Alexander Fleming (1881-1955)	Histology	Xavier Bichat (1771-1802)
Ayurveda	Charaka	Homeopathy	Hahnemann (1755-1843)
Bacteriology	Antony Van Leeuwenhoek (1632-1723)	Immunology	Edward Jenner
Biochemical genetics	Archibald Garrod	Indian palaeobotany	Birbal Sahni (1891-1949)
Biochemistry	Justus vol Liebig (1803-73)	Medicine	Hippocrates (460-377 BC)
Biology	Aristotle (384-322 BC)	Microbiology	Antony Van Leeuwenhoek
Blood circulation	William Harvey (1578-1657)	Microbiology	Louis Pasteur (1822-1895)
Blood groups	Karl Landsteiner	Microscopic Anatomy	Marcello Malpighi (1628-1694)
Botany	Theophrastus (372-287 BC)	Microscopy	Antony Van Leeuwenhoek
Chromatography	Micheal Tswett	Modern embryology	Von Baer (1792-1876)
Comparative anatomy	Georges Cuvier (1769-1832)	Modern genetics	William Bateson (1861-1926)
Cytology	Robert Hooke (1635-1703)	Modern palaeontology	Georges Cuvier (1769-1832)
ECG	Einthoven	Palaeontology	Leonardo da Vinci
Ecology	Theophrastus (370-285 BC)	Parasitology	Platter
Embryology	Aristotle	Protozoology	Antony Van Leeuwenhoek
Endocrinology	Thomas Addison (1793-1860)	Science	Aristotle
Eugenics	Francis Galton	Surgery	Susruta
Experimental genetics	Thomas Hunt Morgan (1866-1945)	Taxonomy	Carolus Linnaeus (1707-1778)
Gene Therapy	Anderson	Tissue culture	Harrison
Genetic engineering	Paul Berg	Virology	Wendell M. Stanley
Genetics	Gregor Johann Mendel (1822-1884)	Zoology	Aristotle

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Chapter 1

Systematics

- **Systematics** is the study of the historical relationships of groups of biological organisms – the recognition and understanding of biodiversity.
- The term systematics was coined by **Linnaeus (1735)**.
- The terms systematics, taxonomy and classification are often held as **synonyms but technically they carry different meanings.**
- **G. Simpson** (1961) has distinguished the three terms.
- **Taxonomy** is the branch of study which deals with **identification, nomenclature** and **classification of organisms**.
- Term taxonomy was first given by French botanist **A.P. de Candolle** (1778-1841) for the theory of plant classification.
- Taxonomy is also called **systematic botany**.
- **Carolus Linnaeus** is called **father of taxonomy**.
- **H. Santapau** is called the **father of Indian taxonomy**.
- Taxonomy is of **three types – alpha (α) taxonomy, beta (β) taxonomy** and **omega (ω) taxonomy**.
- When only morphological characters are used for identification and classification of plants then it is called **alpha taxonomy**.
- β-taxonomy involves **genetical, anatomical cytological, palynological, physiological and other characters**.
- β-taxonomy is also called **biosystematics**.
- α and β taxonomy terms were given by **Turill**.
- Analysis and synthesis of all information and types of data to develop classification system based on phylogenetic relationships is called **omega taxonomy**.
- **Classification** is the placing of an organism or a group of organisms in category according to a particular system and in conformity with a nomenclature system.
- **Aristotle (father of zoology)** made the first recorded attempt to classify the animals in his book *Historia Animalium*.
- Aristotle made two main groups - **anaima** (animals with no RBC, invertebrates) and **enaima** (animals with RBC, vertebrates).
- **Theophrastus** (372 - 287 BC), referred to as **father of botany**, classified plants on the basis of form and texture and described 480 plants in his book *Historia Planatarum*.
- **Identification** is to determine the exact place or position of an organism in the set plan of classification. Identification is **carried out with the help of taxonomic keys**.
- A **key** provides a convenient way for easy identification of an organism by applying **diagnostic or distinguishing characters**.
- Taxonomy **discovers and describes new species**, while systematics **uses evolutionary relationships** to understand biogeography, coevolution, adaptation and options for biological conservation.
- **Systematists or taxonomists** are thus the scientists whose expertise provides the data about the identification, description, distribution and relationship of life on Earth.
- **New systematics or biosystematics** is concept of systematics which brings about taxonomic affinity on the basis of evolutionary genetic and morphological traits.
- **Julian Huxley (1940)** proposed the term **new systematics**.

Table : Types of taxonomy

Cytotaxonomy	based on cytological study
Karyotaxonomy	based on nucleus and chromosomes
Morphotaxonomy	based on morphological characters
Biochemical taxonomy	based on biochemical studies
Chemotaxonomy	based on specific chemicals like secondary metabolites
Numerical taxonomy (also called adansonian taxonomy)	based on statistical methods
Experimental taxonomy	based on experimental determination of genetical inter-relationships and role of environment in their formation

Nomenclature

- **Nomenclature** is giving distinct scientific names to various structures including living organisms, for their identification.
- Biological nomenclature is of **two types - vernacular** and **scientific**.
- Common names by which plants and animals are known in their regional places are called **vernacular names**.
- The vernacular name or common names are **based on some peculiarity of the organisms**, eg. Kandiali (a plant having spines).
- **Scientific name** are names given to organisms based on agreed principles and criteria for their acceptability all over the world.
- Scientific names are distinct and specific, they **have particular spellings which are not changed**.
- **Three types of nomenclature** are – **polynomial, trinomial** and **binomial nomenclature**.
- **Polynomial nomenclature** was the **first scientific attempt at nomenclature**, in which an organism is given a name consisting number of words that incorporate all its important characteristics. Eg. *Caryophyllum saxatilis folis gramneus umbellatis corymbis* which means caryophyllum growing on rocks, having grass like leaves and umbellate corymb flowers.
- **Trinomial nomenclature** is a taxonomic naming system that extends the standard system of binomial nomenclature by adding a third taxon. It is used in biology when the organisms within a species fall into separate groupings that need to be distinguished.
- Trinomial nomenclature is **different for animals** and **plants**.
- In animals **trinomen** or **trinominal** name **refers to the name of a subspecies**.
- **Trinomen** is a name **consisting of three names** – **generic name**, **specific name** and **subspecies name**. All three names are typeset in italics and **only the generic name is capitalised**. Eg. *Buteo jamaicensis borealis* is one of the subspecies of the red tailed hawk (*Buteo jamaicensis*).
- For plants trinomial nomenclature provides three part name (**ternary name**) for any taxon below the rank of species.
- **Binomial nomenclature** is a system of providing distinct proper scientific names to organisms with each name consisting of two words, **generic** and **specific**.
- Binomial nomenclature was **developed by Linnaeus** (a swedish biologist) who gave certain principles (called **Linnaean principles**) for this in his book *Philosophica Botanica* (1751). The standard references recognised for this are *Species Planatarum* (1733) and *Systema Naturae* (1758).
- According to binomial system, each organism is given a name made of **two Latin words**.
- For nomenclature the Latin language is used because **it is the dead language and no changes are supposed to occur in it**.
- Binomial system of nomenclature was introduced by **Gaspard Caspar Bauhin (1956)**. But he did not follow it scrupulously.
- Binomial names are of **universal application** for all the countries and languages.
- The **names indicate relationship of a species with others present in the same genus**.
- In binomial nomenclature following **rules are applicable**.
  - Name consist of two words – first word represents **the genus** and is **called generic name (generic epithet)**, whereas the second word represents the **species** called the **specific name (specific epithet)**.
  - The **generic epithet** always starts with **capital**

letters & **specific epithet** starts with **small letter**.
- Both these name must be **underlined separately (if handwritten) or italised (if printed)**.
- **No comma, hyphen etc**. between specific and generic name is used.
- To the two word, name is appended the name of taxonomist who discovered the organism and provided with a scientific name, *e.g., Ficus bengalensis L*, *Homo sapiens L.*
- The different names given to same species by different workers are called **synonyms**, but the name given first is considered to be valid.

- The foundations of **International Code of Botanical Nomenclature (ICBN)** was found in **Philosophia Botanica**, a book written by **C. Linnaeus**. Current code of botanical nomenclature appeared in **1978**.
- Botanical nomenclature is **independent of zoological and bacteriological nomenclature which are governed by their own code**.

Some important abbreviation		
ICBN	–	International code of botanical nomenclature
ICZN	–	International code of zoological nomenclature
ICBacN	–	International code of bacteriological nomenclature
ICVN	–	International code of viral nomenclature
ICNCP	–	International code of nomenclature for cultivation plants

Types of specification

- The particular illustration designed by author of the species to represent the type of species is called **holotype**.
- A specimen which is a duplicate of the holotype, collected from the same place, same time and by the same person is called **isotype**.
- Any one of the two or more specimens cited by the author when no holotype was designated, or any one of the two or more specimens simultaneously designated as types is called **syntype**.
- A **paratype** is a specimen cited in the protologue that is neither the holotype nor an isotype, nor one of the syntypes if two or more specimens were simultaneously designated as **types**.
- A specimen or other element selected from the original material cited by the author when no holotype was originally selected or when it no longer exists is called **lectotype**.
- A lectotype is selected from **isotypes, paratypes or syntypes**.
- A specimen or illustration selected to serve as nomenclatural types as long as all of the material on which the name of the taxon was based is missing is called **neotype**.
- **Epitype** is a specimen or illustration selected to serve as an interpretative type when the holotype, lectotype or previously designated neotype, or all original material associated with a validly published name is demonstrably ambiguous and cannot be critically identified for purposes of the precise application of the name of a taxon.
- **Topotype** is often the name given to a specimen collected from the same locality from which the holotype was originally collected.
- When many names are given to the same species, then the name under which the **species was first described is valid**, provided the publication is **effective** and **valid**.

Taxonomic hierarchy or Linnaean hierarchy

- **Taxonomic hierarchy** is the sequence of arrangements of taxonomic categories in a descending order during the classification of an organism.
- The word **taxa** represents taxonomic groups of any rank *i.e.* **any unit of classification**.
- In Linnaean hierarchy, the **number of taxa is five**, namely – class, order, genus, species and variety.
- The rank of species is basic and relative order of the rank of taxa are **species, genus, tribe, family, order, series, class, division** (= **phylum**) and **kingdom**.
- These categories/rank are ranked one over the other called **'hierarchy'**.
- **Kingdom** is the **highest** and **species** is the **lowest** category in this hierarchy.
- **Species** is the **basic unit of taxonomy**.
- **John Ray** introduced the term animal species.
- Species inhabiting the same geographical area (identical or overlapping) are **sympatric**.
- Species inhabiting different geographical areas are **allopatric**.

- Related species which are reproductively isolated but morphologically similar are called **sibling species**.
- A species restricted to a given area is called **endemic species**.
- Classical systematics is based on the 'typological concept' by **Plato** and **Aristotle**.
- The traditional concept of species was given by Linnaeus in *Systema Naturae*; this is based on morphology, and is **also known as 'morphological concept'**.
- **Genetic species concept** was given by **Lotsy** (1918), according to which, **a species is a group of genetically identical individuals**.
- Species that contain two or more subspecies are called **polytypic species.**
- Species that are not subdivided into subspecies are called **monotypic species**.
- Modern concept of species is **biological species concept** introduced by **Ernst Mayr** (1942).
- **Mayr defined species** as groups of interbreeding natural populations that are reproductively isolated from each other group.
- **Genus** is an assembly of related species which evolved from a common ancestor and have certain common characters called correlated characters, e.g., *Solanum tuberosum* and *Solanum melongena* are two species which belong to same genus of *Solanum*.
- A **family** subdivision of an order consists of a group of closely related genera, which in turn are composed of groups of closely related species.
- The taxon **commonly encountered in routine taxonomic work** is the **family**.
- Family with a single genus is called **monogeneric family**.
- An **order** is a **category within a class**. Carnivora is an order of flesh-eating animals within the class mammalia and there are several other orders of mammals like cattle, rodents, bats, seals, whales, etc.
- A **class** is a subdivision within a phylum made of one or more related orders, for *e.g.*, within the phylum chordata there are five classes: mammals, birds, reptiles, amphibians and fishes.
- **Georges Leopold Cuvier** (1769-1832), the French naturalist, added the '**phylum**' in taxonomy.
- In taxonomy, the **correct sequence** is: **class - order - family - tribe - genus - species**.
- Microbiologists and botanists **(Eichler)** use the term '**division**' **instead of 'phylum**'.
- All **kingdoms** have **more than one phylum**.
- The kingdom plantae contains several divisions (=phyla), including flowering plants, conifer trees, mosses, ferns and several other groups.
- Taxonomic hierarchy is useful in that it **provides information about relationships of an organism with others quick identification of a taxon**, all major traits and nonrepetition of correlated traits of various categories.
- According to ICBN different ranks or categories have following specific '**endings**' (*Refer table given below*).

Ranks	Plants	Algae	Fungi	Animal
Division/ Phylum	- phyta		- mycota	
Subdivision/ subphylum	- phytina		- mycotina	
Class	- opsida	- phyceae	- mycetes	
Subclass	- idae	- phycidae	- mycetidae	
Superorder		- anae		
Order		- ales		
Suborder		- ineae		
Infraorder		- aria		
Superfamily		- acea		- oidea
Family		- aceae		- idae
Subfamily		- ordeae		- inae
Tribe		- eae		- ini
Subtribe		- inae		- ina

Table : Taxonomic status of human & pea

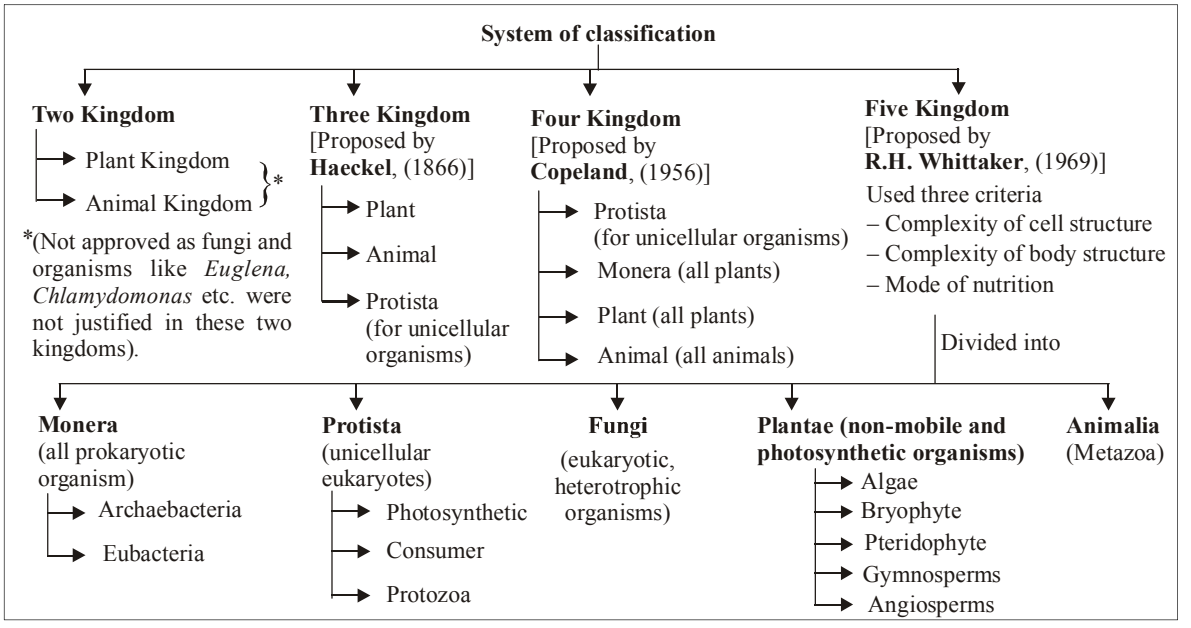
Rank	Human	Pea
Domain	Eukarya	Eukarya
Kingdom	Animalia	Plantae
Phylum or Division	Chordata	Magnoliophyta
Subphylum or Subdivision	Vertebrata	Magnoliophytina
Class	Mammalia	Magnoliopsida
Subclass	Placentalia	Magnoliidae
Order	Primates	Fabales
Suborder	Haplorrhini	Fabineae
Family	Hominidae	Fabaceae
Subfamily	Homininae	Faboideae
Genus	*Homo*	*Pisum*
Species	*H. sapiens*	*P. sativum*

System of biological classification

- There are **four different systems of classification**, mainly used by taxonomists. They are (i) **artificial**, (ii) **natural**, (iii) **phylogenetic**, and (iv) **phenetic**.
- A classification based on one or a few superficial similarities is called an **artificial system of classification**.
- Artificial system of classification was adopted by **Pliny the Elder** (first century AD) for animals on the basis of habitats, *e.g.,* land, air and water.
- The plants are classified on the basis of habit into (i) herbs, (ii) undershrubs, (iii) shrubs, (iv) trees in an artificial classification.
- The Linnaean system of classification of plants **on the basis of number and arrangement of stamens is artificial**. Linnaeus used number, union, length and certain other characters of stamens as the basis of classification of plants in his book '*Genera Planatarum*' (1737).
- In **natural systems of classification** organisms are arranged according to their natural affinities through the use of all important permanent characteristics, especially structural, cytological (chromosomal) reproductive and biochemical.
- **The first natural system of plant classification** was proposed by **Schimper (1879)** followed by **Eichler (1833)**.
- The **most important and last of natural systems for classification of seed plants** was **developed by Bentham (1800–1884) and Hooker (1817–1911)** in the treatise called *Genera Planatarum* (1862–1883).
- **The first natural system of animal classification** was developed by **Linnaeus** in his book "*Systema Naturae*". Improvements were subsequently made by Haeckel (1864) and Lankester (1874).
- The classification **based on evolutionary sequence and the genetic relationships among the organisms** is termed **phylogenetic system**.
- Darwin's book "**On the Origin of Species by Means of Natural Selection**" (1859) provided support to taxonomy.
- The phylogenetic classification of the plant kingdom was proposed by **Adolf Engler** (1844–1930) and his associate **Karl Prantl** (1849–1893) in their book *Die Natürlichen Pflanzen Familien.*
- In this system, flowering plants are placed in ascending series related to complexity of floral morphology.
- This classification was also adopted by the English botanist **John Hutchinson** (1884–1972) in two volumes of his book **"Families of Flowering Plants"**.
- "Taxonomy without phylogeny is similar to bones without flesh" is the statement of **A.L. Takhtajan** (1967) who wrote the book **"A system of phylogeny of flowering plants"**.
- According to zoologists, the natural system of classification **includes the phylogenetic and evolutionary trends**.
- A modern method of classification called **cladistics** is based on evolutionary history.
- The phylogenetic tree is also known as **genealogical tree** or **dendrogram**.
- **Phenetic taxonomy (classification)** is based on the overall similarity of organisms evaluated without regard to phylogeny.
- **Phenetic classification** is **based on observable characteristics of existing organisms**.
- Phenetic classification **did not have a strong impact on animal classification** and **scientific interest in this aproach is on the decline**.

Table : Historical accounts

A.P. de Candolle (1813)	–	Term Taxonomy
E.H. Haeckel (1866)	–	Three Kingdom Classification
Copeland (1956)	–	Four Kingdom Classification
Whittaker (1969)	–	Five Kingdom Classification
John Ray (1627-1705)	–	Termed species
Carolus Linnaeus (1753)	–	Binomial System of Classification
Adolf Meyer (1926)	–	Used taxon term w.r.t. animal kingdom
H.J. Lam (1948)	–	Used term taxon in plant kingdom
Haeckel	–	Concept of phylogeny
Turill (1938)	–	Alpha taxonomy
Julian Huxley (1940)	–	Termed New systematics
Cuvier	–	Coined term phylum



- Organisms are classified according to two, three, four, five and six kingdom system (*Refer flowchart*).
- The **major criteria used for delimitation of kingdoms** are - **modes of nutrition, presence or absence of locomotion, complexity of organisation,** and **cell structure**.
- **Viruses** do not fit neatly into any classification of living organisms because they have a very simple noncellular structure and cannot exist independently of other organisms.
- **Herbarium** is a collection of plant parts that usually have been dried, pressed, preserved on sheets.
- **Largest herbarium** of the world is at Kew.
- **Botanical gardens** are the collections of living plants maintained for reference.
- The **largest botanical garden is the Main Botanical Garden, Moscow** covering an area of 900 acres.
- The Royal Botanical Garden, Kew England covers an area of 300 acres.
- **Indian Botanical garden, Sibpur, Kolkata**, is the **largest botanical garden in India**.
- The collection of plants and animals are preserved and kept in museums for study and reference.
- **Zoological parks** are zoos which help to study wild animals and their food habits.
- **Camerarius** was the person who first recognised **sexuality in plants**.
- If the generic and specific names are same it is called **tautonym**. But tautonyms have been rejected by modern scientists.
- **Angiosperms** are the most advanced type of plants.
- Angiosperms contain **seeds enclosed in fruits**.

End of the Chapter

Chapter 2

Viruses

- The term '**Virus**' has been derived from Latin, which means poison or venom or viscous fluid.
- Viruses are defined as **infectious nucleoproteins**.
- Virus are obligate intracellular parasite which can reproduce only by invading and taking over other cells as they lack the cellular machinery for self reproduction.
- A complete virus particle is called **virion** whose main function is to deliver its DNA or RNA genome into the host cell. So that genome can expressed (transcribed and translated) by the host cells.

Characteristic features

- These are submicroscopic organisms generally less than 200 mm.

Important inventions

- Viruses were discovered after Chamberland developed bacterial filters (1884).
- **Meyer (1886)** describe tobacco mosaic disease but he couldn't isolate the causal organism. Further, he said that the disease is transmissible and infectious.
- Russian botanist **D. Ivanowski** (1892), discovered the causal organisms of tobacco mosaic disease and this causal organisms could pass through the filters which retained bacteria.
- **Beijerinck** (1898) confirmed the earliest studies and named these organisms as "***Contagium vivum fluidum***", living infectious fluid.
- **F.W.T'wort.** (1915) and **F.H.d'Herelle** (1917) discovered certain viruses which infect bacteria or bacteria eaters *i.e.*, bacteriophages or phages.
- **Stanley (1935)** crystallized tobacco mosaic virus and said that these crystals retain their infectivity for a long time if kept in bottles.
- **Bawden and Pirie (1936)** first of all studied the chemical nature of viruses and said that these are nucleoproteins.
- **Edward Jenner (1796)** discovered vaccination against small pox
- **Louis Pasteur (1880)** discovered vaccination against rabies
- **Loeffler and Frosch (1898)** discovered first animal pathogenic virus (Foot and mouth virus of cattle).
- **S. Luria**, **M. Delbruck and Lwoff (1942 - 48)** discovered mechanism of replication in bacteriophages.
- **A. Harshey** and **M. Chase (1952)** said that nucleic acids are infective and proteins are non-infective parts of a bacteriophages.
- **T. O. Diener (1971)** discovered some new infectious agents, which are still smaller than viruses.
- **Stanley B. Prusiner** discovered certain infectious agents or slow viruses which contain only proteins. Prusiner got Nobel prize for this work in 1997.
- **Alliac Issacs and Lindeman** (1957) gave the term interferons to the chemical substances responsible for viral interference.
- Mycophages, viruses infecting fungi, were discovered by **Sinden (1957)** in *Agaricus bisporus*. These are having double stranded RNA and are spherical or polygonal in shape.
- **A. Salk (1957)** invented vaccination against Polio
- **Lu Montagnier** *et. al.* (1893); **R. Gallo** *et. al.* (1984) discovered AIDS virus for HIV.
- **Safferman and Morris (1963)** discovered cyanophages (viruses infecting cyanobacteria like Lynggya).

- **Shape** of virus is variable, eg., brick shaped (**influenza virus**), rod shaped (**TMV**), tadpole like (**bacteriophages**).
- They are **obligate parasites** i.e., can live inside living host only.
- They have **either RNA or DNA**.
- They can **pass through bacterial filters**.
- They have characteristic mode of multiplication, *i.e.*, once a virus enters into the host cell, it takes control of whole biochemical machinery of host cell and orders the metabolic machinery to synthesize their own (viral) components.
- **Non living characters of viruses** are –
  - No protoplasm
  - No enzyme system
  - No respiration
  - They can be crystallized
  - Do not grow in culture medium.
- **Living characters of viruses** are –
  - They contain nucleic acid as a result of which they are capable of synthesizing proteins.
  - They can multiply inside living host cell.
  - They causes diseases.
- On the basis of above characters it can be said that viruses **form a transitional group between living and non-living**.
- Viruses are **divided into two main groups** on the basis of the type of nucleic acid present in them.
  - **Deoxyvira** (having DNA).
  - **Ribovira** (having RNA).
- Deoxyvira are further divided into three classes – **deoxyhelica** (helical), **deoxycubica** (cuboidal) and **deoxybinala** (binal).
- Ribovira is divided into two classes - **ribohelica** (helical) and **ribocubica** (cuboidal).
- F. O. Holmes (1948) divided order - Virales into three sub-orders –
  - **Phytophaginae** – Viruses, infecting plants
  - **Zoophaginae** – Viruses, infecting animals
  - **Phaginae** – Viruses infecting bacteria
- Structurally viruses are made up of **envelope**, **capsid**, **nucleoid** and **occasionally one or two enzymes**.
- Some viruses possesses an outer thin loose covering called **envelope**. It is **composed of proteins** (from virus), **lipids and carbohydrates** (both from host). It has subunits called **peplomeres**.
- The viruses, which do not possess envelope, are called **naked**.
- **Capsid** is the protein coat that **surrounds the central protein of nucleoid and enzymes** (if present). The capsid consists of a specific number and arrangement of small sub-units called **capsomeres**.
- The nucleic acid present in the virus is called **nucleoid**. It is the **infective part of virus** which utilizes the metabolic machinery of the host cell for synthesis and assembly of viral components.
- Nucleoid **represents the viral chromosomes**.
- The **genetic material of viruses** are of **4 types** – **double stranded DNA** (ds DNA), **single stranded DNA** (ssDNA), **double stranded RNA** (dsRNA) and **single stranded RNA** (ssRNA).
- **Double stranded or dsDNA** are – adenovirus, herpes simplex virus, pox virus, cauliflower mosaic, coliphage lambda T_4 (linear), hepatitis B, simian virus SV – 40, polyoma (circular or cyclic).
- **Single stranded or ssDNA** are – coliphage MS 2, coliphage fd (linear), coliphage $\phi \times 174$ (cyclic).
- **Single stranded or ssRNA** are poliomyelitis virus, foot and mouth disease virus, influenza virus, rous sarcoma virus, retroviruses, turnip yellow mosaic viruses, tobacco necrosis virus, TMV, potato mosaic virus, bean mosaic virus (all linear).
- ***ss*RNA** is of **two types** – **negative stranded** (RNA – RNA viruses) and **positive stranded** (RNA – DNA viruses or retroviruses).
- **Double stranded or dsRNA** are reo-virus, wound tumour virus (all linear).
- Only few viruses contain certain enzymes. For eg., lysozyme in bacteriophages, reverse transcriptase in retroviruses.
- **Symmetry of viruses** may be –
  - **Helical symmetry** : Capsomeres are arranged in helical manner in the capsid, e.g., TMV.
  - **Cubical symmetry** : Capsomeres are arranged on the surface to form a 20 side cube, e.g., turnip mosaic virus.
  - **Biosymmetrical or mixed symmetry** : Bacteriophages

TMV (Tobacco Mosaic Virus)

- TMV is the most thoroughly studied virus and was **discovered by** the Russian worker **D. Ivanowski** (**1892**).

- It is a rod shaped virus measuring 300 × 18 nm and have helical symmetry.
- Have single stranded DNA which is 330 nm in length and having 7300 nucleotides.
- Number of capsomeres in capsid is 2130.
- 5% RNA and 95% protein is present in TMV.

Bacteriophages

- **Viruses infecting bacteria** are known as bacteriophages or phages. Sea water can hold 100 million bacteriophages per µl.
- Bacteriophages may be **virulent or avirulent**.
- **Prophages or non-virulent phages** or **non-infective phages** are the phages which do not cause lysis of bacteria soon after their formation inside. Such bacterial cells which are having prophages inside them are called **lysogenic bacteria**.
- **Virulent phages or infective phages** are the phages which cause lysis of bacterial cell at once.
- Most studied series of bacteriophages is T-series (T_2, T_4, T_6 etc.).
- **T-even phages** are **characterized by angular head and contractile tail**.
- Bacteriophages have tadpole like structure, *i.e.*, with **head and tail**. Inside the head is present **nucleic acid**, **generally DNA**.
- Head is **prism like hexagonal** having length 950Å and breadth 650Å, tail is also 950Å in length, joined to head by neck and collar, tail is having hollow core of 80Å and is surrounded by tail sheath.
- At the end of tail, end plate is present to which 6 **tail fibres** are attached and each is 1500Å in length.

Lytic cycle (T_4 bacteriophage)

- The multiplication process of virulent phage is called **lytic cycle**.
- The main steps **include adsorption**, **penetration**, **formation of new phages** and **lysis**.
- Bacteriophage **attaches to the surface of bacterium by its tail fibres**.
- Lysozymes creates a hole in the host cell wall.
- The **tail sheath contracts and ejects the viral chromosome/DNA into the bacterium**.
- Viral DNA **controls the metabolic machinery of the host cell**. It produces nucleases.
- **Nucleases degrade DNA and mRNAs of the host**.
- Viral DNA is not affected as its cytosine bases are methylated.
- A **number of copies of viral DNA are produced** followed by **synthesis of capsid protein, polyamines and lysozymes**.
- The components assemble and form phage particles or viruses.
- The host cell ruptures to release viruses (**lysis**).

Lysogenic cycle (λ phage)

- The multiplication process of temperate phage is called **lysogenic cycle**.
- The phenomenon of existence of non-virulent prophage in the host cell is called **lysogeny**.
- The host cell in which lysogeny occurs is called **lysogenic cell**.
- **Lysogen** is a strain of bacteria carrying prophage.
- Lysogenic cycle is shown by 1 (lambda) phage which also infects *E.coli* bacterium.
- **Lytic bacteriophage** multiply in host bacterium which then undergoes complete lysis (degeneration) to release the resulting daughter phages.
- The phage attaches to the surface of bacteria by means of tail, which produces a hole in host cell wall and injects the phage DNA.
- Phage DNA produces a repressor, (C1) becomes nonvirulent or temperate and gets integrated to bacterial chromosome at a specific site by means of enzyme integrase.
- The viral genome is now called **prophage/provirus**.
- It multiplies alongwith bacterial genome and is passed on to the progeny.
- Occassionally the synthesis of repressor is stopped due to ultra violet radiations or chemical factors.
- The temperate/non-virulent phage is now changed to lytic/virulent phage.
- The single strand DNA of f × 174 or coliphage *fd* is known as **plus strand**. It forms its complementary or negative strand. The double strand or replicative DNA takes over the metabolic machinery of host to synthesize plus strands DNAs and protein for assembly of new phages.

Pinocytic reproduction

- The whole virus enters the host cell except the envelope. It is quite common in RNA viruses which are of two types as RNA-RNA virus and RNA-DNA virus.
- In **RNA-RNA viruses** DNA has no role in their multiplication. After entering the host cell the viruses produce enzyme **replicase** which helps in producing more genetic RNA over the template

of parent RNA genome. The latter also produces *m*RNAs for synthesis of viral proteins.

- **RNA-DNA viruses** are also called **retroviruses** (Temin, 1970), *e.g.*, Tumor/Cancer viruses, HIV. The viruses possess enzyme **reverse transcriptase** (Temin and Baltimore, 1972; in Rous Sarcoma Virus or RSV of Mouse). The enzyme builds DNA over RNA genome. The phenomenon is called **reverse transcription** or **teminism**.
- The **copy DNA (cDNA)** builds its complementary strand. The double strand copy DNA attaches to host DNA/chromosome and is now called **provirus**.
- **Application of bacteriophages** are –
  - Studying viral infection mechanism.
  - Control of certain bacterial diseases.
  - Purity of Holy Ganges is due to presence of bacteriophages.

Viroids are sub-viral infectious agents, which contains only very low molecular weight RNA and not protein coat. Viroids cause potato spindle tuber disease (PSTV), citrus exocortis etc. The only human disease known to be caused by a viroids is hepatitis D.

Interferons are protein molecules which prevent viral multiplication. These are produced by cells in mammals, rodents, birds, etc. and provide resistance against viruses.

Diseases caused by viruses

- Virus causes diseases in plants, animals and human brings.
- **Plant diseases caused** by viruses are –
  - Tobacco mosaic disease
  - Leaf curl of papaya
  - Yellow vein mosaic of bhindi
  - Potato leaf roll
  - Vein bandings mosaic disease of potato
  - Grassy shoot of sugar cane
  - Bunchy top of banana
  - Tungro disease of rice
  - Tomato leaf curl
- **Human diseases caused** by viruses are –

Chicken pox	:	*Varicella virus*
Small pox	:	*Variola virus*
Measles	:	*Rubeola virus*
Rabies	:	ssRNA (*Rabies virus - Lassa virus*)
AIDS	:	ARV (*Aids associated retrovirus*)
Yellow fever	:	Transmitted by *Aedes aegypti* mosquito
Dengue fever	:	Transmitted by *Aedes aegypti* mosquito
Polio	:	Transmitted through food, water, contact
Hepatitis-B	:	Transmitted through contact and body fluid.

- **Transmission of viruses** occurs by –
  - Polluted air, water and food stuffs help the dissemination of viruses in man and animals.
  - Fly and mosquitoes usually act as carriers.
  - Such virus transmitting agents are called vectors.
  - Most of the virus diseases of plants are transmitted through insects.
  - Sap sucking insects like aphids and white flys are the important ones among such vectors.
  - Virus diseases are also transmitted through stem cuttings, seeds, tubers, agricultural implements etc.
- **Disease can be controlled** by –
  - Removal of diseased plants and plants parts.
  - Using disinfested seed.
  - Testing the germplasm and selecting virus free seed.
  - Destruction of alternative hosts.
  - Destruction of insect vectors.
  - Practising crop rotation.
  - Growing disease resistant varieties.

End of the Chapter

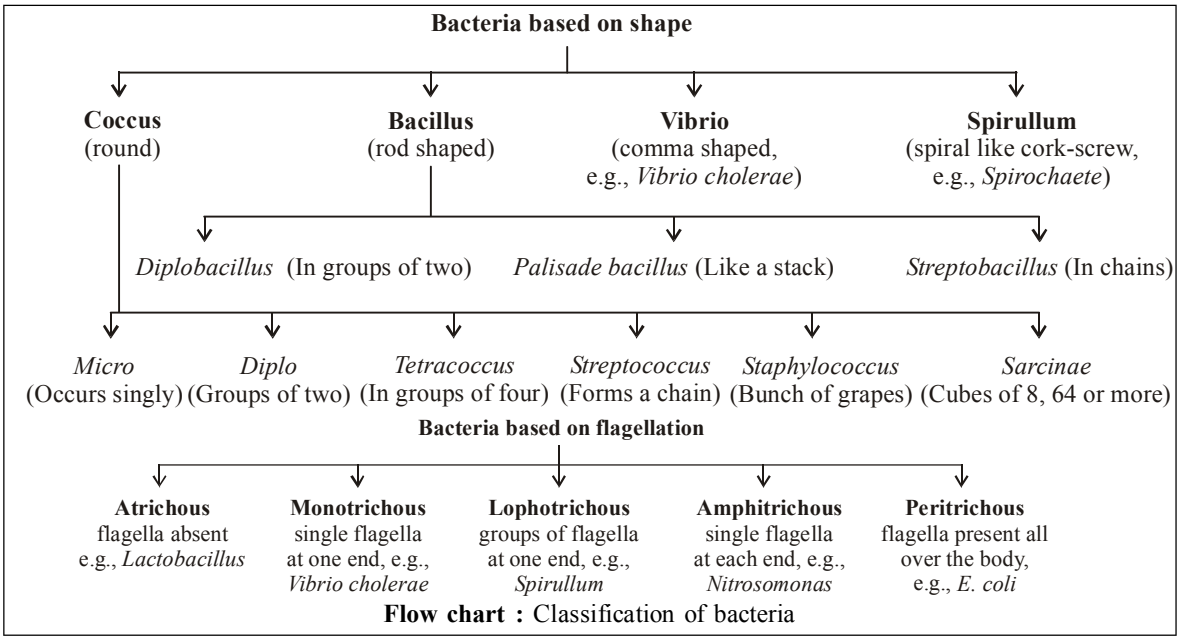
Chapter 3

Kingdom Monera

- **Monera** are the group of all prokaryotes.
- They are basically unicellular, may be mycelial, colonial and filamentous.
- Cell wall is made up of **peptidoglycan**, **polysaccharides** and **cellulose**.
- They do not contain any organised nucleus with distinct membrane.
- **DNA is naked**, *i.e.,* not associated with histone proteins. It is called **nucleoid**.
- All the membrane bound **cell organelles are absent** like mitochondria, lysosomes, golgi bodies, plastids etc.
- In photoautotrophic forms thylakoids are present - without chloroplasts.
- Spindle apparatus do not develop at the time of cell division.
- Single stranded flagella, **composed of flagellin**, is present.
- Ribosomes are **70S type** (subunit 30S and 50S).
- Reproduction is by **binary fission or budding**.
- They have a **various modes of nutrition** like saprobic, parasitic, chemoautotrophic, photoautotrophic, symbiotic.
- Some are capable of nitrogen fixation.
- Monera occur in all environment, eg archaebacteria live in extreme climates.
- The kingdom includes all prokaryotes like **bacteria**, **actinomycetes**, **mycoplasma** and **cyanobacteria**.

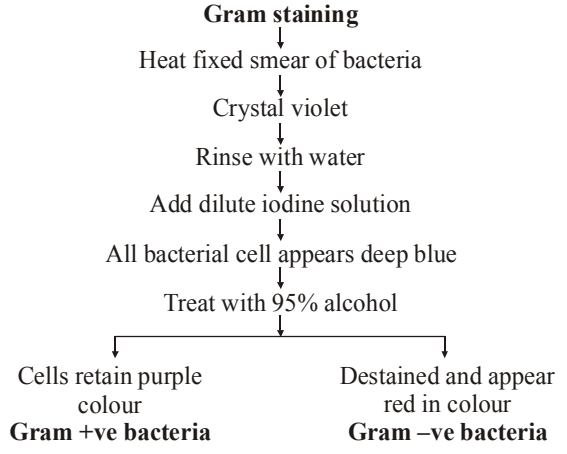
BACTERIA

- Bacteria are the **smallest of free living organism**, **mostly unicellular.**
- Bacteria possess various forms and shapes, and are of **4 different types – coccus**, **bacillus**, **vibrio**, and **spirullum**.



Flow chart : Classification of bacteria

- Bacteria possess a distinct cell wall, with different wall layers like capsule or slime layer, plasma membranes, flagella and pilli.
- Slime layer or capsule is made up of **polysaccharides** and **amino acids** and acts as osmotic barrier.
- Cell wall is made up of **polysaccharides**, **proteins** and **lipids** and **peptidoglycan** or **murein**.
- Plasma membrane is **tripartite** in nature.
- **Mesosomes** are simple infolding of plasma membrane containing respiratory enzymes, like oxidases and dehydrogenase.
- Flagella is made up of **flagellin**.
- **Pili** are small hair like outgrowth present on bacterial cell surface made up of **pilin protein**.
- Pilin **helps in formation of conjugation tube and agglutination**.
- **Based on the nature of staining**, bacteria **may be Gram + ve** (retains the blue stain) or **Gram –ve** (does not retain the stain).



- Inner to the wall layers, there is present matrix or protoplasm which includes **nucleoid**, **plasma**, **episomes**, **ribosomes**, **and granules**.
- In the centre of the bacterial cell, there is present **nuclear material** (DNA) **without any nuclear membrane** (naked). **DNA in bacteria is double helical and circular**.
- This incipient nucleus or primitive nucleus is named as **nucleoid** or **genophore** (sometimes called single naked chromosome).
- Besides this nuclear DNA, there is some extranuclear or extrachromosomal DNA, which is known as **plasmid**.

Table : Difference in the cell walls of gram +ve & gram –ve bacteria

	Gram +ve bacteria	Gram –ve bacteria
1.	Cell wall more thick, thickness varies from 25-30 nm.	Cell wall thin.Thickness varies 10-15 nm.
2.	Cell wall is a homogenous layer.	Three layered.
3.	High content of peptidoglycan (20-80% of the dry weight of the cell).	Less content of peptidoglycan (10-20% of the dry weight of the cell).
4.	Teichoic acids may be present.	Teichoic acids absent.
5.	Very little lipid content (0-2%).	High lipid content (10-20%).
6.	Only a few aminoacids are associated with the muramic acid complex.	Large variety of aminoacids are associated.
7.	Lipopolysaccharide layer (LPS) absent.	Present.
8.	Periplasmic space is absent.	Present.

- The plasmid are **small**, **circular**, **double-stranded DNA molecules** that are separate from main bacterial chromosome and replicate independently.
- The term plasmid was given by **Lederberg (1952)**.
- Plasmids have an independent existence.
- Plasmids **carry genes for fertility**, **antibiotic resistance** (**R-factor**) and **bacterium** (**Colicin**) **production** (**colicinogenic factor**).
- **F-factor** or **fertility factor** is responsible for transfer of genetic material.
- **R-factor** or **resistance factor** provides resistance against drugs.
- **Colicinogenic factor** produces '**colicines**' which kill other bacteria (other than which produces these colicines).
- The term **episome** is applied to extranuclear genetic material which may remain in integrated or free state, e.g., F-factor, temperate phage, etc.
- Ribosomes are evenly distributed in the matrix. Ribosomes are of 70S type (50S + 30S).
- Ribosome are the seat of protein synthesis and are made up of r-RNA and protein.

- There are present different types of granules like volutin granules, fatty acid granules (lipid granules), glycogen and sulphur granules.
- **According to the mode of respiration**, bacteria can be **aerobic** or **anaerobic**. Each of them is further of two types, obligate and facultative.
- **Obligate aerobes** are bacteria which can respire only aerobically. They generally get killed under anaerobic mode of respiration, e.g., *Bacillus subtilis*.
- **Facultative aerobes** are bacteria which respire anaerobically under normal conditions but can respire aerobically when oxygen is available. Most of the photosynthetic bacteria belong to this group.
- **Obligate anaerobes** are bacteria that respire only anaerobically. They generally get killed under aerobic condition, e.g., *Clostridium botulinum*.
- **Facultative anaerobes** are bacteria which generally respire only aerobically but switch over to anaerobic mode of respiration if oxygen becomes deficient.

Nutrition

- Bacteria show both **autotrophic** and **heterotrophic nutrition**.
- **Autotrophic nutrition** consists of manufacture of organic materials from inorganic raw materials with the help of energy obtained from outside sources. It is of two types – **chemosynthesis** and **photosynthesis**.
- The bacteria possess photosynthetic pigments of two types, **bacteriochlorophyll** and **bacteriophaeophytin** (chlorobium chlorophyll). The two types of pigments respectively occur in purple bacteria (e.g., *Thiopedia rosea, Rhodopseudomonas*) in membranes of thylakoids.
- **No oxygen is evolved in bacterial photosynthesis**. Such type of photosynthesis is known as **anoxygenic photosynthesis**.
- Water is not used as a source of reducing power. Instead, hydrogen is obtained either directly (some purple bacteria) or from various types of inorganic and organic compounds, *e.g.*, H_2S (green bacteria), aliphatic compounds (purple nonsulphur bacteria).
- **Chemoautotrophic bacteria** are bacteria which are able to manufacture their organic food from inorganic raw materials with the help of energy derived from exergonic chemical reactions involving oxidation of an inorganic substance present in the external medium. They are of various types.
- **Nitrifying bacteria**, *Nitrosomonas* and *Nitrosococcus* obtain energy by oxidising ammonia to nitrite.
  $NH_4^+ + 2O_2 \rightarrow NO_2^- + 2H_2O + \text{Energy}$
  Nitrocystis and *Nitrobacter* oxidise nitrites to nitrates.
  $2NO_2^- + O_2 \rightarrow 2NO_3^- + \text{Energy}$
- **Sulphur oxidising bacteria**, *Beggiatoa*, a colourless sulphur bacterium, oxidises hydrogen sulphide to sulphur in order to obtain energy for chemosynthesis.
  $2H_2S + O_2 \xrightarrow{\text{Beggiatoa}} 2S + 2H_2O + \text{Energy}$
  Thiobacillus thioxidans, another sulphur bacterium, oxidises sulphur to sulphate state.
  $2S + 2H_2O + 3O_2 \xrightarrow[\text{Thioxidans}]{\text{Beggiatoa}} 2H_2SO_4 + \text{Energy}$
- **Iron bacteria**, *Ferrobacillus ferro-oxidans* obtains energy by oxidising ferrous compounds to ferric forms.
  $4FeCO_3 + 6H_2O + O_2 \rightarrow 4Fe(OH)_3 + 4CO_2 + \text{Energy}$
- Other chemosynthetic bacteria, bacterium *Methanomonas* oxidises methane into CO_2 and H_2O.
  $CH_2 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Energy}$
- **Heterotrophic bacteria** may be **saprophytic**, **parasitic or**, **symbiotic**.
- **Saprophytic** are **living bacteria which obtain their food from organic remains**, *e.g.*, corpses, animal excreta, fallen leaves, vegetables, fruits, meat, jams, jellies, bread and other products of plant and animal origin.
- **Symbiotic bacteria** live in mutually beneficial association with other organisms. Enteric bacterium *Escherichia coli*, live as a symbiont in human intestine.
- **Parasitic bacteria**, live in contact with other living beings for obtaining nourishment or special organic compounds required for growth (growth factors).
- Bacteria **show four major phases of growth** in a fresh nutrient rich medium – (i) **lag phase**, (ii) **log phase** (logarithmic or exponential phase), (iii) **stationary phase**, and (iv) **decline phase** (death phase). These phases constitute the standard bacterial growth curve.

Reproduction

- Bacteria show **3 methods of reproduction** – **vegetation reproduction**, **asexual reproduction**, **sexual reproduction**.

- **Vegetative reproduction** includes **budding** and **binary fission**.
- **Binary fission** takes place during favourable conditions. The bacterial cell divides by a constriction into 2 halves. The nuclear material also divides into 2 equal halves.
- **Asexual reproduction** takes place by **endospore formation**, **conidia** and **zoospores**.
- During unfavourable condition, highly resistant single spore is formed inside the bacterial cell, which is known as **endospore**. (*Endo means inside or within + spore*).
- Endospore is having a characteristic structure *i.e.*, having outer thin **exosporium** followed by one or many layered **spore coat**, followed by many **concentric layers of cortex**, which is followed by **cell wall**, **cell membrane** and **matrix**.
- Endospore is **highly resistant to very high and very low temperature**, **strong chemicals and acids**, **etc**. **due to calcium**, **dipicolinic acid and peptidoglycan in cortex**. Dipicolinic acid (DPA) **helps in stabilizing its proteins**.
- DPA and Ca ions provide resistance to heat.
- When favourable conditions come, outer layers rupture and active bacterial cell comes out. So this is a method of perennation (*i.e.*, to tide over unfavourable condition) and some people say it **"reproduction without multiplication"**.
- **Sexual reproduction** occurs in the form of **genetic recombination**.
- There are **there main methods of genetic recombination – transformation**, **transduction**, **conjugation**.
- **Transformation** : Here genetic material of one bacterial cell goes into another bacterial cell by some unknown mechanism and it converts one type of bacterium into another type (non-capsulated to capsulated form).
- This was **first studied by Griffith** (1928) in *Diplococcus pneumoniae* and hence is known as **Griffith effect**.
- **Transduction** : In this method, genetic material of one bacterial cell goes to other bacterial cell by agency of bacteriophages or phages (viruses, infecting bacteria).
- Transduction was first of all reported in *Salmonella typhineurium* by **Zinder and Lederberg (1952)**.
- In abortive transduction the new gene does not integrate with the recipient genome and is lost.
- **Conjugation** : Cell to cell union occurs between two bacterial cells and genetic material (DNA) of one bacterial cell goes to another cell lengthwise through conjugation tube which is formed by sex pili.
- Conjugation was **first reported by Lederberg and Tatum (1946)** in *E. coli* bacteria.
- Conjugation **occurs between donor cell and recipient cell**. Donor cell is having sex pili and F-factor whereas recipient cell is having both.
- In donor cell, F-factor may unite with main genome or nuclear DNA and this donor cell is called **Hfr-donor cell** (High Frequency donor cell) and here transfer of DNA is rapid.

Importance of bacteria

Useful activities

- **Role of bacteria in agriculture in increasing soil fertility**
  - Some free living nitrogen fixing bacteria like *Azotobacter* and *Clostridium* have the capacity of fixing atmospheric nitrogen into nitrogenous substances, hence increases soil fertility.
  - Similarly symbiotic bacteria *Rhizobium* also fix atmospheric nitrogen.
  - *Nitrosomonas* converts ammonia into nitrites, which is further converted into nitrates by *Nitrobacter* (nitrification).
- **In dairy industry**, lactic acid bacteria (*Bacterium lacticiacidi* and *Bacterium acidi-lactici*) convert lactose of milk into lactic acid and hence milk turns sour.
- **In other industries**
  - In vinegar industry, *Acetobacter aceti* converts sugar solution into acetic acid.
  - Butyl alcohol and acetone are produced by activity of *Clostridium acetobutyricum*.
  - Retting or separation of fibres from stalks, *e.g.*, in jute, sunhemp, *Linum* (flax), etc. is done by water inhabiting bacteria *Clostridium butyricum*.
  - Flavouring of tobacco leaves is done by *Bacillus megatherium*.
  - Curing of leaves of tea is done by *Micrococcus condisans*.

- **Role of bacteria in sewage disposal**
  - For the breakdown of sewage in simple substances, bacteria and algae play important role.
  - Sewage oxidation ponds or tanks have luxuriant growth of bacteria and algae.
- **Role of bacteria in petroleum pollution** : Petroleum pollution in water bodies is checked upto some extent by *Pseudomonas*.
- **Role of bacteria in human being** : *E. coli* (gram-ve) bacteria live in colon region of intestine of man and other animals and play an important role in digestion process.
- Many antibiotic are produced from bacteria. **Antibiotics** are substances produced by micro-organisms which in low concentration are antagonistic to the growth of other micro-organisms. Medicinally antibiotics are those organic secretions which destroy or check the growth of different pathogens without harming the host.

Table : Role of bacteria in medicine

	Antibiotics	Bacteria from which obtain
1.	Subtelin	*Bacillus subtilis*
2.	Polymyxin	*Bacillus polymyxa*
3.	Streptomycin and Cycloheximide	*Streptomyces griseus*
4.	Chloromycetin (Chloramphenicol)	*Streptomyces venezuelae*
5.	Terramycin (Oxytetracycline)	*S. rimosus*
6.	Aureomycin	*S. aurefaciens*
7.	Erythromycin	*S. erythraeus*
8.	Neomycin	*S. fradiae*

Harmful activities

- **Spoilage of food** : Saprophytic bacteria causes rotting of vegetables, fruits, meat, bread, souring of milk, cheese, butter, spoilage of jams, jellies and pickles.
- **Destruction of Penicillin** by *Bacillus brevis*.
- **Cotton spoilage** is done by bacteria called *Clostridium botulinum*.
- **Desulphurification of soils** : Soil sulphates is changed to hydrogen sulphide by *Desulfouibrio desulfuricans*.
- **Reduction of soil fertility** : There are some denitrifying bacteria in soil, which convert nitrates into free nitrogen (denitrification), *e.g.*, *Bacillus denitrificans*, *Micrococcus denitrificans* and *Thiobacillus denitrificans*.

Table : Bacterial diseases of plants, animals and humans

Name of disease	Causal organism
Human beings	
Pneumonia	*Diplococcus pneumoniae*
Typhoid	*Salmonella typhosa*
Cholera	*Vibrio cholerae*
Plague	*Pasteurella pestis*
Meningitis	*Neisseria meningitides*
Gonorrhoea	*Neisseria gonorrhoeae*
Syphilis	*Treponema pallidum*
Diarrhoea	*Bacillus coli*
Gastroenteritis	*E. coli*
Diphtheria	*Corynebacterium diphtheriae*
Tuberculosis	*Mycobacterium tuberculosis*
Gangarin	*Clostridium perfringens*
Jaundice	*Leptospira icterohaemorrhagae*
Whoophing cough	*Haemophilus pertussis* or *Bordetella pertussis*
Tetanus (lockjaw)	*Clostridium tetani*
Bacterial dysentry	*Shiegella dysentirae*
Leprosy	*Mycobacterium leprae*
Animals	
Anthrax	*Bacillus anthracis*
Black leg disease	*Clostridium chauvi*
Plants	
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 beet sugar	*Agrobacterium*
Black rot of cabbage	*Xanthomonas campestris*

Some other types of bacteria

- **Spirochaetes** are free inhabitants of mud and water and are **chemoheterotrophic** bacteria. Many diseases are caused by them as *Treponema pallidum* causes syphilis, *Leptospira* causes infectious jaundice and *Borrelia* causes relapsing fever. Besides some spirochaetes are found in teeth.
- **Rickettsiae** are Gram negative obligate pleomorphic but walled intracellular parasites which are resident of or are transmissible from arthropods. They are **intermediate between true bacteria and viruses**.
- **Chlamydiae** are Gram negative intracellular parasites of about 0.25 μm size, often grouped along rickettsiae but differ from them in reproductive cycle that involves formation of initial or **reticulate bodies** (RB) and **elementary bodies** inside host phagosome. *Chlamydia trachomatis* causes conjuctivitis, sexually transmitted nongonococcal urethritis, epididymitis, cervicitis, proctitis and lymphogranuloma venereum. *C. pneumoniae* causes pneumonia and bronchopneumonia.

ACTINOMYCETES

- Actinomycetes are **mycelial (aseptate branched filaments) bacteria which form radiating colonies in culture**. Because of this, actinomycetes were **formerly called ray fungi**.
- Mycelial form is reduced in *Mycobacterium* and *Corynebacterium*.
- Mycelia have a diameter of 1mm or less.
- Wall contains mycolic acid (fatty acid), lipid and wax.
- Different **modes of reproduction** are by **conidia**, **sporangiospores** and **arthrospores** or **oidia** and **fragmentation**.
- Most of the actinomycetes are saprotrophic and constitute an important component of decomposers, e.g., *Actinomyces, Streptomyces*.
- A few are pathogenic in plants, animals and humans, e.g., *Mycobacterium*.
- In pathogenic actinomycetes or *Mycobacterium* a derivative of mycolic acid called **mycoside**/cord factor is involved in causing disease.
- A **number of antibiotics are produced** by actinomycetes, especially the genus *Streptomyces* (streptomycin, chloramphenicol, tetracyclines, terramycin, erythromycin, viomycin, novobiocin, nystatin).

The term **antibiotic was given by Abraham Selman Waksman** (1888 - 1973) **who also extracted first antibiotic** from *Streptomyces griseus* and named it streptomycin. For this Waksman was given Nobel Prize in 1952.

ARCHAEBACTERIA

- They are a group of most primitive prokaryotes which are believed to have evolved immediately after the evolution of the first life. They are also called living fossils.
- Archaebacteria are characterised by **absence of peptidoglycan in their wall**.
- Instead the wall contains **protein and non-cellulosic polysaccharides**. It has **pseudomurein in some methanogens**.
- The **cell membranes** are characterised by the **presence of a monolayer of branched chain lipids**.
- Archaebacteria even now live under extremely hostile conditions where very few other organisms can dare subsist, e.g., salt pans, salt marshes, hot sulphur springs.
- Their rRNA nucleotides are quite different from those of other organisms.
- The archaebacteria are of two broad categories – obligate anaerobes and facultative anaerobes or aerobes.
- Archaebacteria are of **three types – methanogens**, **halophiles** and **thermoacidophiles**.

Archaebacteria are **also known as living fossils because** they represented one of the earliest forms of life which experimented on the absorption of solar radiations for the first time, lived comfortably under anaerobic conditions and developed techniques to oxidise the chemicals present in the substratum on the availability of oxygen.

Methanogens

- These archaebacteria are **strict anaerobes**.
- Nutritionally they are "**autotrophs**" which obtain both energy and carbon from decomposition products.
- They occur in marshy areas where they convert formic acid and carbon dioxide into methane.
- This capability is commercially exploited in the production of methane and fuel gas inside gobar gas plants. E.g., *Methanobacterium, Methanococcus*.

- Some of the methanogen archaebacteria live as symbionts (e.g., *Methanobacterium*) inside rumen cow, buffalo and helpful to the ruminants in fermentation of cellulose.

Halophiles

- Halophiles are named so because they usually occur in salt rich substrata (2.5 - 5.0 M) like salt pans, salt beds, and salt marshes, e.g., *Halobacterium*, *Halococcus*.
- They are **aerobic chemoheterotrophs**.
- Their cell membranes have **red carotenoid pigment** for **protection against harmful solar radiations**.
- Under anaerobic conditions, halophiles cannot use external materials.
- At this time they subsist on ATP, synthesized by membrane pigmented system from solar radiations.
- Halophiles growing in salt pans and salts beds gives offensive smell and undesirable pigmentation to the salt.
- Halophiles are **able to live under high salt conditions due to the following reasons** –
  - **Presence of special lipids** in the cell membranes.
  - **Occurrence of mucilage covering**.
  - **Absence of sap vacuoles** and hence plasmolysis.
  - High internal salt content.

Thermoacidophiles

- These archaebacteria **have dual ability to tolerate high temperature as well as high acidity** due to two reasons - branched chain lipids in the cell membranes and presence of special resistant enzymes capable of operating under acidic conditions.
- They often live in hot sulphur springs where the temperature may be as high as 80°C and pH as low as 2, e.g., *Thermoplasma, Thermoproteus*.
- Basically these archaebacteria are **chemosynthetic** *i.e.*, they obtain energy for synthesis of food from oxidising sulphur.
- Under aerobic conditions they usually oxidise sulphur to sulphuric acid.
  $2S + 2H_2O + 3O_2 \rightarrow 2H_2SO_4$.
- If the conditions are anaerobic, the thermoacidophiles may reduce sulphur to H_2S.
- Bicarbonates are also precipitated into the carbonate form by their activity.

MYCOPLASMA (PPLO)

- Mycoplasmas or **mollicutes** are the **simplest and the smallest of the free living prokaryotes**.
- They were **discovered in pleural fluid of cattle**, suffering from pleuropneumonia **by Nocard and Roux**, (**1898**).
- The organisms are **often called MLOs** (*Mycoplasma like Organisms*) **or PPLOs** (*Pleuropneumonia like Organisms*).
- The size ranges from 0.1 - 0.15 mm.
- Plasma membrane forms the outer boundary of the cell. A substantial amount of **polysaccharides** having even **acetyl glucosamine** are associated with cell membrane which is rich in **cholesterol**.
- A cell wall is absent. Due to the absence of cell wall the organisms can change their shape and are pleomorphic – **cocoid**, **cocobacillus**, **helical**, **fine unbranched or branched**.
- Like other prokaryotes, mycoplasmas **possess one envelope system**.
- They **lack organised nucleus, endoplasmic reticulum**, **plastids**, **mitochondria**, **golgi bodies**, **lysosomes**, **centrioles**, **flagella** etc.
- The genetic material is represented by a **single DNA duplex which is naked because of absence of histone association**.
- The **DNA duplex is not compacted as in other prokaryotes but instead lies coiled throughout the cytoplasm**.
- Ribosomes are 70s. Granules of various types occurs here and there in the cytoplasm, mesosomes absent.
- Enzymes lie both freely in the cytoplasm as well as associated with the plasma membrane.
- DNA **possesses a replicating disc at one end to assist in replication** and **separation of the genetic material**.
- Some of them **live as saprophytes** but majority parasites plants and animals.
- The **parasitic habit is due to the inability of most mycoplasmas to synthesize the required growth factors**, e.g., *Mycoplasma gallisepticum*.
- Electron transport system is rudimentary or absent.
- Reproduction occurs by fission or first forming a branching filament with numerous nuclear bodies followed by constriction in between the nuclear bodies and separation of cells as new individuals.

- They mostly produce pleuropneumonia in domestic animals, atypical pneumonia and mycoplasmal urethritis in humans, little leaf disease of brinjal and witches broom in plants.
- Mycoplasmas are not affected by penicillin (inhibitor of wall formation) but are inhibited by tetracyclines.

CYANOBACTERIA (BLUE GREEN ALGAE)

General characters

- Cyanobacteria are **gram –ve prokaryotes** which **perform oxygenic photosynthesis like plants**.
- They were the **first organism to make the atmosphere aerobic**.
- The blue green algae live virtually in all environments that contain water.
- The organisms range from tropics to plains and they occur in soil, fresh water and ocean.
- In lakes and in the ocean they form part of planktons.
- Some cyanobacteria live in the icy water of glaciers others in hot springs where temperatures reach 85°C or more (due to homopolar bonds).
- Some blue-green algae live as symbionts with other organisms, e.g., lichens.
- Cyanobacteria can be **unicellular** (*e.g., Spirulina*), **colonial** (*e.g., Nostoc*) or **filamentous** (*e.g., Oscillatoria*). Filaments **contain one or more trichomes inside a mucilage sheath**.
- Trichomes may be **homocystous** (without heterocysts, *e.g., Oscillatoria* which shows apical oscillations) or **heterocystous** (with heterocysts, *e.g., Nostoc*, *Anabaena*).
- Nitrogen fixing *Nostoc* and *Anabaena* live freely as well as symbionts (in *Azolla*, *Anthoceros*, *Cycas* roots, *Gunnera* stems amd nodules of *Trifolium alexandrintum*).
- The cell wall possesses an **outer sheath** (outside) which is **jelly like**, **slimy and mucilaginous**.
- The cell contents are divided into two regions – **outer chromatoplasm** having photosynthetic pigments in free thylakoids and **inner colourless centroplasm**.
- The **cell wall is two layered** whose **inner wall is made up of peptidoglycan or mucopeptides** built up from amino sugars (eg., glucosamine) and amino acids (eg., muramic, diaminopimelic).
- In the cytoplasm photosynthetic lamellae are present.
- These lamellae or thylakoids contain dominating pigments phycocyanin allophycocyanin and phycoerythrin (phycobilins) in addition to chlorophyll *a*.
- Bacteria and blue green algae lack mitochondria, true vacuoles and endoplasmic reticulum.
- Sterols are absent in bacteria as well as cyanobacteria.
- **True nucleus is absent**. True fibrils of DNA are either distributed throughout the cell or concentrated in the central part. Its chromosome resembles bacterial chromosomes.
- Gas vacuoles are often present to regulate the buoyancy in water.
- The colour ranges from green to deep purple often blue green.
- These colours are produced by different proportions of several pigments like chlorophyll *a*, carotene, xanthophyll, blue phycocyanin and red phycoerythrin.
- Thylakoid membranes contain chlorophyll *a*, carotenes and xanthophylls. Attached to thylakoids are minute structure called **phycobilisomes**. They have three types of water soluble but protein bound accessory pigments – **phycocyanin**, **allophycocyanin** (both blue) and **phycoerythrin** (red).
- Many forms show **Gaidukov phenomenon or chromatic adaptation** where colour changes according to wavelength of light received by the cyanobacteria. *Trichodesmium erythaeum* is reddish coloured cyanobacterium which occurs in such abundance that a sea is named after its colour – red sea.
- Nucleoid is in contact with a group of coiled membranes called **lamellasome**. Lamellasome develops from plasmalemma. Plasmids or additional small DNA rings may occur. 70 S ribosomes are abundant.
- Cell inclusions are α-granules (cyanophycean starch similar to glycogen), β-granules (lipid droplets), volutin granules and polyhedral bodies.
- The **reserve food** is in the form of **cyanophycean** (**myxophycean**) **starch**.
- **Flagella are absent** in vegetative as well as reproductive phase.

- Well marked reproductive organs, sexual reproduction and motile reproductive bodies are absent in cyanobacteria.
- Reproduction is very simple and takes place by vegetative means only.
- No trace of sexuality has ever been recorded but **gene recombination** can occur through **conjugation**, **transformation** and **transduction**.
- The vegetative reproduction occurs by mere cell division.
- They **reproduce asexually** by **binary fission** (in unicellular forms) and **fragmentation** (by breaking up and regrowth of filaments).
- **Heterocysts** formation is characterized by the presence of thick walls and yellowish contents.
- Each heterocyst is made up of two walls - an inner thin layer and outer thick gelatinous layer.
- Heterocyst develops from recently divided cells, it may be single or paired.
- On germination, it gives rise to a new filaments.
- In many filamentous forms asexual reproduction occurs by **hormogonia formation**.
- They are identified by presence of biconcave discs or separation discs between two adjacent cells.
- The filaments gets broken from such places into many hormogonia and each of them forms a new filaments, eg., *Oscillatoria*.
- Spore formation also occurs (exospores, endospores, akinetes etc).

Nitrogen fixation in cyanobacteria

- Like many bacteria, several forms of blue-green algae have the capacity to fix atmospheric nitrogen into nitrogenous compounds.
- This capacity is **restricted to filamentous heterocystous forms** like *Nostoc, Anabaena, Aulosira* etc.
- Under anaerobic conditions, some non-heterocystous forms can also fix atmospheric nitrogen (*Gloeocapsa, Oscillatoria*).
- This additional capacity of N_2 fixation alongwith CO_2 fixation makes them truely autotrophic plants.
- In this sense, they are considered to be largely responsible for the maintenance of soil fertility in tropical and temperate regions.
- **Some species** of blue green algae **have a great contribution to increase the fertility of rice fields in tropical countries like India** (e.g., *Anabaena, Tolypothrix*, *Aulosira*).

Economic importance of cyanobacteria

Useful aspects

- Some fifty species of cyanobacteria are capable of fixing atmospheric nitrogen in soil, e.g., *Anabaena, Nostoc*.
- *Spirulina* is being used as a **source of protein rich supplement to diet of human**.
- Bolls of *Nostoc* are **used as food by Chinese and South Americans**. Food is called **yoyucho**.
- Cyanobacteria like *Nostoc, Scytonema* are used for **reclamation of usar** (sterile, alkaline) soil.
- In Sambhar lake of Rajasthan, *Anabaena* and *Spirulina* is produced in large number. Local people use it as **green manure**.
- Some species of *Anabaena*, *Tolypothrix* help in conservation of soil, thus **checking soil erosion**.
- Few cyanobacteria located inside lichens help in **plant succession** due to their growth on barren land.
- *Oscillatoria* is used as pollution indicator.

Harmful aspects

- Forms like *Anabaena* **not only spoil the taste of drinking water but also produce toxic effect**.
- Some cyanobacteria appear on buildings during rainy season and cause **damage to bricks** etc.
- **Skin infections** may be caused by cyanobacteria *Lyngbya*.
- **Toxin secreting cyanobacteria** are mainly **responsible for water blooms**. These on death emit foul smell, water gets contaminated with chemoheterotrophic bacteria and unfit for normal use.
- Some cyanobacteria like *Rivularia* **release toxins which is harmful for aquatic fauna**.

End of the Chapter

Chapter 4

Kingdom Protista

- **Protista** is a kingdom of **unicellular eukaryotes** (except red and green algae).
- The kingdom was created by **Haeckel in 1886**.
- Protists include solitary unicellular or colonial unicellular eukaryotic organisms **which do not form tissue**.
- They are mostly aquatic.
- The unicells may be naked or covered by cell wall, pellicle, shell or cuticle.
- A well defined nucleus is present. Protists can be uninucleate, binucleate or multinucleate.
- The genetic material is **linear DNA**, **enclosed by nuclear envelope**, **complexed with proteins** and **organised into distinct chromosomes**. This character continues in the remaining three kingdoms.
- The cytoplasm contains besides ribosomes, a variety of organelles such as mitochondria, plastids (in photosynthetic protists), lysosomes, cytoskeleton, endoplasmic reticulum and Golgi bodies. Ribosomes are of two types, 80 S cytoribosomes and 70 S organelle ribosomes. Many have centrioles also.
- Cytoplasm is always in motion. The phenomenon is called **cytoplasmic streaming** or **cyclosis**.
- Cell wall, if present, contains cellulose.
- Food reserve is **starch**, **glycogen**, **paramylon**, **chrysolaminarin and fat**.
- All the three types of life styles (plant, animal and fungal) occur in protists.
- **Some protistans are parasitic**. Some **live symbiotically** as in the gut of animals while a few **act as decomposers**.
- Protistans are **connecting link between monerans and rest of the kingdoms**.
- **Asexual reproduction** is quite common and **occurs through budding**, **binary fission**, **multiple fission**, **plasmotomy**, **sporulation**, **cyst formation**, etc.
- **Sexual reproduction** occur with the help of nonjacketed gametangia. It **involves meiosis and karyogamy**.
- Mitotic apparatus is formed during cell division.
- No embryo is formed.
- In many forms, plastids, (9 + 2 strand) flagella and other organelles are present.
- The nutritive modes of these organisms include photosynthesis, absorption, ingestion and combination of these.
- The organisms **move by flagella**, **cilia**, **pseudopodia**, **contraction** and **mucilage extrusion**.
- **Kingdom protista (also called protoctista) is divided into 3 main groups** –
  - **Photosynthetic protists** (Protistan algae) – Eg., **dinoflagellates** or class dinophyceae (certain, *Glenodinium, Gymnodinium, Gonyaulax, Noctiluca* and *Peridinium*); **diatoms** or class bacillariophyceae (*Navicula, Nitzchia, Metosira, Cymbella, Amphipleura, Pinnularia*) and **euglenoids** or *Euglena* like flagellates (*Euglena, Eutreptia, Phacus, Peranema*).
  - **Consumer protists** – Slime moulds or Myxomycetes, eg., *Physarum, Physarella.*
  - **Protozoan protists** – Eg., *Giardia, Trypanosoma, Leishmania, Amoeba, Entamoeba, Plasmodium* (malarial parasite), *Paramecium* etc.

Important groups of protista

Chrysophytes [Diatoms and Golden Algae (Desmids)]

- **Diatoms** included in phylum chrysophyta of algae are also known by the name **golden algae**.
- They have been grouped under two categories, namely pennate types and centric types.

- **Pennate types** are **bilaterally symmetrical and centric types** are **radially symmetrical**.
- Diatoms have cell walls containing **silica**, **constructed in two overlapping halves**, which fit together like two parts of a soap box (pennate types) or pair of petridishes (centric types).
- The **outer wall is called epitheca** and **inner wall is a called hypotheca**.
- They are present in both fresh and salt water and comprise an important food for the aquatic animals. However, out of 5,500 species mostly are marine.
- They **lack flagella** and **float mainly due to light storage lipids** present in them.
- Due to their silica impregnations, the walls of diatoms are indestructible.
- As a result diatomaceous earth formation has occurred due to remains of cell walls of diatoms in the form of fossils.
- Silica wall of diatoms is designed with fine ridges, lines, pores etc.
- These ornamentations are either radially symmetrical or bilaterally symmetrical on either side of the long axis of the cell.
- **Food reserve** is **oil** and **chrysolaminarin** or **leucosin** (β 1 - 3 glucan)
- Multiplication is through **binary fission**.
- Binary fission reduces the size of most daughters due to relation of one valve of the parents. This is corrected through the development of **rejuvenescent cells or auxospores**. Eg - *Coscinodiscus*, *Stephanodiscus*, *Cymbella* etc.
- Diatoms may **exhibit slow gliding movements** produced by streaming of cytoplasm through grooves on the surface of cell wall.
- Due to various designs over the cell wall, they have been **regarded as jewels of the plant kingdom**.
- The oils extracted from some fishes and whales are actually the ones produced by diatoms.
- Diatomite deposits are often accompanied by petroleum fields. Much of the petroleum of today is probably due to decayed bodies of the past diatoms.
- Diatomite is porous and chemically inert. It is therefore, used in filtration of sugars, alcohols and antibiotics.
- Diatomite is employed as a cleaning agent in tooth pastes and metal polishes.
- Diatomite is added to paints for enhancing night visibility.
- Diatomite is employed as insulation material in refrigeraters, boilers and furnaces.
- Diatomaceous earth is added to make sound proof rooms. It is a good industrial catalyst and a source of water glass or sodium silicate.
- Diatomite was at one time employed in handling and storage of dynamite and strong acids.

Dinoflagellates

- They comprise the phylum pyrrophyta of algae, golden brown photosynthetic protists.
- They are single celled, most of them are surrounded by a shell made up of thick interlocking plates covered with cellulose cell wall.
- They are **motile with two flagella** (hence dinoflagellates) one projecting from one end and the other running in a transverse groove.
- Like diatoms they **have fucoxanthin** in addition to chlorophyll.
- They are **autotrophic and photosynthetic** (e.g. *Ceratium*). *Blastodium* is a colourless parasite on animals.
- The **food reserves** is in **the form of oils** and **polysaccharides**.
- Most of the dinoflagellates are marine and important photosynthesizer in the ocean.
- Occasionally members like *Gonyaulax* accumulate in large numbers in some parts of sea, colouring the water red and are responsible for red tide.
- *Gonyaulax* **causes** '**red tides**' because **it shows bioluminescence or phosphorescence** and make the sea look red.
- Some species of dinoflagellates are poisonous to vertebrates and when these accumulate, large number of fish in that region of ocean may be killed.
- A non-contractile vacuole or pusule is present.
- Due to presence of two flagella at right angles to each other, the dinoflagellates show peculiar spinning movement. Hence, they are called **whorling whips**.
- Nucleus is **mesokaryon** with condensed chromosomes even in interphase. Histone is absent. Division occurs through **dinomitosis** in which the **nuclear envelope persists**.
- Microtubular spindle is not formed. **Chromosomes are acentric** and move while attached to inner membrane of nuclear envelope.
- Dinoflagellates may have eye spots, **trichocyst** (*e.g.*, *Peridinium*) and **cnidoblasts** (*e.g.*, *Nematodinium*).

- Some forms show **bioluminescence** or phosphorescence, and are called **fire algae** *e.g.*, *Noctiluca*, *Gonyaulax*.
- Method of reproduction is **only asexual**. **Sexual reproduction is usually absent** (exception– *Ceratium*).
- Some species of dinoflagellates are taken as food by mussels. These mussels remain unharmed by dinoflagellates but if man eats these infected mussels, he may fall ill.

Euglenoids

- Euglenophyceae includes flagellate protists of fresh water and damp soils.
- Presence of anterior invagination like some ciliates has given the name plant-animals.
- **Euglenoids are more advanced than blue-green algae from evolutionary point of view, for they have a definite easily stained nucleus and the chlorophyll is not scattered in granules but is localized in chloroplasts as in higher plants. The nuclear envelope persists during division**.
- They are free living, found in fresh water ponds and ditches or in the damp soil.
- Euglenoids are **characterised by absence of cell wall**, but they do **contain flexible pellicle made up of protein**.
- All the euglenoids **have one or two flagella** (tinsel and tactellum) by means of which they can swim easily.
- *Euglena* is more readily available protist for laboratory studies.
- *Euglena* bears a flagellum inserted at the anterior end in a cavity.
- They **bear a red pigmented eye spot** and a gullet near the base of the flagellum. The pigment in eye spot is **astaxanthin**.
- A swelling called **paraflagellar body** is found in the region of union of flagellar roots.
- Photosynthetic forms bears many, radiating chloroplasts of various shapes.
- The chloroplasts contain pigments like **chlorophyll a**, **chlorophyll b**, **xanthophyll**.
- Nucleus with one or more prominent nucleoli occurs.
- Pyrenoids may or may not be present.
- Some euglenoids are green and **holophytic** (photo autotrophic) like other plants. Few are non-green and **saprobic** like fungi and bacteria.
- Some capture and ingest the organisms like animals (holotrophic). Green forms have saprobic mode pickup organic matter from outside (myxotrophic).
- Holotrophic or phagotrophic nutrition is absent in *Euglena*.
- Euglenoids **store carbohydrates** in the form of **paramylum chemically**, **distinct from starch and glycogen**.
- Reproduction is usually **asexual by cell division** but sexual reproduction has been reported in one genus.
- Under favourable condition, euglenoids reproduce by simple, **longitudinal binary fission**.
- Flagellum disappears prior to division.
- Most of the species produce **cyst** having thick stratified membranes with **deep red colouration due to synthesis of haematochrome**.
- Besides cyst formation, many of non-flagellate cells may get embedded in a common gelatinous sheath resembling a **palmella stage** (as in algae).
- Eg – *Euglena, Paranema, Trachelomonas*.

Slime moulds

- Slime moulds are **consumer decomposer protists**.
- Asexual reproduction takes place through **binary fission**, **plasmotomy**, **spores**, **cyst** and **sclerotium**.
- Sexual reproduction is **isogamous or anisogamous**.
- Both zygotic meiosis (cellular slime moulds) and gametic meiosis (acellular slime moulds) occur.
- Slime moulds have **characters of plants** (cellulose cell wall), **animals** (phagotrophic nutrition), and **fungi** (spores). They **take part in both decomposition of organic matter** and **feeding of other decomposer organisms**.
- Slime moulds, therefore, **live in contact with organic matter**.
- Slime moulds (500 sp.) **have several features** which are **animal like in their vegetative stages** and **plant like in reproductive stages**.
- The slime moulds are widely distributed, growing in damp and shady places.
- They may be found in the soil rich in humus, damp old planks of wood, rotting logs, decaying leaves etc.
- They **prefer moisture and darkness or dim-light for normal growth**, they move to drier and exposed habitats during reproductive phase.
- More than 100 species, have been reported from India.
- The **vegetative phase** of the thallus is a **free-living**,

naked, **multinucleated mass of protoplasm called plasmodium**.

- The plasmodium consists of **diploid nuclei**, **lacks cell wall** and **secretes lime**.
- The plasmodium shows amoeboid movement **by producing pseudopodia**.
- Chlorophyll is lacking, so these are generally saprophytic, rarely parasitic causing abnormal swellings upon the bodies of hosts.
- They reproduce by means of spores produced in sporangia.
- The spores have cellulosic cell wall and are produced through meiosis.
- The slime moulds are generally holocarpic.
- The spores germinate to produce myxamoebae or biflagellated swarm cells behaving as gametes.
- The swarm cells fuse in pairs showing isogamous types of sexual reproduction.
- Slime moulds may be colourless or variously coloured like yellow, orange, brown etc.
- Slime mould are of **two types** – **acellular** and **cellular**.
- **Acellular slime moulds** have a wall-less multinucleate protoplasm or **plasmodium** without (**protoplasmodium**) or with a number of branched veins showing cyclosis (Phaneroplasmodium).
- Multiplication occurs by plasmotomy.
- Normally when food is about to exhaust, the plasmodium comes to rest and develops sporangium.
- Each sporangium has a noncellulosic covering called **capillitium**. Eg, *Fuligo*, *Physarum*.
- **Cellular slime moulds** are initially in the form of haploid uninucleate wall-less **myxamoebae** which are surrounded by mucilage, move about by pseudopodia and feed on bacteria and other micro-organisms through ingestion.
- Myxamoebae multiply by **binary fission**.
- Sexual reproduction occurs occasionally through **macrocyst formation**. Eg. *Dictyostelium*, *Polysphondylium*.

Protozoa

- Protozoa (also included in the animal kingdom) are unicellular organisms having varied form, structure, and holozoic, saprobic or parasitic nutrition. Reserve food is glycogen, cysts occurs during unfavourable condition. Asexual reproduction by fission or budding and sexual reproduction by conjugation or syngamy.
- Major groups of protozoans based on locomotary organs are –
  - **Zooflagellata** (Flagellated protozoans)
  - **Sarcodina** (Amoeboid protozoans)
  - **Ciliata** (Ciliated protozoans)
  - **Sporozoa**

  [*For more details refer chapter Protozoa*]

End of the Chapter

Chapter 5

Fungi, Lichen and Mycorrhiza

FUNGI

- The **fungi** (*singular*, fungus) are a group of eukaryotic micro-organisms that lack chlorophyll, are unable to synthesize their own food and are therefore, heterotrophic. They live either as saprophytes, obtaining their food from the dead organic matter, or parasites, obtaining food from the bodies of living plants and animals.
- The term fungus is a latin word meaning **mushroom**.
- The branch of science that deals with the study of fungi is called **mycology** (Greek word *mykos* = mushroom and *logos* = discourse), and the branch that deals with the study of fungal disease is called **fungal pathology.**
- **Clausius** (1601) is regarded as the earliest writers who described fungi.
- The founder of mycology is **Antonio Micheli**. He **gave the first systematic account of fungi** in his book *Nova Plantarum Genera.*

General characters of fungi

- Fungi is very large group of over 100,000 species.
- Fungi are **ubiquitous** *i.e* occurs in a variety of habitats.
- Most of them are **moisture loving and terrestrial**, but a few are **aquatic**, *e.g., Monoblepharis* and *Saprolegnia* and these are commonly known as '**water moulds**'.
- A few fungi are **epiphytic**, live on trees, *e.g., Armillaria* on apple tree and causes red rot of apple.
- It is usually defined as a group of those organisms which form the thallus (*i.e.*, not differentiated into root, stem and leaves), built up of single cell or cells (unicellular or multicellular).
- Fungi **lack chlorophyll** and are unable to synthesize their own food by the process of photosynthesis.
- Fungi **obtain their nutrition from the external source by the process of extracellular digestion** and **absorption of the digested material**.
  Such **mode of nutrition** is called **heterotrophic** and the organisms are called **heterotrophs**.
- Heterotrophic organisms either live on dead decaying organic matter or on living organisms.
- **According to their mode of nutrition**, fungi are of **two types – parasites** and **saprophytes**.
- **Parasite** may be defined as "an organism existing in an intimate association with another living organism from which it derives an essential part of the materials for its existence". Thus, these organisms grow on living organisms and obtain their food from it.
- **Parasitic fungi** obtain their food from living hosts.
- These may be :
  - **Ectophytic :** These are externally on the host, e.g., *Erysiphe* (Powdery mildew).
  - **Endophytic :** These are inside the tissue of plants, e.g., *Albugo*, *Phytophthora*, *Alternaria*.
- **Saprotrophs** obtain their food from non-living decaying organic matter (such as bread, meat, fruit, vegetables, animal dung etc.). Such mode of nutrition is called saprophytic.
- Some fungi grow in **symbiotic association with algae to form lichens**. Some other grow in close association with the **roots of higher plants and form mycorrhiza**.
- Fungi posses definite cell wall (containing cellulose or chitin or both *i.e.*, fungus cellulose) and true nucleus (eukaryotic) but lack chlorophyll (achlorophyllous) and differentiation of vascular tissue (*i.e.* non-vascular).
- They are spore forming and **reproduce by vegetative**, **asexual** and **sexual methods**.

- The **reserve food material** is in the form of **glycogen** and **oil globules**.
- Fungi grow well at **20-30ºC** and at **acidic pH** (6.0).
- Fungi may be unicellular (yeast), much branch filamentous (*Rhizopus*) type.
- The filamentous thread like structures that make up the fungal body is called **mycelium**.
- **Hyphae** is the **unit structure that make up** the **mycelium** (gk word *hypha* - web).
- Hyphae are of **two types** – **aseptate** or **coenocytic** (multinucleate) and **septate** (number of partitions or septa).
- Aseptate hyphae may form septa during reproduction, eg *Rhizopus*, *Albugo*, *Phytophthora* etc.
- In septate form cell may be **monokaryotic** (uninucleate) or **dikaryotic** (two nuclei) or **multinucleate**.
- Septa are of **3 types** – **complete septum**, **septum with simple pore** and **septum with dolipore**.
- In **complete septum** the cross wall is complete without distinct pores, e.g., *Geotrichum*.
- In most ascomycetes and deuteromycetes, the **septum possesses simple central pore**. Simple central pore may get plugged by crystalline structure called **woronin body**, e.g., trichomycetes. Woronin body is secreted by microbody and covered by membrane.
- In basidiomycetes, the septum becomes barrel-shaped around a central pore called **dolipore septum**, it may be surrounded by pore cap.
- Septal pores **allow quick transport of nutrients from the region of absorption to all parts of the mycelium**.
- The reproductive hyphae are supplied with the nourishment from the vegetative hyphae throughout the septal pores.
- When mycelium is interwoven to form web like structure it is called **plectenchyma**.
- It is of two types – **prosenchyma** and **pseudoparenchyma**.
- **Prosenchyma** is the mycelium in which hyphae are loosely interwoven and lie more or less parallel to each other.
- **Pseudoparenchyma** is the mycelium in which the hyphae are very loosely packed, so individual hypha cannot be identified and appear as isodiametric cells giving the appearance of parenchyma cells in higher plants.
- When mycelium by interweaving forms compact resting structure it is called **sclerotium**.
- When fungal mycelia are interwoven to form thick cord-like structures like roots, that help in absorption, it is called **rhizomorphs**.
- When the plant body is unicelled at one stage and mycelial at the other end then the organisation is described as **dimorphic**.
- When the entire mycelium is converted into reproductive structure, the thallus is called **holocarpic**.
- In **eucarpic forms** only a part of thallus become reproductive. This can be **monocentric** (have single sporangium) or **polycentric** (have many sporangia).
- The hyphal wall is a made up of **fungal cellulose** in which **cellulose is impregnated with chitin and contains nitrogen in addition to carbon and hydrogen**. **Chitin is a polymer of N-acetyl glucosamine**.
- The protoplast is covered by a thin semipermeable plasma membrane.
- The cytoplasm appear granular and contains many minute nuclei scattered in the peripheral layer.
- The nuclei are very small and inconspicious.
- The cytoplasm contains many small vacuoles filled with cell-sap or a number of small gas filled vacuoles.
- The vacuoles are small, few or absent in the actively growing tips of the mycelium.
- The hypha also may be seen to have mitochondria, dictyosomes (golgi bodies), ribosomes, endoplasmic reticulum, oil drops and glycogen, granules etc. under electron microscope.

Reproduction

- The fungi **reproduce by all the three methods** – **vegetative**, **asexual** and **sexual**.
- **Vegetative reproduction** takes place by various methods as fragmentation, fission, budding, sclerotia, oidia and chlamydospores.
- In **fragmentation**, the hyphae of fungus break into small pieces and each piece may later grow into new mycelium.
- **Fission** is common in yeast. The cell divides into daughter cells which separate by constriction or transverse walls.
- In **budding** daughter bud appears from parent cell. After getting the normal size bud break off. When the buds fail to separate, after repeated budding from pseudomycelium.
- **Oidia** are rounded or oval structure having thin

walls. The hyphae undergo segmentation and produce yeast like cells called oidia. Each oidium on germination produces new mycelium.

- Some fungi produce **chlamydospores** which are thick walled resting cells. They are intercalary in position. They are capable of forming a new plant on approach of favourable conditions.
- **Gemmae** resemble chlamydospores in structure but are not very durable and thick walled.
- Many true fungi produce **sclerotia** which are hardened, resistant bodies. Sclerotia are capable of surviving unfavourable periods and as soon the conditions are favourable, they germinate to produce vegetative hyphae.
- Asexual reproduction takes place by means of **spores**.
- The spores in fungi vary in shape. Spores are usually unicellular, thin walled, spherical and diameter ranging from 5-50 m.
- Several types of spores are reported in fungi, eg. zoospores, sporangiospores, uredospores, teleutospores, pycniospores etc.
- Sometimes the spores are produced endogenously in special sac- like asexual reproductive bodies called **sporangia**.
- Spores in such cases are called **sporangiospores**.
- **Zoospores** are uninucleate, thin walled, formed in zoosporangia. They may be **uniflagellate**, *e.g.*, *Synchytrium* or **biflagellate**, *e.g.*, *Saprolegnia*, *Pythium*.
- Biflagellate zoospores are of **two types** –
  - **Pear-shaped** or pyriform, with 2 flagella placed at anterior end, are known as primary zoospores.
  - **Kidney-shaped** or bean-shaped, bearing two oppositely directed flagella inserted laterally in a furrow or concave side (secondary zoospores).
- **Aplanospores** are **thin walled**, **non-motile** spores formed inside sporangium, which **give rise to new mycelium**, *e.g.*, *Rhizopus*, *Mucor*.
- **Conidia** are non-motile, thin walled **exogenously** produced spores on a condiophore and sometimes they are arranged in chains upon the conidiophore, *e.g.*, *Aspergillus* and *Penicillium* or singly in *Pythium*, *Phytophthora*.
- Hyphae bearing conidia are called **conidiophores**.
- The conidiophores in groups may form structures like acervuli, synnemata etc.
- **Pycniospores** are small conidia-like bodies produced in flask-shaped cavities called the pycnia, *e.g.*, *Puccinia*.
- **Ascospores** are uninucleate, unicellular non-motile, usually eight in number produced in sac-like structures called ascus, characteristic of ascomycetes.
- **Basidiospores** are characteristic of basidiomycetes, produced exogenously by club-shaped basidium or sterigma. Usually four basidiospores are produced.
- **Uredospores and teleutospores** are binucleate spores produced in clusters called **uredosori**.
- **Sexual reproduction** in fungi **involves three process – plasmogamy** (fusion of protoplast), **karyogamy** (fusion of two haploid nuclei) and **meiosis**.
- Fungi may be dioecious or unisexual some are monoecious or bisexual. Former are heterothallic and latter are homothallic.
- Fungi generally possess **unicellular sex organs** and show **gradual degeneration of sexes**.
- **Male gametangia** is called **antheridium.** It is s**maller in size**.
- **Female gametangia** is called **oogonium** which are comparatively **larger in size**.
- The gametes are formed within gametangium.
- All three types of sexual reproduction is present in fungi as isogamy, anisogamy, oogamy.
- In **isogamy** fusing gametes are exactly alike in appearance and functions.
- Fusion of dissimilar gametes is called **anisogamy**. In anisogamous forms both fusing male and female gametes are usually motile.
- Fusion of male gamete with female gamete is called **oogamy**.
- In **gametangial contact** the two gametangia come close to each other, but do not fuse. The male gametangium sends a tubular outgrowth, called fertilization tube, through which the non-motile male gamete or male nucleus migrates into the female gametangium. Eg. *Phytophthora, Albugo*.
- In **gametangial copulation** two gametangia fuse with each other and lose their identity in the sexual act resulting in the formation of zygospore. Eg. *Mucor, Rhizopus*.
- In **spermatization** some fungi produce numerous, minute, uninucleate, spore-like

bodies called **spermatia**. These are transferred through various agencies to **receptive hyphae** or **trichogyne** of female gametangium. Finally the contents of spermatium is transferred into receptive hypha through a pore. Eg- *Puccinia graminis*.

- In **somatogamy**, the sex organs are not formed and the fusion occurs between two vegetative or somatic cells resulting **dikaryotization**. Eg. *Agaricus*.
- **Homothallism** is the condition whereby thalli are morphologically and physiologically identical. So that fusion can occur between gametes produce on the same thallus.
- **Heterothallism** is the phenomenon in which the fusing gametes belong to two genetically distinct strains of the some species though there may not be any morphological distinction between the gametes or structures bearing them. It was first **discovered by Blakeslee** in 1904.

Blakeslee found that in *Mucor* and *Rhizopus*, certain strains formed zygospores even in pure cultures where different mycelia belongs to the same genetic strain, eg. *Rhizopus sexualis*.

Heterothallism is a mechanism to perform outbreeding and prevent inbreeding. As it involves sexual reproduction between genetically different strains, the product of sexual reproduction comes to have different alleles and different genes linkages. It introduces variations that are helpful in adapting to diverse habitats, unfavourable environments and toxic chemicals.

Classification of fungi

- Fungi are divided into **4-classes**, according to the septation of the mycelium and on the basis of characteristic features of reproduction – **phycomycetes**, **ascomycetes**, **basidiomycetes**, **deuteromycetes** (*Refer table given below*).

Phycomycetes

- **Phycomycetes** are algae like fungi.
- Hyphae of phycomycetes are **coenocytic** and **non septate**.
- Phycomycetes are **entirely aquatic** and **known as water moulds**.
- Phycomycetes are the **most primitive true fungi**.
- In phycomycetes, reproduction takes place by both **sexual** and **asexual methods**.
- Asexual reproduction **takes place by spores**.
- Motile spores are called **zoospores** and non-motile spores are called **aplanospores**.
- **Chlamydospores** are those thick walled resting spores which are formed on the hyphae of some lower fungi.
- Two types of flagella are present in phycomycetes, these are **whiplash** and **tinsel type**.
- Sexual reproduction in phycomycetes takes place by **planogametic copulation**, **gametangial contact** (or **gametangial copulation**.)
- The **most common examples of phycomycetes** are *Saprolenia, Rhizopus, Mucor* etc.

Table : Classification of fungi

Features	Phycomycetes	Ascomycetes	Basidiomycetes	Deuteromycetes
Common name	Algae like fungi	Sac fungi	Club fungi	Fungi imperfecti
Mycelium	Aseptate, coenocytic	Septate, branched unicellular	Secondary, mycelium, dikaryotic	Branched, septate mycelium
Asexual reproduction	Zoospores, aplanospores, chlamydospores, sporangiospore	Conidia, budding	Oidia, basidiospores	Conidia
Sexual reproduction	Isogamy, oogamy	Fusion of compatible nuclei. Ascospores formed in ascus	Somatogamy, Basidiospores formed on sterigmata	Absent or not known
Fruiting body	Zygospore	Ascocarp (cleistothecium, perithecium, apothecium)	Basidiocarp	Absent

Ascomycetes

- Ascomycetes are commonly called as **sac fungi**.
- Ascomycetes are characterised by **well developed thallus** and **production of ascospores**.
- Cell in ascomycetes are **uninucleate** or **multinucleate**.
- Mycelium of ascomycetes are **branched and septate except in** Yeast.
- Yeast is **unicellular** ascomycetes.
- **Ascospores** are formed inside the ascus during sexual reproduction.
- The typical number of ascospores in an ascus is **eight**.
- **No flagellated cells** are found in ascomycetes.
- Asexual reproduction may take place by **budding**, **fission**, **fragmentation**, **oidia**, **conidia formation** etc.
- Sexual reproduction takes place by **plasmogamy** which may be **isogamous** or **heterogamous**.
- Fruiting body of ascomycetes is **ascocarp**.
- Ascocarp may be **cleistothecium** (globose having no natural opening), **perithecium** (globose having one apical opening) or **apothecium** (saucer shaped).
- The **most common examples** of ascomycetes are *Penicillium, Neurospora, Yeast* etc.

Basidiomycetes

- Basidiomycetes are **commonly called as club fungi**.
- Basidiomycetes resembles the ascomycetes in having a **septate mycelium** and **production of non-motile spores**.
- **Dikaryotization** or **diplodization** is the process by which binucleated condition is attained from uninucleated conditions.
- Basidiomycetes have a **short lived uninucleate stage** and a **dominant binucleate stage**.
- Cells of basidiomycetes are made up of **chitin-mannan**.
- Basidiomycetes are characterised by the **dolipore septa and clamp connections** (a hook like clamp is formed which help in passage of nuclei) in the mycelium.
- Basidiospores are **formed over the basidium during sexual reproduction**.
- Fruiting body of basidiomycetes is known as **basidiocarp**.
- **Asexual reproduction** occurs by **fragmentation**, by means of spores such as **conidia**, **oidia**, **arthrospores etc.**
- **No specialised sex organs** are present in basidiomycetes.
- The **life cycle** of basidiomycetes **consists of** three clear and distinguishable phase. These are **plasmogamy, karyogamy** and **meiosis**.
- Common basidiomycetes are *Ustilago, Puccinia Agaricus, Polyporus* etc.

Deuteromycetes

- Deuteromycetes is an **artificial group without any common relationship**.
- Deuteromycetes are commonly called as **fungi imperfecti** due to the absence of perfect sexual stage.
- Deuteromycetes have **septate hyphae** and **reproduce asexually by means of conidia**.
- Beside conidia **thallospores** are – also found in some fungi imperfecti.
- Two types of thallospores are – **chlamydospores** and **arthrospores**.
- Common deuteromycetes are *Cercospora, Collectotrichum, Pyricularia, Fusarium*.

Harmful and beneficial aspects of fungi

- Some fungi are **used as delicious food**. The fructifications of certain fungi are used as nutritious and delicious foods, *e.g.*, *Agaricus bisporus* and *A. campestris* (mushrooms). *Morchella* and *Lycoperdon*, *Clavatia*, *Pleurotus*, *Volvaria*, *Volvariella*, etc., are also edible fungi.
- Yeast is an **important source of vitamin B and D**. *Saccharomyces*, *Endomyces*, *Rhodotorula*, *Torulopsis* are **rich in proteins**.
- A food called '**Sufu**' is produced from *Mucor* and antimucor.
- Fungi are used in the **production of different antibiotics** (substances of microbial origin and having antimicrobial activites).
- In **alcoholic industry** yeast (*Saccharomyces*) is used for **fermentation**.
- In **baking industry** CO_2 evolved raises '**dough**'.
- **Enzymes** like **taka diastase**, **digestin** and **polyzime** are produced from *Aspergillus flavus-oryzae* series.
- **Invertase** is prepared from *Saccharomyces cerevisiae*, **amylase** from *Aspergillus oryzae*, **zymase** from yeast (*Saccharomyces cerevisiae*)
- *Penicillium camemberti* and *P. roqueforti* are **used for flavouring cheese**.

- **Various organic acids** are obtained from fungi, ***e.g.*, citric acid** by *Aspergillus niger* and *A. wentii*, *Mucor*, etc, **gluconic acid** by *Aspergillus niger* and *Penicillium purpurogenum*; **gallic acid** by *P. glaucum* and *A. gallomyces*; **kojic acid** by *A. oryzae*; **fumaric acid** by *Rhizopus stolonifer*.
- **Gibberellic acid** is obtained from a fungus *Fusarium moniliforme* (*Gibberella fujikuroi*).
- **Fungus** widely **used in genetic engineering** is *Neurospora crassa*. While working on *Neurospora crassa*, Beadle and Tatum (1941) proposed **one gene one enzyme hypothesis** and received Nobel prize in 1958.
- *Aspergillus niger* is widely used to **determine available copper, magnesium, potassium and molybdenum in the soil**.
- Saprophytic fungi live upon dead organic matter and thus break down complex substances into simple ones, which are again absorbed by plants has increasing soil fertility.
- Soil inhabiting fungus *Trichoderma* kills *Pythium* fungus (root rot fungus). Similarly *Penicillium vermiculatum* checks *Rhizoctonia solani*.
- **Predacious fungi** like *Dactyllela, Dactylaria, Zoophagus* and *Arthrobotrys*, etc.,destroy certain nematodes, eelworms, etc., causing plant diseases.
- They help in absorption of **water and nutrients** and in turn get ready-made food (symbiosis).
- *Absidia*, *Aspergillus*, *Cladosporium*, *Mucor*, *Penicillium* and *Rhizopus* have soil binding property (by mucilage) and they make the soil good.
- Many **insect pests** can be controlled by use of fungi like *Aschersonia aleyroides*, *Isoria ferinosa*, *Empusa*, etc.
- Few fungi like *Saccharomyces, Rhodotorula* **fix-atmospheric nitrogen in soil**.
- Fungi is the **causative organism** of many diseases in plants, animals as well as in **humans**.
- *Claviceps purpurea* causes **ergotism** and also yield a hallucinogenic drug called **LSD**.
- The potato crop was destroyed in Ireland in the middle of 19th century due to infection of *Phytophthora*.

Diseases associated with fungi

Plant diseases:

- Black wart disease of potato– *Synchytrium endobioticum*.
- White rust of crucifers– *Albugo candida or Cystopus candidus*.
- Late blight of potato– *Phytophthora infestans*. (Famous famine of Ireland (1845) is associated with this disease which caused death of lakhs of people).
- Early blight of potato– *Alternaria solani*.
- Powdery mildews– *Erysiphe* sps.
- Damping of seedling– *Pythium* sps.
- Loose smut of wheat– *Ustilago tritici.*
- Black rust of wheat– *Puccinia graminis-tritici*.
- Apple scab– *Venturia inaequalis*.
- Downy mildews– *Peronospora* sps.
- Red rot of sugar cane– *Colletotrichum falcatum*
- Tikka disease of groundnut– *Cercospora* sps.
- Stem gall of coriander– *Protomyces* sps.
- Wilt of arhar– *Fusarium* sps..
- Leaf rust of coffee– *Haemelia vastatrix*.
- Blast disease of rice– *Pyricularia oryzae*.
- Green ear disease of bajra– *Sclerospora graminicola*.
- Flag smut of wheat– *Urocystis tritici*.
- Maize smut– *Ustilago maydis*.
- Loose smut of oat– *Ustilago avenae*.
- Covered smut of oat– *Ustilago kolleri*.
- Covered smut of jowar (*Sorghum*)– *Sphacelotheca sorghii*.
  (Severe famine of Bengal (1943) which caused death of a large number of people was due to this disease).

Human diseases:

- Aspergillosis (lung disease)– *Aspergillus niger*, *A. flavus, A. fumigatus*.
- Ring worm– *Trichophyton*, *Microsporum*.
- Neuritis (Infection of nervous system)– *Mucor pusillus*.
- Mental disorder (Cryptococcosis)– *Lipomyces neoformans*.
- Ear infection (Automycosis)– *Aspergillus flavus, A. nidulans*.
- Thrush disease of throat– *Monilia*

Animal diseases:

- Athlete foot– *Tinea rubrum*.
- Ringworm– *Trichophyton, Microsporum, Epidermophyton*.
- Mucomycosis– *Mucor, Rhizopus*.
- Aspergillosis– *Aspergillus*.
- Penicillosis– *Penicillium*.

- *Boletus* and *Amanita* spp.are **poisonous fungi**.
- The **fungus that produces latex** is *Mycena*.
- *Mucor*, *Rhizopus*, *Penicillium*, *Neurospora*, *Amanita*, *Polyporus* are commonly called as **pin bread mould**, **bread mould**, **green mould**, **pink bread mould**, **toad stools and brackett fungi** respectively.
- Spores of *Rhizopus*, *Mucor*, *Aspergillus* germinate on jam, jellies, pickles, bread, etc., and destroy them, *Penicillium*, *Mucor* and *Aspergillus* destroy meat.
- *Polyporus* (Pore fungi) causes **wood rot**.
- *Alternaria, Penicillium, Trichoderma, Mucor, Chaetonium, Cephalothecium* and *Fusarium* destroy leather, cloth, rubber, paper, camera lenses, etc.
- **Aflatoxins** are **mycotoxins** (harmful secretion) produced by *Aspergillus flavus, A. fumigatus*, *Penicillium islandicum*, etc.
- These **bind with DNA** and **prevent transcription**, hence protein synthesis. These **cause liver cancer in animals and men**.
- In **VAM** the hyphae develop an arbuscule (penetrate) within the cortex of root. It **helps mainly in phosphate absorption from the soil**.

LICHENS

- Lichens are formed by a **symbiotic relationship between algae** or **cyanobacteria and fungi**, in which individual photobiont cells are embedded in a complex of fungal tissue.
- The number of lichen genera is 400 and species over 15,000.
- The study of lichens is called **lichenology**.
- Body of the lichen is made of a fungus partner called **mycobiont** and a photosynthetic algal partner called **photobiont** or **phycobiont**.
- In 98% of the lichens, the mycobiont or fungal partners belong to ascomycetes. Few lichen shows basidiomycetes fungal partner also.
- Photobionts or phycobionts **either belongs to cyanobacteria or green algae**.
- **Photobiont performs** photosynthesis, nitrogen fixation and elaborates vitamins and other growth substances while **mycobiont takes part in** protective covering body, attachment, absorption and retention of moisture from dew, rain and wet air, and protection against harmful radiations.

History of Lichen

- The term lichen was first given by **Theophrastus** for superficial growth on bark of *Olea europea* (olive) tree.
- **Morisson** (1699) called lichen as musco-fungus.
- **Schwendiner** (1867) gave **dual hypothesis** and established the composite nature of lichen. He defined lichen as 'fungi parasitizing algae'.
- **Bonnier** (1886 - 89) successfully synthesized a lichen by growing fungal spores with algae.
- **Reininke** (1872) gave the term **'Consortium'** for the association of algae and fungi. The term means mutual growth and interdependence. **De Bary (1879)** termed this association as symbiosis.
- **Crombic (1885)** gave the term **helotism** *i.e.* master and slave relationship to the algal and fungal association in lichen. Helotism is the most accepted term used now a days to describe this relationship.

- Algae are present on the **upper part** of thallus and fungi are present on the **lower part** of thallus.
- Fungal partner provides **protection to algal** partner and are also **responsible for the sexual reproduction**.
- Such a mutually beneficial relationship is called symbiosis or mutualism.
- For proper diffusion of nutrients the algal cells and fungal hyphal tips become surrounded by common extracellular substance.
- At times, the mycobiont send haustoria into algal cells, prevent alga to secrete pectic substances or induces alga to secrete nutrients.
- Consequently, fungus is considered to be controlled parasite. The phenomenon of **controlled parasitism** is called **helotism**.
- As algae and fungi both contain **cell wall** which is the characteristic feature of plant cell, **so lichens are considered as plants**.
- About **12 genera** of cyanobacteria and **21 genera** of green algae are considered as lichen symbiont.
- Important **cyanobacteria** are *Nostoc*, *Gloeocapsa* and *Rivularia*.
- **Green algae** symbiont involves *Protococcus*, *Trentepohlia*, *Cladophora* and *Trebauxia.*

- Lichens generally grow on **old walls, roof of house, trunk of trees** or **exposed rocks**.
- Lichen like *Usnea* hangs from the smaller branches of trees.
- Lichen can withstand extreme of cold, heat and drought.
- They are dominant form of vegetation in alpine and arctic tundras.

Reproduction

- **Reproduction** may be vegetative, asexual or sexual.
- **Vegatative reproduction occurs** by –
  - **Fragmentation** – When thallus break into small fragments develop into new lichen thalli.
  - **Soredia** – Soredia are small masses of hyphae enclosing a few algal cells. Soredia are dispersed by air currents. Each soredium develops into a new thallus.
  - **Isidia** – They are **superficial outgrowths** from the upper surface of the thallus. Isidia consist of an external cortical layer and an internal algal layer.
- **Asexual reproduction**
  - In some lichens pycnidiospores are produced at tips of fertile hyphae inside pycnidium which is a flask shaped structure, opening through a pore called ostiole.
  - These spores germinates to produce a fungi mycelium.
  - The fungal mycelium with corresponding alga form new lichen thallus.
- **Sexual reproduction**
  - It is **performed** mainly by its **fungal component**.
  - Most of the lichens belong to the division ascolichens, in which the fungal partners belong to ascomycetes.
  - The male reproductive organ is flask shaped **spermogonium** which produces non-motile male gametes or **spermatia**.
  - The female reproductive organ is **carpogonium** which is differentiated into basal coiled **ascogonium** and upper long tube like **trichogyne**.
  - The **fruiting body ascocarp** formed after fertilization may be a **apothecium** type or **perithecium** type.
  - The bottom of ascocarp is lined by **hymenium** which consists of asci in spread with paraphysis. The wall of ascocarp (apothecium or perithecium) is composed of the vegetative part of the thallus consisting of algal and fungal layers.
  - Each ascus contains eight ascospores which germinate and form fungal mycelia.
  - The mycelium when comes in contact with a suitable alga, forms new lichen thallus.

Classification of lichens

- **On the basis of their fungal partner** the lichens are divided in **two groups** –
  - **Ascolichens** – Fungal partners belongs to ascomycetes. Gymnocarpae, fruiting body is apothecium type. Pyrenocarpae, fruiting body is perithecium type.
  - **Basidiolichens** – Fungal partners belongs to basidiomycetes.
- **On the basis of habitat** lichens are –
  - **Saxicolous** : Rock-dwellers and adapted to xerophytic adaptation, eg. *Xanthoria*.
  - **Corticolous** : Bark-dwellers and grows in adaptation of plenty of moisture, eg. *Parmelia*.
  - **Terricolous** : Terrestrial species and thus grows in soil, eg. *Cladonia floerkeana*.
  - **Lignicolous** : Lichens which grow on wood directly, eg. *Cyphelleum*.
- **On the basis of thallus** lichens may be –
  - **Leprose lichens** – The lichens are in the form of minute scales, attached superficially over the substratum, e.g. *Lepraria incana*.
  - **Crustose** – Lichens are crust-like, closely attached to substratum due to adhesion at several points, eg. *Graphis, Rhizocarpon*.
  - **Foliose** – Lichen body is like a crinkled and twisted leaf, *ie*. flat, branched or lobed. It is attached to substratum by one or a few points, eg. *Parmelia, Peltigera*.
  - **Fruticose** – The lichen shows branched, erect or pendulous with bushy appearance, An attaching disc is present at the base, eg. *Ramalina, Cladonia, Usnea*.
  - **Filamentous** – The photosynthetic partner is well developed and filamentous. It is covered by a few fungal hyphae, eg., *Racodium*.
- **On the basis of distribution of algal component in the thallus** lichens are of **two types** –
  - **Homoisomerous thalli** – Algal cells and fungal hyphae are uniformly dispersed throughout the thallus, eg. *Collema*.

– **Heteromerous thalli** – The algal cells are found in algal zone only. The bulk of lichen body is formed by fungal partner (mycobiont). It includes the surface, medulla and rhizinae. The algal constituents hardly 5% of the lichen body, eg *Parmelia*.

Economic importance of lichens

- Fresh water species of lichen is *Hymenelia lacustris* and marine water species is *Caloplaca marina*.
- *Cladonia rengiferina*, commonly called as **reindeer moss**, is an **important source of food for reindeer**.
- *Cetraria islandica*, commonly called **iceland moss** is **used as source of food of sheep, cattle as well as human**.
- *Everina* **used for making bread**, *Lecanora* is also edible.
- Lichen *Evernia prunastri* **yields an excellent perfume**.
- *Roccella, Parmelia, Evernia* etc. are **dye yielding** (**orchil**) lichen species.
- **Litmus** is **obtained from** lichen *Roccella montaignei*.
- Medicinal property of lichen is due to a substance **lichein**.
- **Usnic acid**, an important broad spectrum antibiotic, **is obtained from** *Usnea* and *Cladonia*.
- *Xanthoria parietina* is used against **jaundice**.
- *Peltigera canina* is used against **hydrophobia**.
- *Cetraria* is used as **laxative**.
- The **protolichesterinic acid**, obtained from some lichen like *Cetraria icelandica*, has anticarcinogenic properties.
- Lichens **serve as indicator of air pollution**, as they are very sensitive to air pollution, especially SO_2 pollution.
- **Crustose lichens** are pioneers in xerosere (succession beginning in dry condition).
- In **Russia** and **Sweden**, some lichens like *Cetraria* and *Lecanora* are used for **alcoholic fermentation**.
- Lichens secrete some organic acids which break down rocks and thus help in soil formation.
- Some lichens are **poisonous also due to various substance present in them** as :

Lichen	Poisonous due to
Letharia Vulpina	Vulpinic acid
Cetraria juniperina	Pinastrinic acid
Parmelia molluscula	Selenium
Xanthoria parietina	Beryllium
Everina fur furcea	Chlorine

MYCORRHIZA

- Mycorrhiza is symbiotic relationship between fungi and roots of higher plants.
- They are thick, irregular with wooly covering devoid of root hair and root cap.
- In a **mycorrhizal association**, the fungus may colonize the roots of a host plant either intracellularly or extracellularly.
- This mutualistic association provides the fungus with a renewable source of food through access to fixed carbon (sugars) from the plant photosynthate.
- These are translocated to the root tissues from their source location (usually leaves), and then to the fungal partners. In return, the plant gains the use of the mycelium's tremendous surface area to absorb mineral nutrients from the soil.
- The **mycelia of mycorrhizal networks have better mineral absorption capabilities** compared to plant roots.
- Mycorrhizal plants are often **more resistant to diseases**, such as those caused by microbial soil-borne pathogens, and are **also more resistant to the effects of drought**, perhaps due to the improved water uptake capability of the fungal hyphae.

Types of mycorhizza

- The two most common types of mycorrhizas are – the **ectomycorrhizas** and **endomycorrhizas** (more commonly known as **arbuscular mycorrhizas**).
- The **two groups are differentiated by the fact that** the **hyphae of ectomycorrhizal fungi do not penetrate the cell wall** of the plant's root cells, while the **hyphae of arbuscular mycorrhizal fungi penetrate the cell wall**.

Ectomycorrhizae

- Ectomycorrhizas, typically form between the roots of woody plants and fungi belonging to the divisions basidiomycota, ascomycota, or zygomycota.
- These are **external mycorrhizae** that form a cover on root surfaces and between the root's cortical cells.
- Besides the mantle formed by the mycorrhizae, most of the biomass of the fungus is found branching into the soil, with some extending to the apoplast, stopping short of the endodermis.

- These are found in 10% of plant families, mostly the woody species, including the Oak, Pine, *Eucalyptus*, *Dipterocarp*, and olive families.

Endomycorrhizae

- Arbuscular mycorrhizas, or VAM (formerly known as **Vesicular-Arbuscular Mycorrhizas**) involves entry of the hyphae into the plant cell walls to produce structures that are either balloon-like (vesicles) or dichotomously – branching invaginations (arbuscules).
- In VAM the hyphae develop an arbuscule (penetrate) within the cortex of root. It helps mainly in **phosphate absorption** from the soil.
- The fungus is generally a zygomycetes.
- The fungal hyphae do not in fact penetrate the protoplast (*i.e.* the interior of the cell), but invaginate the cell membrane.
- The structure of the arbuscules greatly **increases the contact surface area between the hypha and the cell cytoplasm to facilitate the transfer of nutrients between them**.
- Arbuscular mycorrhizas are **formed only by fungi** in the division glomeromycota, which are typically associated with the roots of herbaceous plants, but may also be associated with woody plants.
- Arbuscular mycorrhizas are likely to be very helpful in protecting plants from adverse conditions such as lack of water and nutrients.
- Arbuscular mycorrhizal fungi are quite extraordinary organisms. First they have been asexual for many million years and secondly, individuals can contain many genetically different nuclei (a phenomenon called **heterokaryosis**).
- This type of association is found in 85% of all plant families in the wild, including many crop species such as the grains.

[*For more on mycorrhiza refer chapter Pesticides and Biofertilizers*]

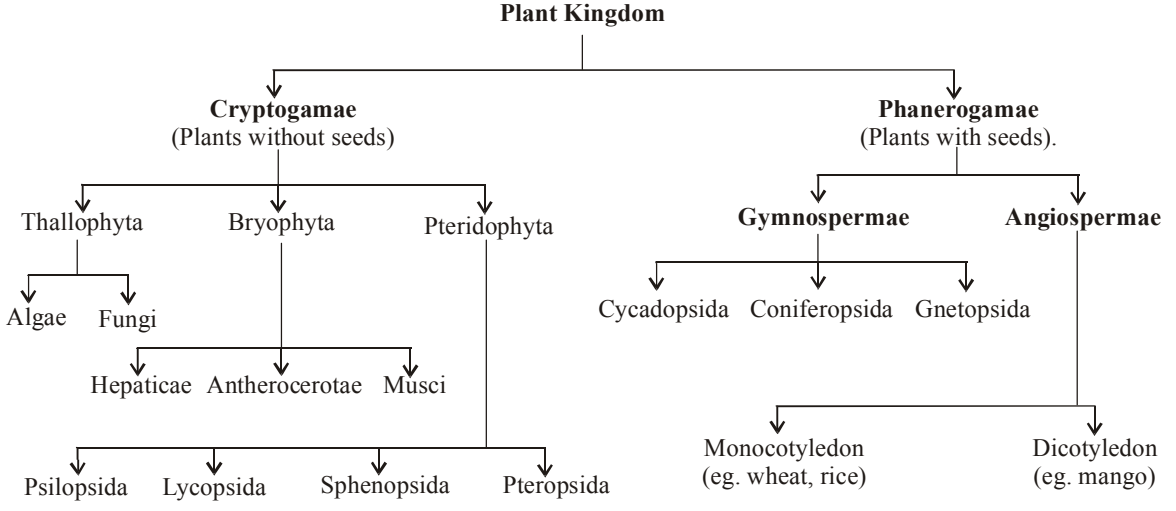
End of the Chapter

Chapter 6

Plant Classification

- **Plant classification** is arrangement of plants into groups and subgroups on the basis of affinities.
- In the two kingdom classification, plants comprise all the photoautotrophic organisms and their non photosynthetic relatives which have absorptive type of nutrition, a wall around the cells and all groups of algae, besides the embryophytes.
- In five kingdom classification, **plant kingdom** comprises only embryophytes and some eukaryotic algae.
- Bacteria, blue green algae, euglenoids, diatoms, dinoflagellates and fungi are excluded.
- **Kingdom Plantae** includes all multicellular, eukaryotic, photosynthetic organisms.
- **Main characters of this kingdom** are –
  - With definite cellulosic cell wall.
  - These are basically non-motile, excepting some aquatic forms.
  - Reproduction is primarily sexual.
  - Presence of definite chloroplasts
  - Photosynthetic mode of nutrition (oxygenic photosynthesis), eg. different types of algae (green, brown, red algae), bryophytes, pteridophytes, gymnosperms and angiosperms.
- In traditional system of classification (Eichler, 1883), plant kingdom is **divided into two subkingdoms – cryptogamae** and **phanerogamae**.
- Plants included under cryptogamae are called **cryptogams** while those placed in phanerogamae are known as **phanerogams.**
- **Cryptogams** (Gk. *cryptos* – hidden, *gamos*-marriage) do not bear conspicious reproductive structures like seeds. Therefore, they are called **lower plants or seedless plants**.
- Cryptogams have **three divisions – thallophyta**, **bryophyta** and **pteridophyta**.
- **Thallophyta**
  - Plant body not differentiated into root, stem and leaves.
  - They do not have well developed conducting tissues.
  - Sex organs are simple.
  - Thallophyta includes – algae, fungi.
  - **Algae** : Green, autotrophic thallophytes, *e.g. Spirogyra*, *Ulothrix*. etc.
  - **Fungi** : Non-green (achlorophyllous) thallophytes having heterotrophic mode of nutrition, *e.g. Albugo*, *Mucor*, yeast etc. [*Discussed under Fungi chapter*]
- **Bryophyta**
  - Plant body gametophytic, thalloid or foliose.
  - Rhizoids present instead of roots.
  - Conducting tissues absent or represented by thick walled cell. (eg. *Funaria*).
  - Sex organs are multicellular and jacketed.
- **Pteridophytes**
  - Plant body sporophytic, differentiated into root, stem and leaves.
  - Xylem and phloem are conductive tissues hence called **vascular cryptogams**.
  - Reproduce by spores.
  - Sex organs are like those of bryophytes.
  - Embryo is always present.
  - Sporophytic and gametophytic phases are morphologically distinct.
  - Show regular alternation of generation.
- **Phanerogams** (Gk, *phaneros*-visible, *gamos*-marriage) have evident reproductive structure in the form of seeds. Therefore, they are called as **seed bearing plants**.
- Phanerogams have **two divisions – gymnosperms** and **angiosperms**.

- **Gymnosperms**
  - Plants having naked ovule in surface of megasporophyll.
  - Flowers-unisexual cone.
  - They are called as phanerogams without ovary.
- **Angiosperms**
  - They are advanced phanerogams
  - Have distinct unisexual or bisexual flowers.
  - Ovules (seeds) are enclosed without ovary wall (fruit wall).
  - The fruit formed as a result of fertilization.
- Angiosperms are divided into **two classes** –
  - **Monocotyledonae** : It is a class of angiosperm having only one cotyledon, eg wheat, rice.
  - **Dicotyledonae** : It is a class of angiosperms having two cotyledons, eg mango.



Flow chart : Classification proposed by A.W. Eichler.

End of the Chapter

Chapter 7

Algae

- The word **algae** was coined by **Linnaeus** (1753).
- The branch of botany dealing with the study of algae is called as **phycology** or **algology**.
- Term phycology is derived from the Greek word *phykos* which means 'alga' or "sea weed".
- Algae are defined as **chlorophyllous**, **thalloid**, **avascular plants with no cellular differentiation**.
- A plant body that is not differentiated into a root stem and leaf is known as **thallus**.
- Algae contains about **18,000 genera** and **29,000 species.**
- Structure and reproduction of algae was written by **Fritsch**. He is known as **Father of algae**.
- Fritsch **divided algae into 11 classes** on the basis of **type of pigments**, **nature of reserve food material** and **mode of reproduction**.

Table : The distinctive features of the major 11 classes of algae

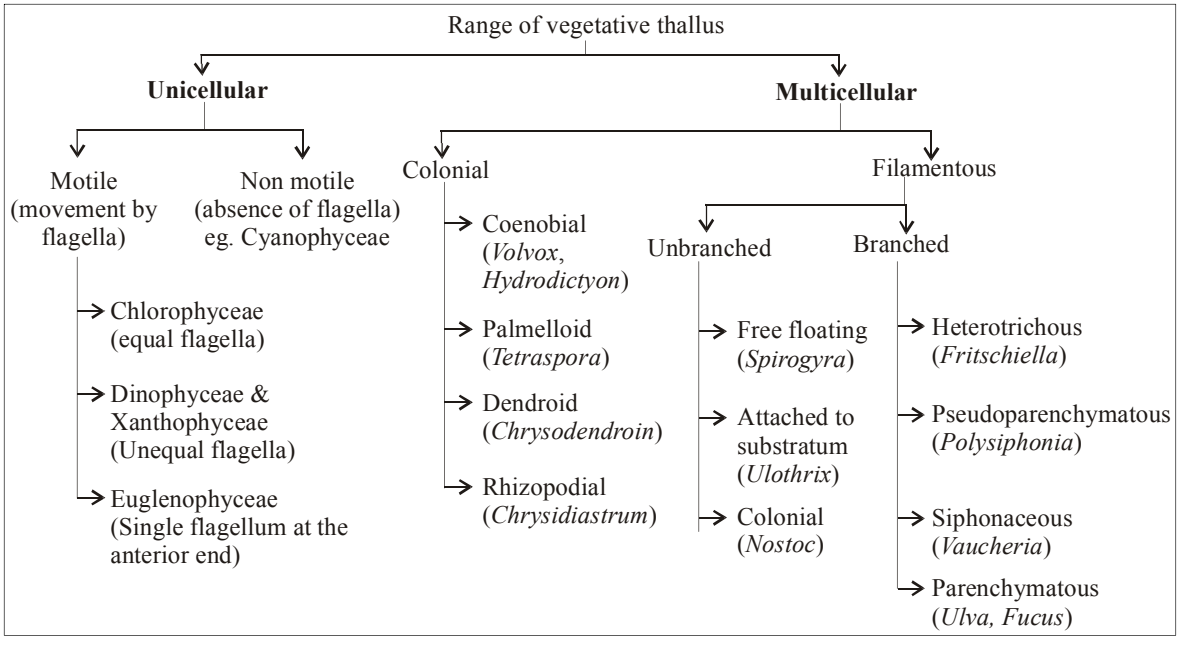
	Class	**Major photosynthetic pigments**	**Reserve food material**	**Number of flagella & their arrangements**
1.	Chlorophyceae	Chl. a & β + carotenoids and xanthophyll	True starch and sugar	Vegetative or gamete cells with two or four equal flagella
2.	Xanthophyceae	Xanthophylls & β-carotenes +Chl. a & e	Oil or leucosin	Two flagella of unequal length
3.	Chrysophyceae	carotene, fucoxanthin, lutein + Chl. a	Leucosin, rarely oil	Flagella when present one or three
4.	Bacillariophyceae	Diatoxanthin, diadinoxanthin, fucoxanthin + Chl. a & c	Oil, volutin	Flagella absent
5.	Cryptophyceae	Chl. a and c, carotenes, xanthophylls	Starch	Two unequal flagella at interior end
6.	Dinophyceae	Chl. a & c, xanthophylls (diadinoxanthin, dinoxanthin)	Oil & starch	Flagella two, lateral in position
7.	Chloromonadineae	Chlorophylls, xanthophylls	Fatty substance or oil	Flagella two, apical or subapical
8.	Euglenophyceae	Chl. a & b, carotenes	Paramylum a starch-like substance but negative to iodine test	Number variable in *Euglena*
9.	Phaeophyceae	Fucoxanthin, flavoxanthin β-carotenes + Chl. a and c	Laminarin, mannitol	In gametes flagella two, unequal and lateral in position
10.	Rhodophyceae	Phycoerythrins + Phycocyanin + Chl. a and d	Floridean starch	Absent
11.	Cyanophyceae	Phycocyanin, Phycoerythrin & chlorophyll	Cyanophycean starch	Absent

Habitat - or occurrence of Algae

- Found in mud - eg *Chara*.
- Found at the banks of lakes or ponds - eg *Rivularia* or *Spirogyra*.
- Found in high temperature - *Oscillatoria brewis*
- Found in very low temperature - In snow, providing different colours to snow are –
  - (i) Red snow – It caused by *Chlamydomonas nivalis* (haematochrome pigments present)
  - (ii) Green snow - *Withyellow stonensis*
  - (iii) Black snow - *Scofiella nivalis*
- Epiphytic algae - *Oedogonium*, *Bulbochaete*
- Epizoic algae - *Chladophora* or snail
- Endozoic algae - *Zoochlorella*
- Parasitic - *Cephaleurous virescens*
- Terrestrial - *Fritschiella tuberosa*
- Cryptophytic - *Nostoc*
- Marine - *Fucus*, *Laminaria*
- Halophytic - *Chlamydomonas ehrenbergii*
- Symbiotic - Blue green algae in lichens.

General characters

- Algae are mostly found in **fresh water** as well as **salt water.**
- The plant body is a simple thallus consisting of **parenchymatous cells** or tissues. (*Given in flowchart*).
- **Filamentous form** may be branched or unbranched, free floating or attached to the substratum.
- The cell which is attached to the substratum is called **holdfast**.
- The body of multicellular algae ranges from **small colonial** (*Volvox*) to largest like *Macrocystis* having length of several hundred feet.
- The cell wall is usually made up of **cellulose**.
- The reserve food material is in the form of **starch** mainly.
- Large marine algae are generally known as **sea weeds** or **kelps**.
- Algae lack **vascular differentiation**.
- Sex organs are usually **unicellular and non jacketed**.
- **Dominant plant phase** in algae is **gametophyte**.
- Sporophytic and gametophytic stages are **independent**.
- Most of the algae are **autotrophic**.
- The shape of chloroplast is variable in different algae. These are **cup shaped** in *Volvox*, **girdle shaped** in *Ulothrix*, **ribbon shaped** in *Spirogyra*, **reticulate** in *Oedogonium* and **stillate** in *Zygnema*.
- All kinds of reproduction **vegetative, asexual** and **sexual reproduction** are found in algae.
- Vegetative reproduction occurs through **fragmentation** and **fission**, **hormogonia**, **tubers**, **buds** etc.



- Asexual reproduction occurs through **zoospores, hypnospores**, **akinetes**, **endospores** or **cysts** etc.
- Asexual reproduction occurs in **favourable condition** (by mitospores).
- Under **unfavourable conditions** algae **reproduce sexually**.
- Depending upon the **size of gametes** the **sexual reproduction is of two types - isogamous** and **heterogamous** (anisogamous, oogamous).
- **Isogamy** occurs commonly in unicellular algae, e.g. *Ulothrix*. Here the male and female gametes are **morphologically similar but differ in physiology**.
- **Anisogamy** is the fusion of gametes where male gametes are comparatively smaller in size and more active than female gametes which are larger and sluggish, *e.g. Chlamydomonas brausii*.
- **Oogamy** is the **most advanced type** of sexual reproduction. Here the **male gametes** are **motile** and formed in large numbers whereas **female gametes** are **non-motile** and **bigger in size**.
- Male gametes are produced in **antheridium** whereas female gametes are produced in **oogonium**.
- Some special complex type of reproductive bodies found in Rhodophyceae are called **spermatium** and **carpogonium**.
- **Water** is the **suitable medium for the fusion of gametes** during sexual reproduction.
- Fusion of male and female gametes occur and zygote is formed.

Salient features of some selected classes

Chlorophyceae (green algae)

- Plants fresh water or marine
- The structure is various - unicellular motile (*Chlamydomonas*) non-motile (*Chlorella*), colonial (*Volvox*, *Hydrodictyon*), parenchymatous (*Ulva*), coenocytic (*Volvox*)
- Cell wall is composed of cellulose.
- Chief pigments – chlorophyll a, b, α, β, γ – carotenes, lycopene, lutein, galaxanthin.
- **Reserve food – starch and oils**.
- Asexual reproduction by zoospores, aplanospores and hypnospores.
- Male gamete flagellate
- Flagella identical.
- Sexual reproduction – isogamous, anisogamous or oogamous.
- E.g. *Chlamydomonas*, *Spirogyra*.

Xanthophyceae (yellow green algae)

- Plants generally fresh water
- Forms unicelled to simple filamentous.
- Chief pigments – chlorophyll a, e; β-carotene, violaxanthin, neoxanthin.
- **Reserve food – chrysolaminarin and oils**.
- Zoospore formation occurs.
- Male gametes flagellate, flagella non-identical (unequal).
- Sexual reproduction – isogamy, anisogamy or oogamous.

Phaeophyceae (brown algae)

- Plants marine (except-few)
- The body is differentiated into 3 parts – holdfast, stipe and **lamina**.
- They have holdfasts for attachment but *Sargassum* and *Fucus* become free floating. North Atlantic ocean is often called **Sargasso Sea** because of the abundant growth of Gulf Weed or *Sargassum*.
- Some brown algae are very large. They are called **trees of seas** or **kelps**. Depending upon the size, kelps are differentiated into **giant kelps** (*e.g.*, *Macrocystis* 40 – 60 m; *Nereocystis* 20 – 30 m) and **small kelps**.
- Cell wall contains cellulose and phycocolloids (alginic acid).
- Asexual reproduction by fragmentation and spores.
- Cells showing eukaryotic organization.
- Chief pigments – chlorophyll a, c; β-carotene, fucoxanthin (**for brown colour**), lutein, violaxanthin, diatoxanthin.
- **Reserve food – laminarin**, **mannitol**, **fats and oils**.
- Male gametes flagellate, flagella unequal (tinsel and whiplash), lateral.
- Sexual reproduction – isogamy, anisogamy or oogamous.
- **Life cycle** is **diplohaplontic** (eg *Dictyota*) or **diplontic**.
- Eg - *Fucus*, *Sargassum*, *Laminaria* etc.

Rhodophyceae (red algae)

- Plants generally marine.
- The plants are simple filamentous to attaining complexity of structures.
- Some cells show protoplasmic or pit connections.
- Chief pigments – chlorophyll a, d; α, β-carotene, lutein, violaxanthin, fucoxanthin, myxoxanthin, r-phycoerythin, r-phycocyanin, and allophycocyanin.

- Red colour is **due to phycoerythrin**.
- **Reserve food – floridean starch**, **galactan - SO_4**, **polymers**.
- No zoospore formation.
- Male gametes-non flagellate.
- Sexual reproduction by special type of oogamy.
- Life cycle haplobiontic or diplobiontic,
- E.g. *Batrachospermum*, *Gelidium*.

Myxophyceae or Cyanophyceae (blue green algae)

- Plants generally freshwater, a few forms marine.
- Forms unicelled to filamentous. Cell wall made up of mucopeptide.
- Possess some specialised cells called **heterocysts**.
- Cells showing prokaryotic organization.
- Chief pigments – chlorophyll-a, β-carotenes, luteins, xanthophyll, oscillaxanthin, c-allophycocyanin, allophycocyanin.
- **Reserve food – cyanophycean starch (glycogen) and cyanophycin (protein)**.
- No zoospore formation.
- No flagellate bodies.
- No sexual reproduction.
- E.g. *Nostoc*, *Oscillatoria*, *Anabaena*.

Life cycle patterns found in algae

- It is recurring morphological and cytological phases in an organism that occur in each individual from its birth to death.
- It is of following types – **haplobiontic**, **diplobiontic** and **triplobiontic**.
- **Haplobiontic** : Only one somatic phase is present. It is of two types – **haplontic** and **diplontic**.
- **Haplontic** is a single somatic phase which is haploid. Diploid condition is present only in zygote or zygospore wherein meiosis occurs to produce haploid condition again, *e.g.*, *Spirogyra*, *Chlamydomonas*, *Ulothrix*, *Chara*. Alternation of generations is absent.
- **Diplontic** is a single somatic phase which is diploid. Haploid condition occurs in gametes (formed through meiosis) which fuse to restore diploid state, *e.g.*, *Cladophora glomerata*, *Bryopsis*, *Fucus*, *Sargassum*. Alternation of generations is absent.
- **Diplobiontic.** Two somatic phases are present in the life history – **diplohaplontic** and **haplohaplontic**.
- **Diplohaplontic**. Both haploid gametophytic and diploid sporophytic somatic phases occur in the life history. It has **two subtypes** :
  - **Isomorphic or monomorphic diplohaplontic** : Gametophytic and sporophytic phases are morphologically similar though cytologically they are haploid and diploid respectively, *e.g.*, *Dictyota*, *Ulva*. There is an **isomorphic** or **homologous alternation of generations**.
  - **Heteromorphic or dimorphic diplohaplontic** : Haploid and diploid phases are morphologically dissimilar. One of them is dominant. A **heterologous** or **heteromorphic alternation of generations** occurs, e.g., bryophytes (gametophyte dominant), pteridophytes (sporophyte dominant).
- **Haplohaplontic.** Only haploid cytological stage is present in two somatic phases, *e.g.*, *Porphyra* (dimorphic haplobiontic or diphasic haplohaplontic).
- **Triplobiontic.** Three somatic phases occur.
  - **Haplohaplohaplontic.** Three haploid phases occur in the life history.
  - **Diplodiplohaplontic.** Triphasic or trimorphic life history with two diploid and one haploid stages, *e.g.*, *Polysiphonia*.

SOME IMPORTANT EXAMPLES

Chlamydomonas

- *Chlamydomonas* is a free living aquatic **unicellular** and flagellate green alga (10 – 30 μm) that **occurs in ammonium rich fresh water**.
- Excessive growth of *Chlamydomonas* may impart green colour to water.
- Cell wall **does not contain cellulose**. Instead glycoprotein is present.
- Internally the alga contains a single nucleus, two contractile vacuoles for osmoregulation and excretion, a basin or cup-shaped chloroplast with a red eye spot or stigma and a pyrenoid for storage of starch.
- **Asexual reproduction** occurs **through zoospore formation**, **palmella stage**, **aplanospores** and **hypnospores**.
- **Palmella stage** is **produced in response to toxic chemicals and unfavourable water conditions**. Here the cells lose flagella and enclose themselves in mucilage. They, however, continue to grow and divide. On being flooded with water or removal of toxic chemicals, the mucilage dissolves and each cell forms a flagellate individual.

- Sexual reproduction involves fusion of two compatible gametes.
- Life cycle is **haplontic**.

Ulothrix

- *Ulothrix* is an **unbranched filamentous green alga of fresh aerated waters** which is covered by a thin sheath of mucilage. Lowermost cell is colourless and functions as **holdfast**.
- Cell wall consists of two layers. Inner layer is made up of **cellulose** and outer layer is mostly made up of **protopectin** which is insoluble in water.
- **Due to presence of protopectin**, *Ulothrix* filaments appear as **wet threads**.
- **Asexual reproduction** occurs **through fragmentation**, **zoospores**, **palmella stage**, **aplanospores**, **hypnospores** and **akinetes**. Only green cells take part in reproduction.
- **Sexual reproduction** occurs **through isogamy** (fusion of similar gametes).
- Gametes are **biflagellate** and produced like zoospores. The fusion product is **diploid zygote** which **forms a resting diploid zygospore**.
- Under favourable conditions, meiosis occurs in the zygospore.
- **Life cycle** is **haplontic** as dominant phase in life cycle is haplophase (n) and diploid phase is represented only by zygote or zygospore which undergoes meiosis (reduction division) during its germination.

Volvox

- *Volvox* is a **fresh water green colonial algae first observed by Leeuwenhoek (1700)**.
- *Volvox* is a small hollow green ball of 0.5 – 2.5 mm diameter which is popularly called **rolling ball**.
- The algae rotates on its axis during swimming.
- Reproduction is both **asexual and sexual**. The reproductive cells or gonidia usually occur in the posterior part.
- **Asexual reproduction** occurs through the formation of **daughter colonies**. Each gonidium can form a daughter colony.
- **Sexual reproduction** is **oogamous**. Colonies may be monoecious or dioecious. In monoecious forms, the male and female sex cells mature at different times.

Chlorella

- *Chlorella* is a **nonmotile (nonflagellate) unicellular green alga** which **occurs in diverse aquatic habitats**, preferably rich in organic matter.
- **Wall contains cellulose**. It is **three layered**. Outer layer may have sporopollenin-like material.
- **Sexual reproduction** is not known. **Asexual reproduction** occurs **through autospores**. Here divisions of the parent protoplast forms 2 – 32 daughter protoplasts, each of which develops a wall and gets transformed into an autospore.
- *Chlorella* can be used as food because it is rich in proteins (50%), carbohydrates (20%), vitamins (A, C, K, B_1, B_2, B_{12}) and minerals. It contains an antibiotic **chlorellin** but can be also cause allergic asthma.
- *Chlorella* is used as experimental plant for physiological records. It is an **important component of sewage oxidation tanks**.

Spirogyra

- *Spirogyra* is an unbranched filamentous green alga of stagnant fresh waters which forms floating masses called **pond scum**.
- *Spirogyra* is also called **pondsilk**, **water silk** or **mermaids tresses**.
- Cell wall consists of two distinct layers. The **inner layer is of cellulose** and the **outer is of pectose** which gets changed into pectin and this pectin dissolves in water to form a slimy or mucilaginous sheath. (It is sometimes referred to as third layer.)
- The protoplast is differentiated into plasma membrane, cytoplast, nucleus, chloroplast with pyrenoids and a large central vacuole.
- **Pyrenoids** are situated in the chloroplasts. They lie **equidistant** from one another and **are the centres of starch formation**.
- All the cells in the free floating species of *Spirogyra* are alike, no differentiation into apex and base. Each cell can synthesize its own food, respire, divide and reproduce. Thus the organism may be looked upon as a '**colony of independent cells**'.
- *Spirogyra* is **autotrophic**.
- **Growth** in *Spirogyra* is **intercalary or diffused**.
- In *Spirogyra* **reproduction takes place by three methods** – vegetative, asexual and sexual.
- Under exceptionally favourable conditions *Spirogyra* multiplies by the method of **fragmentation**.
- Fragmentation may be **brought about in the following ways** –
  - Through accidental breaking resulting from mechanical injury.

- Softening and subsequent dissolution of middle lamella of the septa.
- Due to sudden change in the temperature and acidity of water.

- Normally **asexual reproduction is absent** in *Spirogyra*. It **takes place only in some species**. It is of **3 types** –
  - By aplanospores
  - By azygospores (parthenospores)
  - By akinetes
- **Sexual reproduction** takes place towards the end of growing season usually in the late spring. It commences when the filaments are well mature and have stored sufficient food. The **external conditions which favour the process** are :
  - Nitrogen deficiency.
  - The change in pH of the aquatic medium on alkaline side.
- The sexual reproduction in *Spirogyra* is called **conjugation**. It involves the fusion of two **morphologcally identical** but physiologically dissimilar nonciliated gametes.
- The fusion of these gametes takes place by the following 2 methods.
  - **Scalariform conjugation**.
  - **Lateral conjugation**.
- **Scalariform conjugation** (in both monoecious or dioecious) **takes place during the night** and between the recently divided cells of the conjugating filaments.
- The conjugation tube between the two filaments looks like a ladder, through which gamete from one of the gametangia passes through to fuse with the passive gamete of another filament. The gametes are formed singly and both **active and passive gametes** are considered **male and female gametes** respectively. The **fusion of both kinds of gametes** with each other **results into formation of zygospore**.
- **Lateral conjugation** (monoecious species) **takes place between two nearest cells of the same filament**. Both male and female gametes are found in same filament.
- It is of two types – **indirect lateral conjugation** and **direct lateral conjugation**.
- **Life cycle** in *Spirogyra* is **haplontic** as dominant phase in life cycle in haploid (*n*) and diploid phase is represented by only zygospore and it undergoes R.D. or meiosis (zygotic meiosis).

ECONOMIC IMPORTANCE OF ALGAE

Beneficial aspects

Algae as food and fodder

- Sea weeds, especially brown algae, are used as food for domestic animals in different parts of the world and their wide scale usage centres in countries like Norway, Scotland, France, Great Britain, Scandinavia, America, New Zealand, etc.
- *Pelvetia canaliculata* is **used as food for young live-stocks**. *Sargassum*, *Fucus* and *Laminaria* are eaten by cattle in Scotland and Island. *Macrocystis* spp. and other kelps being rich in vitamins A and E are served as cattle fodder.
- The marine algae are of considerable importance in food value. They are often mixed with rice and fish and served as base for soups, condiments and eaten alone as salads. The edible forms are called **Limu** in Hawaii, **Tsao** in China and **Rimu** in Tahiti.
- *Chlorella* is **rich in protein and carbohydrates**.
- *Spirulina platensis* is one of the **richest sources of protein**, containing 40-50 percent crude protein on dry weight basis which under favourable condition may reach upto 70 percent.
- The mucoprotein constituents of cell wall are easy to digest and thus making *Spirulina* a good item for both, human beings and animals.
- Algae **serves primary food for fishes and other small aquatic animals**. Such algae may be both a plankton or an attached form in the sea as well as in fresh water.
- In fresh water lakes and ponds, *Oedogonium*, *Spirogyra*, *Microspora*, *Ulothrix*, *Cladophora*, *Pithophora*, etc, serve directly as fish food.

Algae in industries

- **Alginic acid** derivatives are extracted from the members of Phaeophyceae such as *Laminaria*, *Ascophyllum*, *Macrocystis*, *Ecklonia*, *Lessonia*, *Durvillea*.
- **Carrageenin** is the most famous carbohydrate mucilage named after Irish village Carrageenan. The gelatinous carbohydrates are variously used with puddings, eaten with milk or mixed with fruit and even in ice cream. It is also used as clearing agents in beer preparation. It is **extracted from red alga** *Chondrus crispus* – "Irish moss" and to a lesser extent from *Gigartina spp*.
- **Agar**, dried gel-like non-nitrogenous extract from

red algae, is **used as a medium in the cultures of bacteria, fungi and algae** and **also in numerous industrial processes**. Agar was largely prepared from *Gelidium*. Algae such as *Camplaephora*, *Pterocladia*, *Gracilaria*, *Ahnfeldtia*, *Eucheuma*, *Chondrus*, *Gigartina*, *Phyllophora*, *Furcellaria* are used for extraction.

- Brown algae like *Laminaria digitata*, *Ecklonia*, *Easenia* and *Fucus spp.* are **largely known for the extraction of iodine**.
- Other micronutrients useful for human consumption such as iron, copper, manganese and zinc have been found in sea weeds.
- Diatoms and their large sedimentary deposits "diatomaceous earth" are quite useful in industry. Diatomite is **used in industrial filtration processes, sugar refining** and **brewing industries**.

Medicine and antibiotics

- **Because of high iodine content** brown algae are used in various **goiter medicines**, either mixed or directly as a powder.
- *Laminaria stipes* are **used as surgical tool** in the opening of wound owing to its property of gentle swelling subject to moisture exposure.
- **Chlorellin** is extracted for *Chlorella* which inhabits growth of certain bacteria and a few algae.
- *Microcystis* is popularly known for its inhibitory action to *Staphylococcus* and *Chlostridium* and zooplanktons such as *Daphnia* and *Cyclops*.

Water purification

- In water reservoirs, the larger growth of algae creates great nuisance but lesser growth of algae acts as biological filters by forming a microzone of the sand surface which together with bacteria and fungi forms a mucilage layer. By this microzone, harmful bacteria are trapped and water also gets aerated.

Sewage disposal

- The presence of algae facilitates oxygenation of sewage to a great extent. The algae known to grow in sewage are *Euglena*, *Chlorella*, *Scenedesmus*, *Chlamydomonas*, *Pyrobotrys*, *Microactinum*, etc.

Algae in biological research

- Recent knowledge of photosynthesis is based on research carried on *Chlorella* (unicellular green alga).

Algae in space travels

- A spaceman will need a device to get rid of CO_2 and other body wastes and will require sources of O_2 and food. So *Chlorella*, *Synecoccus*, etc., are useful for this purpose and they grow very quickly.

Harmful aspects

- A compound toxin produced by certain algae proves fatal to fishes, e.g. the growth of *Aphanizomenon* and *Microcystis aeruginosa* in fish ponds are poisonous to *Crappis perch* and *Gambusia*, respectively.
- A few blue-green algae such as *Microcystis*, *Anabaena*, *Nodularia*, *Gloeotrichia* and *Aphanizomenon* produce exotoxin and endotoxin causing death of animals, horses, cattle, sheep, etc.
- Several cases of human death have been reported as a result of indirect consumption of dinoflagellates through fishes which have eaten them.
- The pollution caused by algae is well known. They produce effective problems in water supply and purification and become obnoxious in water reservoirs, rivers and oceans. Some **blue-green** and **green algae** grow over the surface of water bodies in abundance, especially in rainy season, and cause **water bloom**. On death and decay, these algae give bad smell. Some dinoflagellates (members of class dinophyceae of algae) secrete poisonous or toxic substances.
  - **Important algae causing water bloom** are *Microcystis*, *Chroococcus*, *Oscillatoria*, etc. These **deplete the water of O_2** and hence animals like fish are killed.
  - Marine algae growing in abundance retard the speed of ships.
- India suffers enough serious problem of blue-green algae causing threat of enormous loss to Indian Government revenue by effecting the quality of salt in Sambhar lake in Rajasthan. Algae (such as *Arthrospira*) produce an offensive smell, impart pink rust red colour to the salt and turn brine into a gelatinous fluid making it impossible to develop crystals.

End of the Chapter