CLASSIFICATION

Introduction

There are millions of organisms – plants, animals, bacteria and viruses. Each one is different from the other in one way or the other. About more than one million of species of animals and more than half a million species of plants have been studied, described and provided names for identification. Thousands are still unknown and are yet to be identified and described. It is practically impossible to study each and every individual. Also, it is difficult to remember their names, characters and uses. However, biologists have devised techniques for identification, naming and grouping of various organisms.

The art of identifying distinctions among organisms and placing them into groups that reflect their most significant features and relationship is called **biological classification**. Scientists who study and contribute to the classification of organisms are known as systematists or taxonomists, and their subject is called systematics (*Gk. Systema* = order of sequence) or **taxonomy** (*Gk. Taxis* = arrangement; *nomos* = law).

History of classification : References of classification of organisms are available in **Upanishads** and **Vedas**. Our Vedic literature recorded about 740 plants and 250 animals. Few other significant contributions in the field of classification are :

(1) **Chandyogya upanishad :** In this, an attempt has been made to classify the animals.

(2) **Susruta samhita :** It classifies all 'substances' into **sthavara** (imbobile) *e.g.* plants and jangama (mobile) *e.g.* animals .

(3) **Parasara :** Here, angiosperms were classified into **dvimatruka** (dicotyledons) and **ekamatruka** (monocotyledons). He was even able to find that dicotyledons bear **jalika parana** (reticulate veined leaves and monocotyledons bear **maun laparna** parallel veined leaves).

(4) **Hippocrates, and Aristotle :** They classified animals into four major groups like insects, birds, fishes and whales.

4.1 Types of system of classification

Different systems of classification proposed from time to time have been divided into three basic categories *viz.*, artificial systems, natural systems and phylogenetic system (However, Redford, (1986), included mechanical systems as a fourth category).

(1) **Artificial system of classifications :** These systems are more or less arbitrary as the plants are classified merely on the basis of gross morophology, habit and their importance to man. The main advocates of artificial system of classifications were :

(i) **Theophrastus :** Father of botany. Theophrastus was a disciple of Plato and later Aristotle. In his book *De Historia plantarum,* he classified about 500 kinds of plants into four major group; trees, shrubs, subshrubs and herbs.

(ii) **Caius Plinius Secundus :** He described the biological, medicinal and agricultural aspects of plants in 37 volumes of *Natural History*. He used the term 'Stamen' for the first time.

(iii) **Pedanios Dioscorides :** He described about 600 plants of medicinal importance in his *Materia Medica*.

(iv) **Charaka :** Indian Scholar. He classified plants of medicinal importance in his *Charaka Samhita*.

(v) **Andrea Caesalpino :** He described 1520 species in 16 volumes of *De Plantis libri* grouped as herbs and trees. He further classified plants based on fruit and seed characters.

(vi) **John Ray :** He was a British botanist who published three volumes of his work *Historia Generalish Plantarum* consisting of improved classification originally proposed by him in *Methodus Plantarum Noven*. He was the first to divided the groups herbs, shrubs and trees into Dicots and Monocots on the basis of the presence of two or one cotyledons respecitvely. He coined the term **species**.

(vii) **Carolus Linnaeus :** Father of taxonomy. A swedish botanist, who published an artificial system of classification based exclusively on floral characters. Linnaeus published several manuscripts including *Hortus cliffortianus* and *Genera plantarum* (1737). In his *Genera plantarum* he listed all the plant genera known to him. He published his best known *Species plantarum* in 1753. In this book he listed and described all species of plants known to him. He established binomial nomenclature.

(2) **Natural System of Classifications :** These systems of classification are based not only on the characters of reproductive organs and structural morphology but used as many taxonomic characters or traits as possible to classify the plants. The advocates of **natural** systems of classification are listed below :

(i) **Michel Adanson :** A French botanist, who classified plants and animals using as many characters as possible and proposed a natural system of classification.

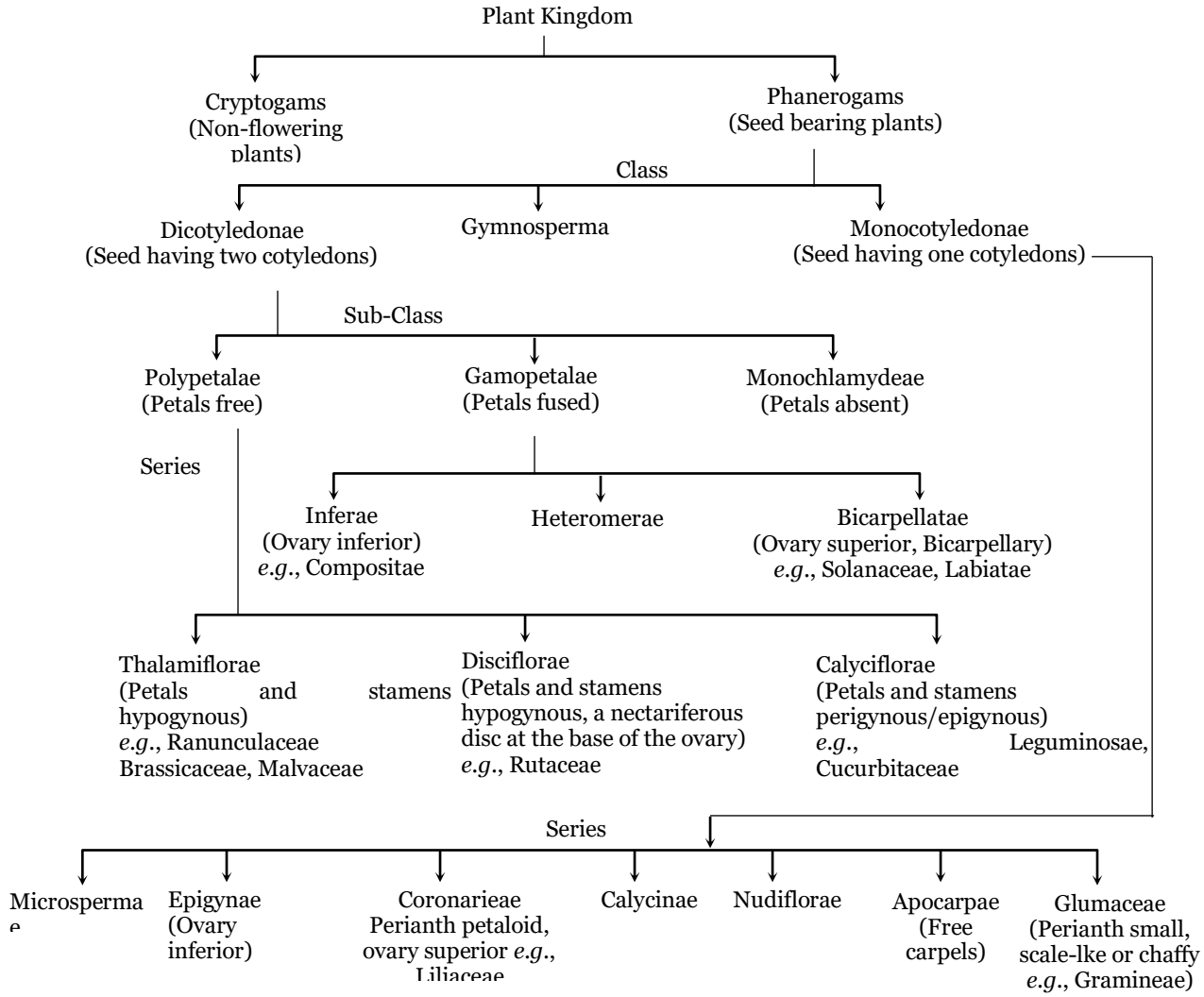
(ii) **A.L. de Jussieu :** Classified plants based on natural characters. In his system of classification he grouped the plants resembling each other in a set of characters.

(iii) **A.P. de Candolle :** He grouped all alike plants together and published a new classification of plants in his book *Theorie elementaire de la botanique* (1813).

(iv) **George Bentham and Joseph Dalton Hooker :** These two English botanists classified plants based on original studies of specimens. They published their well known scheme of classification in

Genera plantarum (1862–83). This system of classification is still regarded as the best classification, especially from the practical point of view.

Bentham and Hooker's classification (Broad outline)



Merits and Demerits of Bentham and Hooker's system of classification

Merits

This system is regarded as most convenient and suitable for practical utility and is followed by most of the herbaria due to following reasons :

(a) Every genus and species was **studied from actual specimens** available in British and continental herbaria.

(b) It is the **first great natural system of classification**. This is very useful for practical purposes.

(c) Gymnosperms have been considered as third taxon and kept between dicots and monocots.

(d) In monocots, stress has been given to relative position of ovary and perianth characteristics.

(e) Great emphasis has been given to free or fused conditions of petals distinguishing dicots into three sub-classes Polypetalae, Gamopetalae and Monochlamydeae.

Demerits : There are some demerits in the classification of Bentham and Hooker. Some of them are :

(a) The greatest demerit of this system is the retention in the group monochlamydeae, a number of orders which represent affinities with those in which biseriate perianth is the rule.

(b) Placing gymnosperms between dicots and monocots.

(c) Here monochlamydeae is considered as most highly evolved and polypetalae as primitive among dicots.

(d) Cucurbitaceae family with fused petals is placed in Polypetalae.

(e) Liliaceae is separated from Iridaceae and Amaryllidaceae merely on the character of ovary, without keeping in mind other similarities.

Differences between Natural and Artificial classification

No.	Characters	Natural classification	Artificial classification
1.	Number of characters	Almost all the characters are considered.	Only few characters are considered.
2.	Hereditary constitution	Members are mostly alike in hereditary pattern of different groups.	Members of different groups are usually not similar in hereditary pattern.
3.	Flexible	May change with advancement in knowledge.	Stable classification.
4.	Phylogeny	Closely related phylogenetically.	Not related phylogenetically.
5.	Information	Provides plenty of useful information.	Provides only limited information.
6.	Recent advances	Recent useful research can be easily incorporated.	Cannot incorporate new work.
7.	Convenience	Identification of plants easy.	Difficult.
8.	Little known plants	Got the place at definite place.	Not certain about position and identification.

(3) **Phylogenetic system of classifications :** These systems of classifications are mainly the rearrangements of natural systems using as many taxonomic characters as possible in addition to the

phylogenetic (evolutionary) informations. Some important phylogenetic systems of classifications were proposed by –

(i) **A.W. Eichler :** A German botanist who proposed phylogenetic system of classification and published in the third edition of *Syllabus der vorlesungen* (1883).

(ii) **Adolph Engler and Karl Prantl :** These two german botanists classified plant kingdom on the basis of their evolutionary sequences. They started with simplest flowering plants and ended with plants of complex floral structures.

(iii) **C.E. Bessey :** He classified flowering plants on the basis of their evolutionary relationships.

(iv) **John Hutchinson :** A British botanist published his phylogenetic system of classification in '*The Families of Flowering Plants*'.

(v) **Armen Takhtajan :** A Russian botanist who published his system of classification in *Botanical Review.*

(vi) **Arthur Cronquist :** Published his classification in '*An Integrated System of Classification of Flowering Plants*'.

Differences between Natural and Phylogenetic classification

No.	Characters	Natural classification	Phylogenetic classification
1.	Number of characters	Based on several constant characters.	Along with several constant characters, evolutionary sequences are also considered.
2.	Evolutionary sequences	Not considered. Classification based basically on common characters.	Evolutionary sequence, natural affinities and relationship taken into account.
3.	Practical utility	Used adequately as an aid for easy identification.	Phylogenetic and adopted by many countries.

4.2 Plant nomenclature

Plant nomenclature may be defined as the system of naming plant. Almost all plants (and animals too) are known by different common names in different parts of the world. Even within the same country people of different states and regions use different common names. *Iphomoea batatas*, for example, is called **sweet potato** in English, **Shakarkandi** in Hindi, **Meetha alu** in Assamies and Bengali, **Kundmul** in Telagu, **Ratalu** in Marathi and **Jenasu** in Kannad. The common names are thus quite confusion. This necessiated the need of giving scientific names so that scientists of different parts of the world could understand each other work. The earliest scientific names were **polynomial**, *i.e.*, they were composed of many words (which gave the characteristics of plants), *e.g.*, *Sida acuta* (a

member of Malvaceae) was named as *Chrysophylum foliis, ovalis superne glabris parallel striatis subtus, tomentosonitidis*. Such long names were difficult to remember. Hence, to make it easier binomial system of nomenclature was introduced.

(1) **Binomial system of nomenclature :** The credit of giving binomial system of nomenclature goes to Swedish naturalist, Carolus Linnaeus. He employed this system in his book ***Species Plantarum***, published in 1753. According to this system the name of a plant or animal is composed of two Latin (or Latinised) words, *e.g.*, potato is *Solanum tuberosum*. The first word (*i.e., Solanum*) indicates the **name of the genus** (called **generic name**) and the second word (*i.e., tuberosum*) denotes the **name of the species** (called **specific name**). The generic name always begins with a capital letter and the specific name with a small letter and printed in italics.

The generic and specific names always have some meaning. They are based on some special characters of the plant, on the name of any scientist or on some legend.

All plants having general similarity and relations are given a common generic name, *e.g.*, potato, brinjal, black nightshade (makoi) have been placed in the genus *Solanum*. However, their specific names distinguish them from each other – potato is *Solanum tuberosum*, brinjal is *S. melongena* and black nightshade is *S. nigrum*.

Usually the name of the author, who names a plant, is also written in full or in abbreviated form after the specific name. Thus, in case of *Mangifera indica* L., the L. stands for **Linnaeus** and in *Lychnis alba* Mill., the Mill. stands for **Miller**.

Sometimes a single species is described under different names by different authors. These name are called **synonyms**. In such cases, the name under which the species is first described, is considered to be valid.

(2) **Trinomial nomenclature :** Certain species are divisible into smaller units, called varieties, on the basis of finer differences. The name of the variety is written after the specific name. Thus, the name may become trinomial or three word name. *e.g.*, *Homo sapiens europeus* is the name of the man of European race. Trinomial nomenclature is simply an extension of the Linnaean system.

(3) **Code of biological nomenclature :** Anyone can study, describe, identify and give a name to an organism provided certain universal rules are followed. These rules are framed and standardised by International Code of Botanical Nomenclature (ICBN) and International Code of Zoological Nomenclature (ICZN). The codes help in avoiding errors, duplication, confusion and ambiguity in scientific names. The codes are established and improved upon at International Botanical and Zoological Congress held from time to time. The names of bacteria and viruses are decided by International Code of Bacteriological Nomenclature (ICBN) and International Code of Viral Nomenclature (ICVN). Similarly, there is a separate International Code of Nomenclature for Cultivated Plants (ICNCP).

4.3 Explanation of terminology (Units)

(1) **Taxon :** The term taxon is used to represent any unit of classification. The unit (*i.e.*, taxon) many be large (*e.g.*, Plant Kingdom) or small (*e.g.*, Algae, Fungi, or a single species).

(2) **Category :** Various sub-divisions of plants kingdom such as division, class, order, family, etc., are referred to as categories. In the hierarchy of categories kingdom is the highest and species is the lowest category. The following is hierarchial series :

(i) **Kingdom :** It is the highest category in biological classification. All plants are include in plant kingdom.

(ii) **Division :** It is a major group in the Linnean hierarchy used in the classification of plants (equivalent to *phylum* in animal classification). It is a taxonomic category between kingdom and class. The subcategory of division is **subdivision**. The suffix of division is – ophyta.

(iii) **Class :** A division is divided into classes. It is a taxonomic category between the division and order. Its suffix is – ae. The subcategories of class are subclass and series. In the class contain organism least similar to one another.

(iv) **Order :** A class includes one or more orders. It is a taxonomic category between the class and family. Its suffix is – ales. The subcategory of order is **suborder.**

(v) **Family :** An order is divided into one or more families. It is the taxonomic category between the order and the genus. Its suffix is – aceae. The subcategories of family are **subfamily, tribe** and **subtribe**.

(vi) **Genus :** The plural of genus is genera. A family includes one or more genera. The generic name is important and printed in Italics (If hand written, it is underlined). The subcategories of genus are **subgenus, section** and **subsection**.

(vii) **Species :** It is the smallest rank of taxonomic classification. The first letter of the species is denoted with small letter. The species is printed in Italics (It is underlined if hand written). A genus may include one or more species. The subcategories of species are **subspecies, varieties, subvarieties, form** and **subform**.

(3) **New systematics or Biosystematics :** The term new systematics was proposed by Sir Julian Huxley in 1940. In the new systematics, the species are considered related to one another, mutable and the work of gradual modification. This is in confirmity with the facts of evolution.

Forms of new systematics : There are several forms of new systematics –

(i) **Morphotaxonomy :** It is based on the structural features of the organisms.

(ii) **Cytotaxonomy :** It is based on the somatic chromosomes of organisms.

(iii) **Biochemical taxonomy or Chemotaxonomy :** It is based on the protein and serum analyses and on the chemical constituents of the organisms.

(iv) **Numerical taxonomy :** It involves quantitative assessment of similarities and differences in order to make objective assessments. Characters of organisms are given equal weight and the relationships of the organisms are numerically determined, usually with the aid of a computer.

(v) **Experimental taxonomy :** It is based on the genetic relationship determined with the help of experiments.

Important Tips

- The arrangement of organism in to groups termed as classification.
- Forming the rules for classification known as Taxonomy.
- De candolle : Coind the term taxomy in 1913.
- Floral characters are used as basis of classification and for identifying new species because floral characters are conservative when compared with vegetative characters.
- In Bentham and Hooker's classification Dicotyledons have been kept before Monocotyledons. Seeds plants have been divided into Dicots, Gymnospermae and Monocots.
- Among the vegetative characters, venation in leaf in one of highly acceptable characters for classification of angiosperms.
- In Engler and Prantl's system Monocotyledons have been kept before Dicotyledons.
- In Bentham and Hooker's classification 202 families have been identified.
- Bentham and Hooker's classification is a natural system of classification and very helpful for practical purposes.
- For declaration of new species, floral characters of new species should be used.
- In Bentham and Hooker's system of classification, evolutionary criteria have not been followed hence not phylogenetic.
- Hooker complied first complete flora of India and wrote the book 'Flora of British India'.
- **Bentham and Hooker :** Gave the first natural classification of plants.
- **Engler and Prantl :** Gave the first phylogenetic classification of plants.
- Engler and Prantl's and Hutchinson's system of classification are phylogenetic.
- 411 families have been recognised in Hutchinson's system of classification and 280 families have been identify in Engler and Prantl's system of classification.
- **Father of Botany :** Theophrastus, a Greek philosopher, produced the first book on botany, **Historia Plantarum**, student of Aristotle.
- After the work of Linnaeus, another significant publication was that of **Augustin de Candolle** in theory elementaire de la botanique.
- The correct sequence of taxa in Linnaean hierarchy is species $\rightarrow$ genus $\rightarrow$ family $\rightarrow$ order$\rightarrow$ class.
- A system for naming the organisms called nomenclature.

- Bauhin (1623) proposed the binary system of nomenclature which was elaborated by Linnaeus (1753) in to binomial system.
- An international code of Botanical nomenclature (IBCN) come into existence in 1930.
- International code for nomenclature is divided into three parts i.e. (i) Principles (ii) Rules and recommendations (iii) Provisions.
- **Priority :** Nomenclature of taxonomic groups is based upon priority of publication.
- **Monotypic Genus :** A genus having only one species, e.g., Home.
- **Polytypic Genus :** A genus containing more than one species, e.g., Panthera, Solanum.
- **John Ray :** An English naturalist, 1627–1705, introduced the term species. It is a basic unit of classification.
- J.K. Maheswari described the plants of India in 'Flora of Delhi'.
- Phylogeny was introduced by Homock but concept was introduced by Heackel.
- Phylogenetic classification reflect the evolutionary relationships of organisms.
- **Type Specimen :** Original specimen is called **holotype**; duplicate of holotype is termed **isotype**; additional one is known as **paratype**; and a new one when the original is lost is referred to as **neotype**.

4.4 Modern system of classification

(1) **Two kingdom system of classification :** This system of classification is the oldest it was suggested by *Carolus Linnaeus* in 1758. He divided the living word (organism) in to two kingdoms, Plantae (for all plants like tree, shrubs, climbers, creepers, moss and floating green algae) and Animalia (For animals).

(2) **Three kingdom system of classification :** *Ernst Haeckel*, a German biologist and philosopher, suggested a third kingdom protista in 1866 for –

(a) Unicellular organisms such as bacteria, protozoans and acellular algae.

(b) Multicellular organisms without tissue such as algae and fungi.

(3) **Four kingdom system of classification :** It was proposed by *Copeland* in 1956. The two additional kingdoms were Monera for the bacteria and blue green algae and Protista for protozoans, algae and fungi.

(4) **Five kingdom system of classification :** *R.H. Whittaker*, an American ecologist. He proposed five kingdom system of classification in 1969.

This system replaced the old, two-kingdom grouping of living organisms. As already discussed, a division of living world merely into plant and animal kingdoms is too simple. It does not take into account the **gradual** evolution of distinct plant and animal groups and it allows no place for those

primitive organisms that even now are neither plants nor animals nor that are both. In this classification eukaryotes were assingned to only four of the five kingdom.

Five-kingdom classification is based on the following four criteria :

(i) Complexity of cell structure.

(ii) Complexity of organism's body.

(iii) Mode of obtaining nutrition.

(iv) Phylogenetic relationship.

The five kingdom are : Monera, Protista, Fungi, Plantae and Animalia.

4.5 Kingdom Monera (The prokaryotes)

Monera (*Monos – single*) includes prokaryotes and shows the following characters :

(1) They are typically unicellular organisms (but one group is mycelial).

(2) They lack nuclear membranes.

(3) Ribosomes and simple chromatophores are the only subcellular organelles in the cytoplasm. The ribosomes are 70 S. Mitochondria, plastids, Golgi apparateus, lysosomes, endoplasmic reticulum, centrosome, etc., are lacking.

(4) The predominant mode of nutrition is absorptive but some groups are photosynthetic or chemosynthetic.

(5) Reproduction is primarily asexual by fission or budding.

(6) Protosexual phenomenon also occurs.

(7) The organisms are non-motile or move by beating of simple flagella or by gliding.

(8) Flagella, if present, are composed of many intertwined chains of a protein **flagellin**. They are not enclosed by any membrane and grow at the tip.

(9) Moneran cells are microscopic (1 to few microns in length).

(10) Most organisms bear a rigid cell wall.

(11) The kingdom Monera includes true bacteria, mycoplasmas, rickettsias, actinomycetes (ray fungi) etc. Microbiologists also include blue green algae (*i.e.*, Cyanobacteria) under the group bacteria because of the presence of prokaryotic cell structure. Studies have established that the members of archaebacteria group are most primitive and have separated from eubacteria group very early in the process of evolution. Furthermore, these studies have also concluded that the archaebacteria and eubacteria possibly originated from a more ancient form of life called **Progenote**.

(12) **Nutrition :** They show both autotrophic and heterotrophic modes of nutrition.

(i) **Autotrophs :** These are able to form their own food by one of the following methods.

(a) **Photoautotrophs :** They prepare their own food by reducing CO_2 using light energy.

(b) **Chemoautotrophs :** They form their food by energy derived from chemical reaction.

(ii) **Heterotrophs :** A few live in **symbiosis** while others form association of commensalism. **Saprophytes** also called 'saprobes' cause decay, fermentation or putrefaction of dead organic matter. Some bacteria are facultative sasprophyte (= facultative parasites). In the process of fermentation there is anaerobic break-down of carbohydrates into CO_2, alcohol and some energy. **Putrefaction** or decay is anaerobic break-down of proteins accompanied by foul smell due to evil smelling gases produced in the process.

The saprobes produce enzymes which convert non-diffusible food substrates (carbohydrate fats, proteins, etc.) into simpler diffusible form which diffuses into the cytoplasm and is assimilated, *i.e.*, converted into body cytoplasm or stored as reserve food.

Still others live on other living organisms (animals, plants or man) in the form of parasites directly absorb their food from the body of host. Some of the parasites are **non-pathogenic** *i.e.*, cause no ill-effect or disease in the host, while some are **pathogenic** causing diseases in the host.

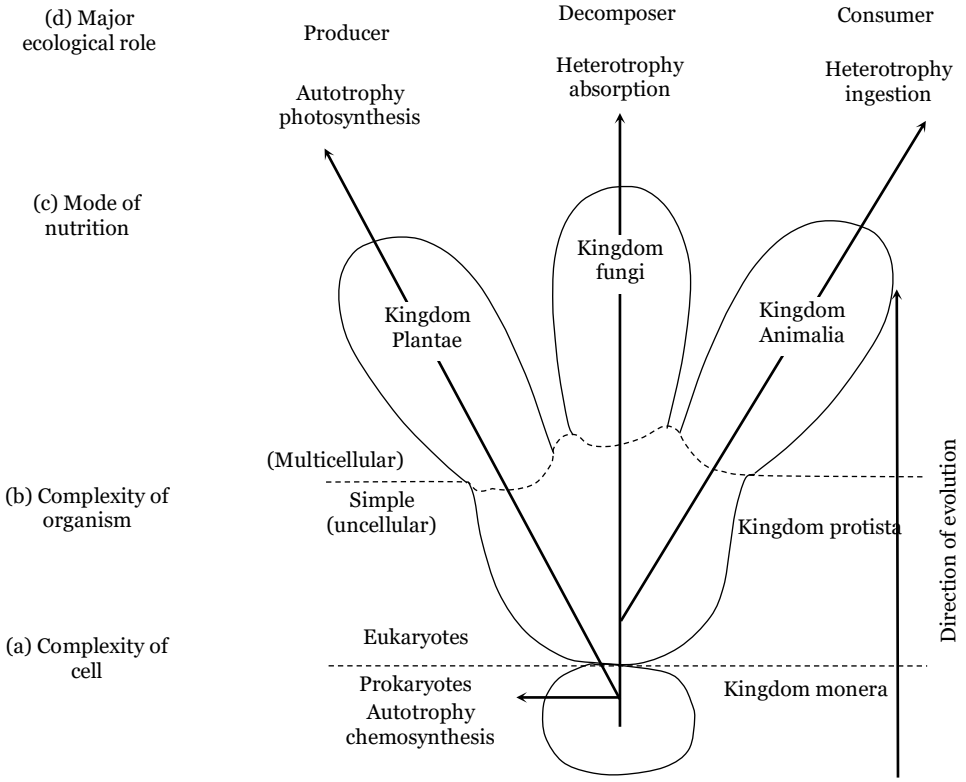


Fig : Probable phylogenetic relationships among the kingdoms

(13) **Reproduction :** It is primarily asexual by binary fission or budding. Mitotic apparatus is not formed during cell division. Distribution of replicated DNA into daughter cells is assisted by cell membrane. Exchange of genetic material between two bacterial cells is known to occur but no gametes are formed. Sterols, the precursor molecules of sex hormones, have been reported from certain prokaryotes. Many bacteria form resistant spores.

4.6 Kingdom Protista (Unicellular eukaryotes)

Protista (*Protistos* = Primary) includes unicelluar eukaryotes and show the following characters :

(1) Protists include solitary unicellular or colonial unicellular eukaryotic organisms which not form tissues.

(2) Simple multinucleate organisms or stages of life cycles occur in a number of groups.

(3) The organisms possess nuclear membranes and mitochondria.

(4) In many forms, plastids, (9+2 strand) flagella and other organelles are present.

(5) The nutritive modes of these organisms include photosynthesis, absorption, ingestion and combination of these.

(6) Some protists possess contractile vacuole for regulation of their water content.

(7) Their reproductive cycles typically include both asexual divisions of haploid forms and true sexual processes with karyogamy and meiosis.

(8) The organisms move by flagella or by other means or are non-motile.

(9) **Nutrition :** It is may be photosynthetic, holotrophic, saprotrophic and parasitic. Some have mixotrophic nutrition (holotrophic + saprobic). Chemosynthetic nutrition is lacking. Certain protozoans decompose organic matter, such as cellulose, in the gut of termites and woodroaches. They live as symbionts. The photosynthetic, floating protists are collectively called **phytoplankton**. They usually have a cell wall. The free-floating, holozoic protozoans are collectively termed **zooplankton**. They lack cell wall to allow ingestion of particulate food.

(10) **Reproduction :** It is occurs by both asexual and sexual methods :

(i) **Asexual reproduction :** It is the most common method of reproduction in protists in which the genetic constitutions of young ones remains the same as that of the parent. Under favourable environmental conditions, they reproduce asexually several times a day resulting in population explosions. The major types of asexual reproductions are as follows :

(a) **Binary fission :** The parent cell divides into two approximately equal daughter cells either transversely (*e.g.*, *Paramecium*), longitudinally (*e.g., Euglena*) or axially (*e.g., Amoeba*) by mitosis.

(b) **Multiple fission :** Division of parent cell into a number of daughter cells is called multiple fission. It occurs in *Amoeba*.

(c) **Plasmotomy :** Fission of multinucleate protist into two or more multinucleate offsprings by the division of cytoplasm without nuclear division is called plasmotomy. It occurs in *Opalina*.

(d) **Budding :** In this type of asexual reproduction, a small bud is formed from the parent body which separates and develops into new individual. *e.g., Paracineta, Arcella, etc.*

(e) **Spore formation :** Sessile or stalked sporangia containing spores are formed in slime moulds. They liberate the spores which can withstand a prolonged period of desiccation. On germination, each spore gives rise to new individual. *e.g.*, Slime moulds.

(ii) **Sexual reproduction :** Sexual reproduction is believed to have originated in primitive protists. It involve meiosis (reduction division) and syngamy. It occurs following types.

(a) **Isogamy :** The two fusing gametes are structurally and functionally similar, *e.g.*, *Monocystis*.

(b) **Anisogamy :** The two fusing gametes are similar but differ only in their size and/or motility, *e.g., Ceratium*.

(c) **Oogamy :** Large non-motile gametes are fertilized by smaller motile gametes, *e.g., Plasmodium*.

(11) **Major group of protists :** Unicellular protists have been broadly divided is to three major grous

(i) **Photosynthetic protists :** Protistan algae *e.g.* **Dinoflagellates** (*i.e. Ceratium, Glenodinium, Gymnodinium, Gonyaulax, Noctiluca* and *Peridinium*), **Diatoms** (*Navicula, Nitzchia, Melosira, Cymbella, Amphipleura, Pinnularia*) and **Euglenoids** or Euglena like flagellates (*Euglena, Eutreptia, Phacus, Peranema*).

(ii) **Consumer protists :** Slime moulds or Myxomycetes, *e.g., Physarum, Physarella*.

(iii) **Protozoan protists :** It is include four phyla – **Zooflagellata** (*e.g., Trypanosoma, Giardia, Trichonympha, Trichomonas, Leishmania* etc.), **Sarcodina** (*e.g., Amoeba, Entamoeba, Pelomyxa, Mestigamoeba* etc.), **Sporozoa** (*e.g., Plasmodium, Monocystis, Eimeria* etc. all are endoparasites) and **Ciliata** (*e.g., Paramecium, Vorticella, Opalina, Podophyra* etc.).

- **Dinoflagellates (Division-Pyrrophyta)**

(1) **Habit and Habitat :** This is well defined group of unicellular, golden-brown photosynthetic organisms. Majority of them are motile and flagellated but a few are non-motile and non-flagellated. Flagellated forms exhibit peculiar spinning movement. Hence, they are called **whorling whips.** The group includes about 1000 species. Most of them are marine but some occur in fresh water. Majority of the forms are **planktonic** and cover the surface of water body imparting them the characteristic colours.

(2) **Structure**

(i) **Cell wall :** The cell wall of dinoflagellates, if present, is composed of a number of plates made up of cellulose. It is called **theca** or **lorica**. The theca contains two grooves-longitudinal **sulcus** and transverse **girdle** or **annulus**. The cell surface usually bears sculpturing and hexagonal platelets.

(ii) **Flagella :** Usually the cells possess two **flagella** which are of different types (heterokont). One flagellum is transverse which arises from an anterior point in the transverse girdle. It is helical in form and ribbon-furrow and trails behind the cell. It is narrow, smooth and acronematic type. Both the flagella arise through pores in lorica.

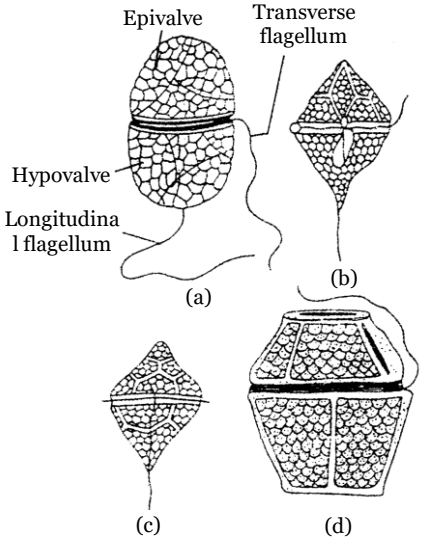


Fig : Some dinoflagellates (a) Glenodinium (b) Peridinium (c) Gynnodium (d)

(iii) **Nucleus :** Cells possess a relatively large and prominent nucleus known as **mesokaryon.** The interphase nucleus has condensed chromosomes which lack histones.

(iv) **Plastids :** There are numerous discoid chloroplasts without pyrenoids. They are yellow-brown to dark-brown in colour due to presence of characteristic **pigments** – Chlorophyll a, c, α - carotene and xanthophylls (including dinoxanthin and peridinin).

(v) **Reserve food :** The reserve food material is starch or oil.

(vi) **Pusule :** The cells possess an osmoregulatory organelle called **pusule** which superficially looks like contractile vacuole.

The cells posses mitochondria, ribosomes and Golgi bodies. They also possess mucilage bodies or vesicles below the cell membrane.

(3) **Nutrition :** In dinoflagellates it is mainly holophytic or photosynthetic. However, some forms are saprobic, parasitic, symbiotic or holozoic. For example, an colourless *Blastodinium* is parasite on animals.

(4) **Reproduction**

(i) **Asexual reproduction :** Dinoflagellates reproduce asexually through cell division or by the formation of zoospores and cysts.

The cell division starts from posterior end. During cell division, centromeres and spindle are not seen. The spindle is replaced by cytoplasmic microtubules. During mitosis, the chromosomes break up into pairs of romatids. The nuclear envelops and nucleolus persists during divison.

(ii) **Sexual reproduction :** If it is occurs, is isogamous or anisogamous. Two cells conjugate by a conjugation canal where the two amoeboid gametes fuse to form a diploid zygote. Life cycle involves zygotic meiosis (*e.g., Ceratium, Gymnodinium* etc.) or gametic meiosis (*e.g. Noctiluca*).

Diatoms (Division-Bacillariophyta)

(1) **Habit and Habitat :** Most of the diatoms occur as **phytoplanktons** both in fresh and marine waters. A few forms occur as benthos the bottom of water reservoirs. Some are terrestrial and grow on moist soil. Diatoms constitute a major part of phytoplankton of the oceans. It is estimated that a 60 ton blue whale may have approximately 2 tons of plankton (mostly diatoms) in its gut.

(2) **Structure**

(i) **Shape :** The cells of diamots are called frustules or shell. They are microscopic, unicellular, photosynthetic organisms of various colours and diverse forms. They may be circular, rectangular, triangular, elongated, spindle-shaped, half-moon shaped, boat-shaped or filamentous.

(ii) **Symmetry :** They exhibit mainly two types of symmetry-radial symmetry as in **centrales** (*e.g. Cyclotella*) and isobilateral symmetry as in **Pennales** (*e.g. Pinnularia*).

(iii) **Cell wall :** The cells of diatoms are called **frustules.** The cell wall is chiefly composed of cellulose impregnated with glass-like silica. It shows sculpturings and ornamentations. It is composed

of two overlapping halves (or theca) that fit togather like two parts of a soap box. The upper half (lid) is called **epitheca** and the lower half (case) is called **hypotheca.**

(iv) **Flagella :** Diatoms do not possess flagella except in the reproductive stage. They show **gliding** type of movement with the help of mucilage secretion. They float freely on the water surface due to presence of light weight lipids.

(v) **Nucleus :** Each cell has a large central vacuole in which a prominent nucleus is suspended by means of cytoplasimc strands. The cells are **diploid** (2 N). In case of centrales, the nucleus lies in the peripheral region.

(vi) **Plastids :** The cells possess plate-like or discoid chromatophores (or chloroplasts). They contain Chlorophyll *a*, Chlorophyll *c*, carotenes, diatoxanthin, diadinoxanthin and fucoxanthin (chlorophyll *b* is absent).

(vii) **Reserve food :** The reserve food material is **oil** and a polysaccharide – **chrysolamisarin** (or **leucosin**).

(3) **Reproduction**

(i) **Asexual reproduction :** The most common method of multiplication is **binary fission** (cell division) that occurs at night. In this process, each daughter individual retains one half of the parent cell and the other half is synthesized *i.e.* epitheca is retained and the hypotheca is synthesized. As a result, one of the two daughter individual is slightly smaller than the parent cell and there is gradual reduction in the frustule over the generations. However, the normal size is maintained by – formation of rejuvenescent cells (auxospores), growth of protoplast secreted from the frustule and secretion of new frustule of larger size.

(ii) **Sexual reproduction :** Reproduction takes place by the fusion of gametes. Meiosis is gametic *i.e.* takes place during the formation of gametes. The diploid nucleus of parent cell divides by meiosis into 2 or 4 daughter cells. Out of 4 haploid daughter nuclei only one or two survive and rest degenerate. Thus they produce only one or two gametes. The gametes may come out by an amoeboid movement and fuse externally in pairs within a mucilaginous sheath to produce zygote. The diploid zygote then a transformed into **auxospore.**

Important Tips

- The term prokaryotes and eukaryotes were coined by Fott.
- In five kingdom system of classification, the main basis of classification is structure of nucleus.
- Gold Fuss give the term 'Protozoa'.
- Ernst Haeckel proposed the term 'Protista'.
- Photosynthetic protists fix about 80% of CO_2 in the biosphere.
- **Protistology :** Study of protists.
- **Monerology :** Study of monerans.
- Slime moulds possess animal like as well as fungi like character.

- Euglenoids possess plant like as well as animal like characters.
- De Bary (1887) classified slime moulds as a animal and called them 'Mycetozoa'.
- Macbrid coind the term 'Myxomycetes' (Slime moulds).
- Dinoflagellates, due to **spinning** caused by activity of transverse flagellum (in cingulum/annulus) and longitudinal flagellum (in sulcus), represent whorling whips.
- Dinoflagellates with bioluminescence/phosphorescence due to light producing protein luciferin are called **fire algae**. e.g. Noctiluca, Pyrocystis, Pyrodinium etc.
- **Leeuwenhock** (1674, 1675, 1681) was first to observe and sketch protozoan protists including Vorticella and Giardia.
- Acellular organisms do not contain cellular structure e.g., viruses or not considered as cells but as complete organisms e.g., protists.
- Wall-less multicellular protoplasm of acellular slime moulds having branched veins and with process of cyclosis are called **phaneroplasmodium.**
- Dinoflagellates symbionts in other protists and invertebrates are called zooxanthellae.
- Some dinoflagellates produce blooms or red tides. e.g. Gonyaulax, Gymnodinium etc.
- Silicon is present in the frustule of diatoms.
- Auxospones are formed by diatoms.
- Noctiluca dinoflagellate is called 'night light'.
- Diatoms are emploid as a source of water glass or sodium silicate.
- Ganobacteria term was coined by **IBCN** (1978).

4.7 KINGDOM FUNGI

(1) **Introduction :** The science dealing with the study of fungi is called as **mycology**. The knowledge of fungi to mankind dates back to prehistoric times. *Clausius*, 1601 may be regarded as one of the earliest writers to describe fungi. *Bauhin* (1623) also included the account of known fungal forms in his book **Pinax Theatric Botanica**. The fast systematic account of fungi came from Pier Antonio Micheli (1729) who wrote **'Nova Plantarum Genera'**. He is described by some workers as founder or mycology. *Linnaeus* (1753) also included fungi included fungi in his **'Species Plantarum'**. Elias Fries (1821-31) gave a more detailed account of fungi in his **'Silloge Fungorum'** in 25 volumes describing some 80,000 species of fungi. This work remains unparalleld even today.

(2) **Thallus organization :** The plant body of true fungi (Eumycota), the plant body is a **thallus**. It may be **non-mycelial** or **mycelial**. The non-mycelial forms are **unicellular**, however, they may form a **pseudomycelium** by budding. In mycelial forms, the plant body is made up of thread like structures called hyphae (sing. hypha). The mycelium may be **aseptate** (non-septate) or **septate**. When non-septate and multinucleate, the mycelium is described as **coenocytic**. In lower fungi the mycelium is non-septate *e.g.*, Phycomycetae. In higher forms it is septate *e.g.*, Ascomycotina, Basidiomycotina and

Deuteromycotina. In some forms the plant body is unicelled at one stage and mycelial at the other. Their organization is sometimes described as **dimorphic**.

Holocarpic and Eucarpic : When the entire mycelium is converted into reproductive structure, the thallus is described as holocarpic. However, if only a part of it becomes reproductive, the thallus is called as **eucarpic**. The eucarpic forms may be **monocentric** (having a single sporangium) or **polycentric** (having many sporangia).

(3) **Specialised formation :** In higher forms the mycelium gets organised into loosely or compactly woven structure which looks like a tissue called **plectenchyma**. It is of two types :

(i) **Prosenchyma :** It comprises loosely woven hyphae lying almost parallel to each other.

(ii) **Pseudoparenchyma :** If the hyphae are closely interwoven, looking like parenchyma in a cross-section, it is called as pseudoparenchyma.

In addition to above, the fungal mycelium may form some specialized structures as under :

(a) **Rhizomorphs :** Its a 'root-like' or 'string-like' elongated structure of closely packed and interwoven hyphae. The rhizomorphs may have a compact growing point.

(b) **Sclerotia :** Here the hyphae gets interwoven forming pseudoparenchyma with external hyphae becoming thickened to save the inner ones from desiccation. They persist for several years.

(c) **Stroma :** It is thick mattress of compact hyphae associated with the fruiting bodies.

(4) **Cell organization :** The cell wall of fungi is mainly made up of chitin and cellulose. While chitin is a polymer of N-acetyl glucosamine, the celulose is polymer of d-glucose. Precisely, the cell wall may be made up of cellulose-glucan (Oomycetes), chitin chitosan (Zygomycetes) mannan-glucan (Ascomycotina), chitin-mannan (Basidiomycotina) or chitin-glucan (some Ascomycotina, Basidiomycotina and Deuteromycotina). Besides, the cell wall may be made up of **cellulose-glycogen, cellulose-chitin** or **polygalactosamine-galactan.**

In higher fungi, where the mycelium is septate, the septa are of several types :

(i) **Solid septum :** It has no perforations.

(ii) **Perforated septum :** It has several perforations.

(iii) **Acomycetean septum :** It has a single large pore in the centre of the septum.

(iv) **Bordered pit type septum :** It has a perforation in the septum resembling the bordered pit of tracheary elements.

(v) **Dolipore septum :** It has a single barrel shaped pore in the septum due to thickened rim. The pore has a cap of ER called **parenthosome**.

The cell wall is closely associated with the inner layer, the **plasma membrane**. In fungi, specialized structure called **lomasomes** are also found associated to the plasma membrane. They appear to be as

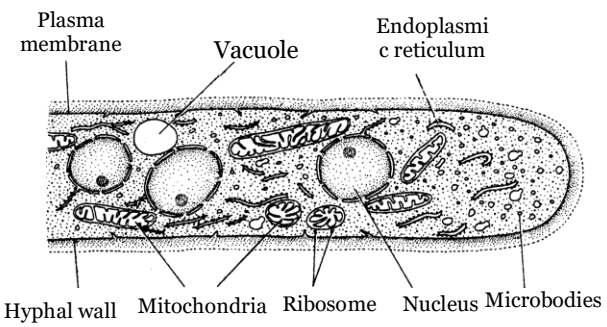


Fig : Diagrammatic electronmicrograph of a fungal cell

infoldings or invagination of the membrane. Almost similar structures called **plasmalemmasomes** are also found associated to the membrane. The cell contains one or more well defined eukaryotic nuclei. In fungi the nuclei show intranuclear mitosis which is sometimes referred to as **karyochorisis**. They also contains mitochondria, E.R., ribosomes, microbodies, lysosomes, vacuoles and crystals of reserve food particles (glycogen, lipid etc.). The cells lack golgi and chloroplast and therefore, chlorophyll and starch grains are also absent. However, a reddish pigment, **neocercosporin** has been isolated from the fungus *Cercospora kikuchii*. The vacuoles are bound by tonoplast. The genetic material is DNA.

(5) **Nutrition :** The fungi are achlorophyllous organisms and hence they can not prepare their food. They live as heterotrophs *i.e.*, as **parasites and saprophytes**. Some forms live **symbiotically** with other green forms.

(i) **Parasites :** They obtain their food from a living host. A parasite may be **obligate** or **facultative**. The obligate parasites thrive on a living host throughout their life. The facultative parasites are infact saprophytes which have secondarily become parasitic. While the above classification is based on the mode of nutrition, however, on the basis of their place of occurrence on the host, the parasites can be classified as **ectoparasite, endoparasite** and **hemiendoparasite** (or **hemiectoparasite**). The ectoparasites occur on the surface of the host tissue whereas the endoparasites are found within the host tissue. The forms belonging to the third category are partly ecto- and partly endoparasites. In parasitic forms. The mycelium may occur within the host cells (**intracellular**) or in between the host cells (**intercellular**).

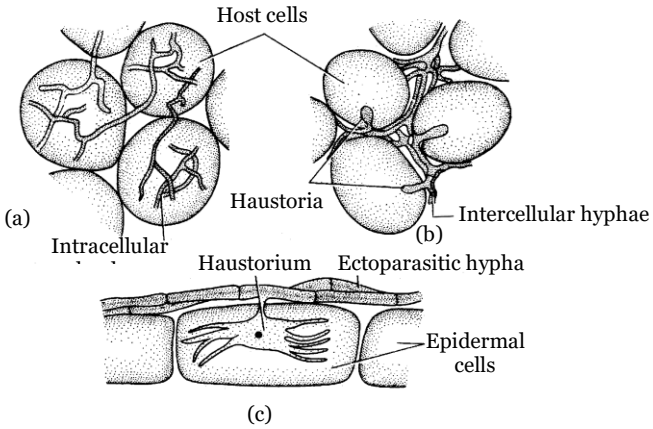


Fig : Parasitic hyphae and haustorial appendages : (a) Interacellular hyphae (b) and(c) Intercellular hyphae with haustoria

Some forms produce **rhizoids** for absorbing food. The parasitic fungi produce **appressoria** for adhering to the host. For absorbing food, the obligate parasites produce **haustoria**. As a result, the plasma membrane of the host cell becomes convoluted but it does'nt break. The fungal cell wall also remains intact. The haustoria may be finger-like, knob-like or branched. Each haustorium is distinguishable into a **base, stem** and **body**.

(ii) **Saprophytes :** They derive their food from dead and decaying organic matter. The saprophytes may be **obligate** or **facultative**. An obligate saprophyte remains saprophytic throughout it's life. On the other hand, a facultative saprophyte is infact a parasite which has secondarily become saprophytic.

(iii) **Symbionts :** Some fungal forms grow in symbiotic association with the green or blue-green algae and constitute the **lichen**. Here the algal component is photosynthetic and the fungal is reproductive. A few fungal forms grow in association with the roots of higher plants. This association is called as **mycorrhiza**. They are two types – Ectotrophic mycorrhiza and Endotrophic mycorrhiza *e.g.*, (VAM).

(6) **Reproduction :** The fungi may reproduce vegetatively, asexually as well as sexually :

(i) **Vegetative reproduction**

(a) **Fragmentation :** Some forms belonging to Ascomycotina and Basidiomycotina multiply by breakage of the mycelium.

(b) **Budding :** Some unicelled forms multiply by budding. A bud arises as a papilla on the parent cell and then after its enlargement separates into a completely independent entity.

(c) **Fission :** A few unicelled forms like yeasts and slime molds multiply by this process.

(d) **Oidia :** In some mycelial forms the **thallus** breaks into its component cells. Each cell then rounds up into a structure called oidium (pl. oidia). They may germinate immediately to form the new mycelium.

(e) **Chlamydospores :** Some fungi produce chlamydospores which are thick walled cells. They are intercalary in position. They are capable of forming a new plant on approach of favourable conditions.

(ii) **Asexual reproduction**

(a) **Sporangiospores :** These are thin-walled, non-motile spores formed in a sporangium. They may be uni-or multinucleate. On account of their structure, they are also called as aplanospores.

(b) **Zoospores :** They are thin-walled, motile spores formed in a zoosporangium. The zoospores are of several types :

- Uniflagellate with whiplash type flagellum *e.g., Allomyces.*
- Uniflagellate with tinsel type flagellum *e.g., Rhizidiomyces.*
- Biflagellate with a tinsel type and a whiplash type flagella *e.g., Saprolegnia*.
- Biflagellate with two whiplash type flagella *e.g., Plasmodiophora.*

(c) **Conidia :** In some fungi the spores are not formed inside a sporangium. They are born freely on the tips of special branches called **conidiophores**. The spores thus formed are called as conidia. On the basis of development, two types of conidia are recognised namely thallospores and blastospores or true conidia.

Thallospores : In some forms the thallus itself forms spore like bodies called **thallospores**. The thallospore are of two types namely **arthrospores** and **chlamydospores**.

- **Arthrospores :** They are thinwalled spores formed in basipetal order *e.g., Endomyces*.
- **Chlamydospores :** Some of the hyphal cells are converted into thick walled chlamydospores. They may be terminal or intercalary *e.g., Ustilago, Saprolegnia*.

Blastospores : They develop on conidiophores in acropetal or basipetal succession. They are of two types –

- **Porospores :** When the blastospores develop by the balooning of the inner wall of conidiophore, it is called as porospore *e.g., Alternaria*.

- **Phialospore :** On the other hand, when the first conidium carries the broken parent wall of conidiophore and subsequent conidia possess a new wall, such basipetally formed conidia are called as phialospore *e.g.*, *Aspergillus*.

Bi-celled conidia are formed in *Trichothecium*. In *Fusarium* it is possible to differentiate smaller **microconidia** from larger **macroconidia**. Sometimes the conidiophores form specialised structures as under :

Synnema or Coremium : Here the conidiophores get arranged in closely placed parallel plates.

Acervulus : It is a cushion-shaped mass of hyphae having closely packed conidiophores.

Sporodochium : It is also a cushion-shaped acervulus like structure having loosely arranged conidiophores.

Pycnidium : It is pitcher-shaped, embedded body which opens to exterior by a pore called **ostiole**. It is lined by conidiogenous hyphae. The conidia developing in pycnidia are often described as **pycniospores.**

(iii) **Sexual reproduction :** With the exception of Deuteromycotina (Fungi imperfecti), the sexual reproduction is found in all groups of fungi. During sexual reproduction the compatible nuclei show a specific behaviour which is responsible for the onset of three distinct mycelial phases. The three phases of nuclear behaviour are as under :

Plasmogamy : Fusion of two protoplasts.

Karyogamy : Fusion of two nuclei.

Meiosis : The reduction division.

These three events are responsible for the arrival of the following three mycelial phases :

Haplophase : As a result of meiosis the haploid (*n*) or haplophase mycelium is formed.

Dikaryotic phase : The plasmogamy results in the formation of dikaryotic mycelium ($n + n$).

Diplophase : As a result of karyogamy the diplophase mycelium ($2n$) is formed.

In some fungi plasmogamy, karyogamy and meiosis do occur in a regular sequence but not at specified time or points in life cycle. Such a cycle is described as parasexual cycle and phenomena celled parasexuality recorded by Pontecorvo and Roper.

The fungi reproduce sexually by the following methods :

- **Isogamy :** It involves fusion of two morphologically similar flagellate gametes.
- **Anisogamy :** Here the two gametes are motile but morphologically dissimilar. The larger gamete may be called as female and the smaller one as male.
- **Heterogamy :** It involves fusion of a non-motile female gamete (egg) with the motile male gamete (antherozoid). While the male gamete is formed inside the **antheridium**, the female is produced inside the **oogonium**. Both the sex organs are unicelled structure.
- **Gametangial contact :** It involves fusion of two gametangia. In lower forms the female gametangium is called as **oogonium.** The male gametangium is termed as **antheridium**. A

contact develops in between the two gametangia and then the male nucleus is transferred into the female directly or through a tube.

- **Gametangial copulation :** In this case the fusion occurs in between the two gametangia. When it occurs in some holocarpic forms where the entire thallus acts as gametangium, the phenomenon is called as **hologamy**. In others, dissolution of cell wall in between the two gametagial brings about gametangial copulation.
- **Spermatization :** Here the uninucleate male gametes called **spermatia** are formed in special structures called **spermogonia** or **pycnidia**. The female gametangium is called as **ascogonium** which has a long neck called **trichogyne**. The spermatium attaches itself with the trichogyne and transfers the male nucleus, thus bringing about **dikaryotisation**.
- **Somatogamy :** In higher fungi there is reduction of sexuality to the maximum level. Here two hyphae of opposite strains are involved in fusion thus bringing about dikaryotization.

(7) **Clamp connection :** In Basidiomycotina, the dikaryotic cells divide by **clamp connections**. They were first observed by Hoffman, (1856) who named it as '**Schnallenzellen**' (buckle-joints). A lateral pouch like outgrowth arises which projects downward like a hook. This pouch or **clamp** becomes almost parallel to the parent cell. The two nuclei now undergo conjugate division in such a way that one spindle lies parallel to the long axis of the cell and the other somewhat obliquely. As a result, one daughter nucleus enters into the clamp. Now, septae appear separating the clamp and the lower hyphal cell. The upper cell has both the nuclei. The clamp with a nucleus now fuses with the lower cell. The septum between the pouch and the lower cell is dissolved and thus the lower cell now contains both the nuclei of opposite strains. The entire process takes some 23-45 minutes.

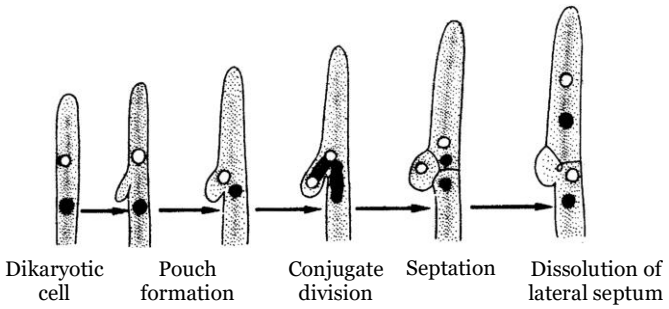


Fig : Various stages in the formation of clamp connections

(8) **Heterothallism :** Blakeslee, (1904) while working with *Mucor* sp. observed that in some species sexual union was possible between two hyphae of the same mycelium, in others it occured between two hyphae derived from 'different' spores. He called the former phenomenon as **homothallism** and the latter as **heterothallism**. Thus, the homothallic species are self-fertile whereas the heterothallic are self sterile. In heterothallic species the two 'thalli' are sexually incompatible. They are said to belong to opposite strains. Blakeslee designated them as + and – *i.e.*, belonging to opposite strains or mating types. Whitehouse, (1949) differentiated the phenomenon into two categories as under :

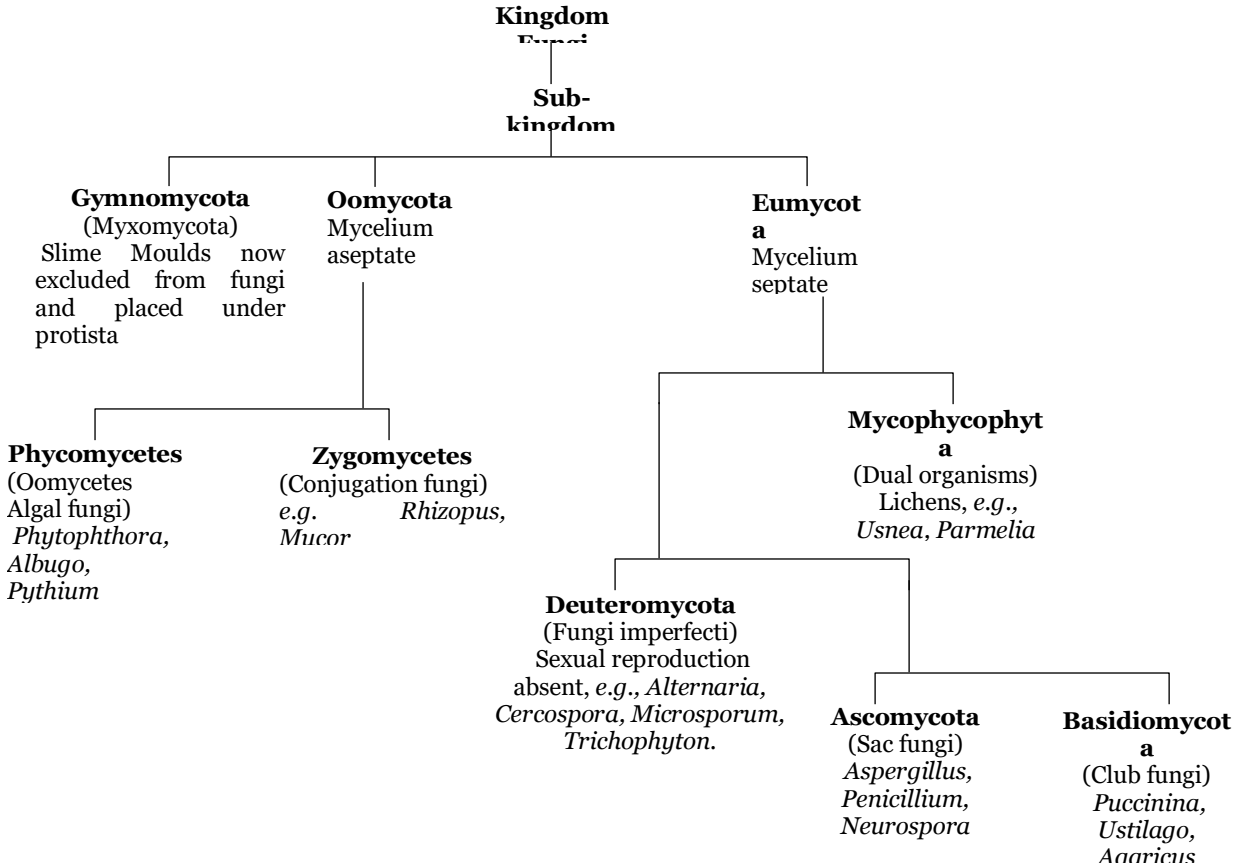
(i) **Morphological heterothallism :** When male and female sex organs are located on different 'thalli' the heterothallism is said to be **morphological**. Such species are generally described as dioecious.

(ii) **Physiological heterothallism :** In bisexual forms the two sex organs may be located on the same 'thallus' or on different 'thalli'. In some forms the two sexes even when present on the same

'thallus' are unable to mate, the heterothallism is said to be **physiological**. Such forms are self-sterile as they need genetically different nuclei. Such nuclei are absent when the same 'thallus' forms the two sex organs. Heterothallic fungi may be bipolar or tetrapolar.

(9) **Classification of fungi :** It is based largely on the characteristics of the life cycle involved like.

Nature of somatic phase, kinds of asexual spores, kinds of sporangia, nature of the life cycle and presence or absence of perfect or sexual stage.



(10) **Salient features of classes**

(i) **Phycomycetes (Oomycetes/Egg fungi) :** It is also called lower fungi, mycelium is coenocytic. Hyphal wall may contain chitin or cellulose (*e.g., Phytophthora*). Asexual reproduction occurs with the help of conidio-sporangia. Under wet conditions they produce **zoospores**. Under dry conditions, the sporangia directly function as conidia. Zoospores have heterokont flagellation (one smooth, other tinsel). Sexual reproduction is oogamous. It occurs by gametangial contact where male nucleus enters the oogonium through a conjugation tube. The fertilized oogonium forms oospore. *e.g., Sapolegnia, Albugo* (*Cystopus*), *Phytophthora, Phythium, Sclerospora*.

(ii) **Zygomycetes (Conjugation fungi) :** Mycelium is coenocytic. Hyphal wall contains chitin or fungal cellulose. Motile stage is absent. Spores (*Sporangiospores/aplanospores*) are born inside sporangia. Sexual reproduction involve fusion of coenogametes through conjugation (Gametangial copulation). It produces a resting diploid Zygospore. On germination, each zygospore forms a germ sporangium at the tip of a hypha called promycelium *e.g., Mucor, Rhizopus.*

(iii) **Ascomycetes** (*Ascus* : sac, *mycete* : fungus) **:** These are unicellular as well as multicellular fungi. In the latter, mycelium is septate. The asexual spores formed in chains are called conidia. The spores are formed exogenously, *i.e.* outside sporangium. They detach from the parent and form new mycelia. Sexual reproduction is through ascospores, which are formed endogenously (within the mycelium) in a sac like structure called **ascus** (pl. asci). The gametes involved in sexual reproduction are nonmotile compatible and are generally represented as + and –. The fusion of gametes is followed by reductional division that produces haploid ascospores. The fruiting body called **ascocarp**.

The ascocarp are of four types :

(a) **Cleistothecium :** It is an ovoid or spherical fruiting body which remains completely closed *e.g., Aspergillus.*

(b) **Perithecium :** It is a flask shaped fruiting body which opens by a single pore called **ostiole**. It is lined by sterile hyphae called **paraphyses**. The asci are also mixed with paraphysis *e.g., Cleviceps*.

(c) **Apothecium :** It is a saucer-shaped fruiting body. The asci constitute the fertile zone called **hymenium** *e.g., Peziza*.

(d) **Ascostroma :** It is not a distinct fruiting body. It lacks its own well defined wall. The asci arise directly with a cavity (locule) of stroma. It is also called as **pseudothecium** *e.g., Mycosphaerella*.

(iv) **Basidiomycetes :** They are the most advanced fungi and best decomposers of wood. These are called club fungi because of a club shaped end of mycelium known as basidium. They have septate multinucleated mycelium. Septa possess central dolipores and Lateral clamp connections. The sexual spores called basidiospores are generally four in number. They are produced outside the body (exogenuous) unlike ascomycetes where they are endogenous. Two compatible nuclei fuse to form zygote, which undergoes meiosis and forms four basidiospores. The fruiting body containing basidia is a multicelular structure called **basidiocarp**. The common members are edible mushrooms (*Agaricus*). Smut and Rust.

(v) **Deuteromycetes (Fungi inperfecti) :** The group include all those fungi in which sexual or perfect stage is not known. Mycelium is made of septate hyphae. Asexual reproduction commonly occur by means of conidia.

(11) **Economic importance**

(i) **Harmful aspects**

(a) **Crop diseases :** Several important crop plants are destroyed due to fungi diseases. Some important ones are listed here under :

Some plant disease caused by fungi

Disease	Crop	Causal organism
White rust of crucifers	Family Cruciferae	*Albugo candida or Cystopus*
Early blight of potato	Potato	*Alternaria solani*
Tikka disease of groundnut	Groundnut	*Cercospora personata or C. arachidicola*
Ergot disease of rye	Rye	*Claviceps purpurea*
Red rot of sugarcane	Sugarcane	*Colletotrichum falcatum*
Powdery mildew	Wheat	*Erysiphe polygoni*
Powdery mildew	Peas	*Erysiphe graminis*
Wilt of gram	Gram	*Fusarium orthaceras*
Bankanese disease and food rot of rice	Rice	*Gibberella fujikuri*
Leaf spot of oats	Oats	*Helminthosporium avenae*
Brown leaf spot of rice	Rice	*Helminthosporium oryzae*
Flag smut of wheat	Wheat	*Urocystis tritici*
Flag smut of oat	Oats	*Ustilago avenae*
Covered smut of barley	Barley	*Ustilago hordei*
Covered smut of oat	Oats	*Ustilago kolleri*
Smut of sugarcane	Sugarcane	*Ustilago scitaminea*
Loose smut of wheat	Wheat	*Ustilago tritici*
Late blight of potato	Potato	*Phytophthora infestans*
Club rot of crucifers	Cabbage	*Plasmodiophora brassicae*
Downy mildew of grapes	Grapes	*Plasmopara viticola*
Black rust of wheat	Wheat	*Puccinia graminis-tritici*

Brown rust of wheat	Wheat	*Puccinia recondita*
Yellow rust of wheat	Whet	*Puccinia striiformis*
Damping off of seedlings	Various seedlings	*Pythium* sp.
Blast of rice	Rice	*Pyricularia oryzae*
Grain smut of jowar	Jowar	*Sphacelotheca sorghi*
Wart disease of potato	Potato	*Synchytrium endobioticum*
Leaf curl of peach	Peach	*Taphrina deformans*

(b) **Diseases in human beings :** Several diseases in human beings are found to be caused by fungi infecting different parts of the body. Some of them are given hereunder as :

Disease	**Causal organism**	**Place of infection**
Athletes foot	*Epidermophyton floccosum*	Foot
Ring worm	*Trichophyton* sp., *Microsporum* sp., *Epidermophyton* sp., *Myxotrichum* sp.	Skin
Moniliasis	*Candida albicans*	Nails
Aspergillosis	*Aspergillus niger, A. flavus, A. terrus*	Lungs
Torulosis	*Cryptococcus neofomans*	Lungs, CNS

(c) **Spoilage of food :** Some forms like *Rhizopus, Mucor, Aspergillus, Cladosporium* grow on food articles and spoil them. *Cladosporium* grows even at a temperature of – 6°*C*.

(d) **Mycotoxins :** Some fungi produce toxic metabolites which cause diseases in human beings. They usually contaiminate cereals and oil seed crops.

Four types of mycotoxins are generally identified :

- **Aflotoxins :***e.g.*, Aflotoxin B_1, B_2, M_1, M_2, G_1, G_2; They are produced mainly by *Aspergillus flavus* and *A. parasiticus*. They are well know for their carcinogenic effect.
- **Zearalenone :** It is produced by *Fusarium* sp.
- **Ochratoxins :** They are produced by *Aspergillus* and *Pennicillium* sp.
- **Trichothecenes :** They are produced by fungi like *Cephalosporium, Fusarium* etc.

(e) **Poisonous fungi :** Some fungi are extremely poisonous *e.g.*, *Amanita phalloides* ('death cup'). *A. verna, Boletus satanus*. Forms like *Coprinus, Psilocybe* are less poisonous. The fungus *Amanita phalloides* produces toxins like α-**amanitin, phalloidin** etc. which are very poisonous.

(f) **Ergotism :**The fungus causing 'ergot' disease of rye (*Secale*) is *Cleviceps purpurea*. It contains many poisonous alkaloids in their sclerotia. It causes poisoning in human beings. It's acute condition is called as '**St. Anthony's fire**'.

(g) **Hallucinogenic drugs :** The hallucinogenic drug LSD (Lysergic acid Diethylamide) is extracted from *Cleviceps purpurea* as also from *Inocybe*. Besides, the mushroom *Amanita muscaria* is also hellucinogenic.

(h) **Rotting of wood :** Rotting of wood is caused due to degradation of lignin and cellulose. It is brought about fungi like *Polyporus* sp., *Fomes* sp. and *Ganoderma* sp., Forms like *Fusarium, Penicillium* leave stains on the wood.

(i) **Allergies :** Spores of *Mucor, Aspergillus, Penicillium, Puccinia* etc., present in the atmosphere cause allergies.

(j) **Deterioration of articles :** Forms like *Aspergillus, Cladosporium, Rhizopus, Chaetomium, Alternaria* deteriorate cork, rubber, leather, textile and even plastics.

(ii) **Useful aspects**

(a) **Food :** Forms like *Agaricus bisporus, Morchella esculenta, Lentinus edodes, Clavatia gigantia, Volvariella volvacea* are edible. The yeast *Saccharomyces cerevisiae* is used for making '**yeast cake**'. When mixed with cereal flour, the yeasts produce a preparation called **incaparina**. The **Single Cell Protein (SCP)** obtained from yeasts, *Penicillium, Fusarium* etc. are used as substitute of protein food, *Rhizopus oligosporus,* when processed with soybeans yield a food preparation called **'tempeh'**. It has high protein contents.

(b) **Flavoring of food :** *Penicillium roquefortii* and *P. camemberti* are employed for flavoring cheese.

(c) **Brewing and baking :** Yeasts are generally used in bakeries and breweries. The sugars are fermented by yeasts into alcohol and CO_2. While the former in main product of breweries CO_2 is mainly useful in bakeries.

(d) **Organic acids :** Several organic acids are commercially produced by fungi, some of which are given hereunder :

Organic acids	Source
Citric acid	*Aspergillus niger*
Gallic acid	*Penicillium glaucum*
Gluconic acid	*Aspergillus niger, Penicillum purpurogenum*
Fumaric acid	*Rhizopus stolonifer, Mucor* sp.
Lactic acid	*Rhizopus nodosus*
Kojic acid	*Aspergillus flavus*
Oxalic acid	*Aspergillus niger*

Acetic acid	*Candida sp.*

(e) **Antibiotics :** The antibiotics are chemicals produced by living organisms that kill other living organisms. The first known antibiotic is **penicillin** that was extracted from *Penicillium notatum* by A. Fleming, (1944). Raper (1952) also extracted the same antibiotic from *P. chrysogenum*. Besides, several other antibiotics have been extracted since then.

Antibiotics	Source
Griseoflavin	*Penicillium griseofulvum*
Citrinin	*P. citrinum*
Cephalosporin	*Acremonium* sp.
Ramycin	*Mucor ramannianus*
Proliferin	*A. proliferans*
Jawaharin	*A. niger*
Patulin	*Aspergillus clavatus*
Fumigatin	*Aspergillus fumigatus*
Viridin	*Gliocladium virens*
Penicillin	*Penicillium chrysogenum, Penicillium notatum*
Trichothecin	*Trichothecium roseum*
Campestrin	*Agaricus campestris*
Frequentin	*Aspergillus cyclopium*
Chaetomin	*Chaetomium cochloids*
Ephedrin	Yeasts

(f) **Other chemicals :** Various chemicals have been obtained from different kinds of fungi. Yeast are good source of glycerol and enzymes like *zymase*, *invertase* and *lipase. Cellulases* are obtained from *Aspergillus*. Some alkaloids are also obtained from fungi *e.g.*, Ergotinine, Ergotetrine and Ergobasine from *Cleviceps purpurea*. Gibberellins (plant hormones) are obtained from *Gibberella fujikuroi*. Another hormone, trisporic acid is obtained from *Mucor mucedo*.

(g) **Biological assays :** The fungi can detect the presence of certain chemicals present in the medium even in traces *e.g.*, *Aspergillus niger* for *Mn, Pb, Zn, Cu, Mo* etc.

(h) **Vitamins :** Various vitamins have been obtained from different kind of fungi.

Vitamins	Source
Vitamin A	*Rhodotorula gracilis*
Vitamin B_{12}	*Eremothcium ashbyii*

Thiamine B_1	*Saccharomyces cerevisiae*
Riboflavin B_{12}	*Saccharomyces cerevisiae*

(i) **Other uses**

- Nitrogen fixation by yeasts like *Saccharomyces* and *Rhodotorula*.
- Production of latex by *Mycena galopus*.
- Soil building by *Rhizopus, Cladosporium, Aspergillus* etc.
- Along with bacteria, the fungi work as decomposers.
- Biological control of growth of hyperparasites like insects, nematodes, bacteria and even other fungi.
- *Neurospora* is a good research material for geneticists and *Physarum* for molecular biologists for the study of DNA.

Important Tips

- **Fungus :** The term was used by Gaspard Bauhin (1560–1624).
- **Father of Mycology :** Pier Antonio Micheli. In 1729 he wrote 'Nova Genera Plantarum' in which 900 fungi were described.
- **Father of Systematic Mycology :** E.M. Fries (1794–1878). He wrote 'Systema Mycologicum' in three volume.
- **Father of Modern Mycology and Plant Pathology :** H.A. de Bary.
- **Father of Indian Mycology and Plant Pathology:** E.J. Butler.
- **Smallest Fungus :** Yeast with a size of 3–15 μm × 2–10 μm.
- **Largest Fungus :** Lignocolous Shelf Fungus/Bracket Fungus Ganoderma applanatum (fruiting body 60 cm across). Glant Puffball/Clavatia is 90–120 cm across. It possesses anticancer properties.
- Millardet discovered fungicide Bordeaux mixture. Which is solution of copper sulphate and calcium hydroxide ($CaSO_4 + Ca(OH)_2$).
- **Pseudogamy :** Fusion between unrelated cells.
- **Pedogamy :** Fusion between mature and immature cells.
- **Adelphogamy :** Fusion between mother and daughter cells or sister cells.
- Non-ciliated spores called **'aplanospores'**.
- Bipolar heterothallism found in Mucor and Rhizopous.
- Reserve food material of fungi is glycogen and oil bodies.
- A fungus which requires only one single host for complition of its life cycle is called 'autoecious'.
- Phycomycetes are called algal fungi or lower fungi.
- Fungi inhabiting wood are known as epixylic.

- Aspergillus secretes toxin during storage conditions of crop plants. The hyphae of this fungus are septate and uninucleate.
- Ascomycetes are our worst fungus enemies.
- Neurospora (an ascomycete) is known as Drosophila of plant kingdom.
- Peziza and Helvella are coprophilous fungi (grow on dung).
- In higher Ascomycota the ascus develops indirectly from the tip of a bi-nucleate ascogenous hypha by becoming curved forming a **crozier**.
- **Emperor Claudius Caesar** was murdered by his wife by giving extract of toad stool fungus – Amanita phylloides which stops m-RNA synthesis, therefore it is called 'Caesar's Mushroom'.
- About 2300 antibiotics have been discovered so far from various fungi. Of these, some 123 have been extracted from Penicillium and 115 from Aspergillus.
- Destruction of potato crop by Phytophthora infestans in Ireland in 1845–49.
- Decrease in the yield of coffee in Srilanka from 42 m. kg. to 3 m. kg due to Hemileia vastatrix.
- Destruction of 5 million elm trees in England in 1967–77 by Ceratocystis ulmi.
- Destruction of 50% maize plants in USA (1970) due to infection of Helminthosporium maydis.
- Famous famine of Bengal in 1942–43 was due to destruction of rice crop by Helminthosporium oryzae.
- Few leading Indian mycologists are : C.V. Subramaniam, T.S. Sadasivan, K.C. Mehta and B.B. Mundkar.
- The fungi which grow on tree are called as lignicolous fungi e.g. Polyporus.
- Keratimorphic fungi appear on nails, feathers, hairs, hoofs etc.
- Hydnum from order agaricales is called tooth fungus.
- **Balanced Parasites :** Parasites which draw nourishment from hosts without killing or weakening them are called balanced parasites. The parasites which bring about disease and destruction of the hosts are known as **destructive parasites**.
- **Biotrophic Parasite** (Gaumann, 1946). Absorbs nutrients from living host/cells.
- **Nacrotrophic Parasite** (Gaumann, 1946). Kills host cells for obtaining nourishment.
- **Luminescent Fungi**. They make wood/leaves/soil luminescent at night. Luminescent parts are pileus in Panus and Pleurorus species, fruiting body and mycelium in Clitocybe illudens.
- **Acetyl Glucosamine/**Chitin**.** $(C_{22}H_{54}N_4O_{21})n$.
- **Vegetative Vultures.** Saprophytic fungi have been called vegetative vultures by Rolfe and Rolfe (1926) as they function as natural scavengers.
- **Primary Host.** Host in which the parasite becomes sexually mature. In stem rust the primary host is Wheat (karyogamy occurs) while alternate/secondary host is Barberry.
- **Penicillin** – Penicillium chrysogenum (initially from P. notatum) first antibiotic drug called **wonder drug** (discovered by Fleming, 1929).
- Species of Morchella are commonly known as 'morels', 'sponge mushrooms' or 'gucchi'.

- The species of Polyporus are commonly called 'bracket fungi' or 'self fungi'.
- Phytotoxin are secreted by plants in response to fungal reactions. They are generally phenolic compound.
- Coprophilou fungi grow on dung e.g., Pilobolus crystallinus.
- Fungi can be stained by cotton blue.
- Deuteromycetes is also known as 'Fungal waste Basket'.
- The edible part of mushroom is basidiocarp.
- Parasexuality was first discovered in fungi.
- The members of Ascomycetes caused power mildew of crops.
- Largest fungus is 'Giant puffball'.

4.8 KINGDOM PLANTAE

Kingdom plantae includes green, brown and red algae, liwerworts, mosses, ferns and seed plants with or without flowers. They have the following characters.

(1) Multicellular organisms with walled and frequently vacuolate eukaryotic cells.

(2) They contain photosynthetic pigment in plastids.

(3) Principal mode of nutrition is photosynthesis but number of plants have become absorptive.

(4) Primarily non-motile, living anchored to a substrate.

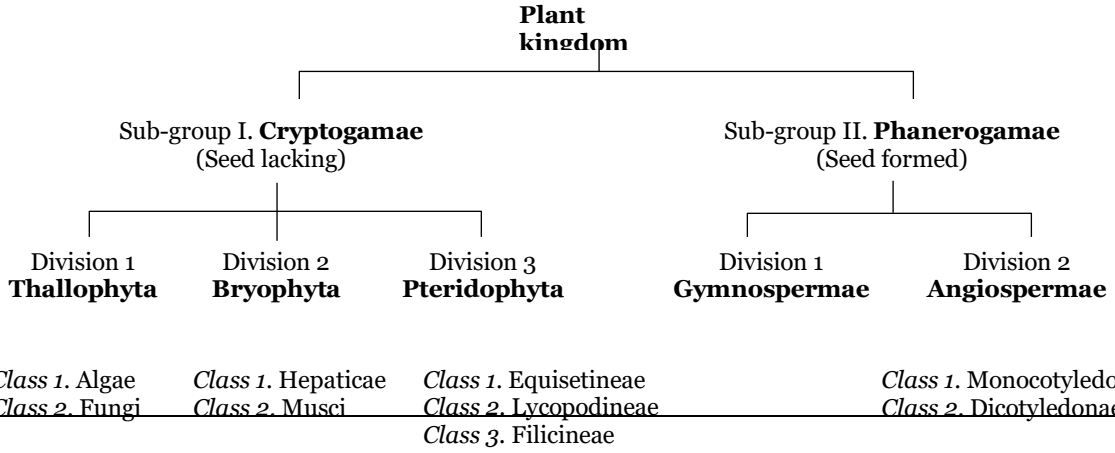
(5) Structural differentiation leading towards organs of photosynthesis, anchorage and support and in higher forms towards specialised photosynthetic, vascular and covering tissues.

(6) Reproduction is primarily asexual or sexual. The reproductive organs are multicellular.

(7) A multicellular embryo is formed during development from the zygote. Algae lack embryo stage. Life cycle consists of alternating haploid gametophyte and diploid sporophyte generation. This phenomenon is called alternation of generation.

(8) **Classification :** The plant kingdom thus comprises individuals which are structurally and functionally unlike one another. Subsequently several systems of classification of plant were proposed by taxonomists.

Classification of A.W. Eichler : *August Wilhelm Eichler*, a Viennese botanist, divided plant kingdom into two subgroups :



4.9 Algae

(1) **Introduction :** The branch of botany dealing with the study of algae is called as phycology or algology. It is derived from the Greek word *Phykos* which means 'alga' or 'sea weed'. They are simple, thallose, autotrophic non-vascular plants having unicelled sex organs and no embryo formation. According to Fritsch, (1935) the designation alga must include all holophytic organisms, as well as their numerous colourless derivatives, that fail to reach the level of differentiation characteristic of archegoniatae plants.

(2) **Occurrence :** The algae occur in a variety of habitats which are summarised hereunder :

(i) **Fresh water forms :** They occurs in rivers, ponds, pools, lakes and ditches. Some forms *e.g.*, diatoms occur as passively floating and drifting flora. They are called as **phytoplanktons**. Those forms which remain attached to bottom soil are called as (**epipelic**). Several forms remain attached to bottom or at the bank or to submerged objects. They are described as (**benthos**). Many forms remain attached to rocks or stones. They are described as (**epilithic** or **lithophytic**). Some blue-green algae form **water blooms** on the surface of water.

(ii) **Marine forms :** Most of the members of brown algae, red algae some green and blue-green algae occur in sea. While some occur as phytoplanktons and benthos, others occur as lithophytes. The giant forms like *Macrocystis* (60 *meters*) and *Nereocystis* (50 *meters*) are also marine.

(iii) **Terrestrial forms :** Several members of green and blue-green algae and a few others occur on damps oil. While forms like *Oscillatoria* and *Nostoc* occur on **alkaline** and **calcareous** soil, *Fritschiella* grown on acidic soil. Xanthophyceae members like *Vaucheria* and *Botrydium* growing on damp shady soil or on shady walls, are often described as **Sapophytes**.

(iv) **Specialized habitats**

(a) **Cryophytes :** Plants growing on snow or ice are called as **cryophytes**. Different algal forms produce a specific colour effect while growing as cryophyte *e.g.*, yellow-green by *Chlamydomonas yellowstonensis*, red by *C. nivalis*, black by *Scotiella nivalis* and purple-brown by *Ancylonema nordenskioldii.*

(b) **Thermophytes :** Plants growing in hot water are called as **thermophytes**. Some blue-green algae grow in hot water springs at about 70°*C e.g., Oscillatoria brevis*.

(c) **Epiphytes :** Several algal forms grow on other plants (algae, angiosperms) as **epiphytes**. *e.g.*, *Oedogonium, Cladophora, Vaucheria* etc.

(d) **Endophytes :** Some blue-green algae grows as **endophytes** inside other plants *e.g., Anabaena* growing inside the leaf of *Azolla* (fern), *Nostoc* inside the thallus of *Anthoceros* (hornwort) and *Anabaena, Nostoc, Oscillatoria* inside the coralloid roots of *Cycas*.

(e) **Epizoic :** Algae growing on the bodies of animals are described as **epizoic**. *e.g.*, *Cladophora crispata* grows on snail shell, *Characium* grows on the antennae of mosquito larvae, *Cyanoderma* (red alga) and *Trichophilus* (green alga) are grow on scales of sloth.

(f) **Endozoic :** Algae growing inside the body of animals. *e.g.*, *Chlorella* grow with in the tissue of *Hydra*. Some blue-green algae also grow in the respiratory tracts of animals. The blue-green algae which grow endozoically inside the protozoans are called as cyanallae.

(g) **Symbiotic forms :** Some algae like *Chlorella, Nostoc* etc. growing in symbiotic relationship with members of Ascomycetes and Basidiomycetes (Fungi) constitute the **lichen**.

(viii) **Parasites :** The alga *Cephaleuros virescens* grows a parasite on the tea leaves. In addition, *Rhodochytrium, Phyllosiphon* are other parasitic algal forms.

(3) **Thallus organization :** The algae show a considerable variation in the organization of the thallus :

(i) **Unicellular forms :** Several members of algae are unicelled. They may be motile (*Chlamydomonas*) or non-motile (diatoms). Forms showing movement by pseudopodia are called as **rhizopodial**. Some forms have a thick wall and become sedentary for certain duration in their life history. They are called as **coccoid** *e.g., Chlorella, Chroococcus*.

(ii) **Multicellular forms :** The multicelled algae show a considerable range in their organization.

(a) **Colonial :** A colony consists of independent organisms. While the colony of *Volvox* is motile, that of *Hydrodictyon* is fixed. A colony having fixed number of cells and division of labour is called as **coenobium** *e.g., Volvox*.

(b) **Palmelloid :** Here the vegetative cells of the alga get surrounded by a mucilagenous matrix *e.g., Tetraspora*.

(c) **Dendroid :** Here the colony appears like a microscopic tree. There is secretion of mucilage from the polar end *e.g., Ecballocystis*.

(d) **Filamentous :** Most of the algal forms are filamentous. The filaments may be uniseriate or multiseriate, free floating or attached, unbranched (*Ulothrix*) or branched (*Cladophora*). The branches may be monomorphic (*Cladophora*) or dimorphic (*Batrachospermum*). The branching may be lateral or dichotomous, true (*Ectocarpus*) or false (*Scytonema*). The filaments may be monosiphonous (*Batrachospermum*) or polysiphonous (*Polysiphonia*). In some filamentous forms there is distinction of a prostrate system and an erect system, thus constituting the heterotrichous habit. *e.g.*, *Stigeoclonium*.

(e) **Siphonous :** An aseptate, multinucleate (**coenocytic**) condition of a filament or thallus constitutes the siphonous habit *e.g., Vaucheria*.

(f) **Parenchymatous :** Parenchymatous organization of the thallus has been observed in many members of brown algae (*Sargassum, Laminaria*), red algae (*Gracillaria, Porphyra*) and a few green algae (*Chara, Ulva*) etc.

(4) **Cell organization :** The algae show three types of cellular organization, **prokaryotic, mesokaryotic** and **eukaryotic**. The mesokaryotic organization is seen in Dinophyceae where a nuclear

membrane and chromosomes are present but the basic proteins are absent. Here we shall describe only prokaryotic and eukaryotic organization in some details.

(i) **Prokaryotic :** The blue-green algae, also called as **Cyanobacteria**, show prokaryotic cell structure. The cell wall may have a mucilagenous sheath. The inner wall layer is made up of **mucopeptide**. It is a polymer of two aminosugars. The cell wall is followed by a plasma membrane**.** Light microscope, the cell is distinguished into a central colourless **centroplasm** and a peripheral coloured **chromoplasm**. The cell lack a well organised nucleus, mitochondria, E.R., and Golgi. However, 70 s ribosomes are present. There are no plastids either but the cell does possess **photosynthetic lamellae** which are comparable to thylakoids. The cells have **gas vacuoles** and granules of several types such as α, β, **polyhedral** and **structured granules**. The α–granules are now called as polyglucoside granules whereas the structured granules are cyanophycin granules.

In some filamentous forms like *Nostoc, Anabaena,* certain large specialized cells also occur. They are called as heterocysts. They form polar nodules, they may be **intercalary** or **terminal** in position.

(ii) **Eukaryotic :** Most of the algal groups (except blue-green and dinoflagellates) show eukaryotic cell structure. The cell wall is made up of **cellulose**. However, there may be additional layers of pectin and chitin. While silica is also present in the cell wall of diatoms whereas some red algae (*Corallina*) have inpregnation of $CaCO_3$. The cells possess a well organised nucleus. The minimum chromosome number in algae is $n = 2$ (*Porphyra linearis*) and the maximum number is $n = 592$ (*Netrium digitalis*). The cells possess distinct mitochondria, plastids, E.R., ribosomes and Golgi. In *Micromonas,* there is only one mitochondrion in a cell. The shape of chloroplasts is variable. It may be **cup-shaped** (*Chlamydomonas, Volvox*), **spiral** (*Spirogyra*), **stellate** (*Zygnema*), **girdle-shaped** (*Ulothrix*) **reticulate** (*Oedogonium*) but generally **discoid**. There may be a single thylakoid in the granum of Rhodophyceae, two in Cryptophyceae, three in Phaeophyceae and Bacillariophyceae but generally many. The cells may also possess simple or contractile vacuoles.

The motile forms and male reproductive cells also possess a photosensitive eye spot or stigma. In dinoflagellate the eye spot is distinguishable **in a lens, photosensitive region** and a **pigmented cup**.

The motile forms also possess flagella. They show the usual 9 + 2 structure. They are of two types – **acronematic** (whiplash type) and **pleuronematic** (tinsel type).

(5) **Pigmentation :** The grouping of algae based on pigments. Algae possess three classes of pigments namely chlorophylls, carotenoids and biliproteins.

(i) **Chlorophylls :** A chlorophyll molecule consists of a head and a tail. The head is made up of **porphyrin**, a tetrapyrrole closed ring compound with a central *Mg* atom; the tail is made up of **phytol**. Some five types of chlorophylls occur in algae namely chl. a, b, c, d and e. The chlorophyll a occurs in the all algal groups, **b** in Chlorophyceae, **c** in Phaeophyceae and Bacillariophyceae, **d** in Rhodophyceae and **e** in Xanthophyceae.

(ii) **Carotenoids :** These pigments are isoprene (C_5H_8) derivatives. They are of two types namely **carotenes** and **xanthophylls**. Some six types of carotenes have been located in algae which have been

designated as α, β, γ, ∈ **carotenes, lycopene** and **flavicine**. Of these, β–carotene is found in all the algal group, α–**carotene** in Chlorophyceae and Rhodophyceae, γ–**carotene** and **lycopene** in Chlorophyceae, ∈–**carotene** in Cryptophyceae and Bacillariophyceae and **flavicine** in Cyanophyceae. Some 20 xanthophylls have been identified from different algal groups such as **lutein, fucoxanthin, violaxanthin, astaxanthin, zeaxanthin, myxoxanthin** etc. Of these, lutein occurs in Chlorophyceae, Phaeophyceae, Rhodophyceae and Cyanophyceae, fucoxanthin in Phaeophyceae, Rhodophyceae and Bacillariophyceae. Myxoxanthin occurs in Cyanophyceae and astaxanthin in Chlorophyceae.

(iii) **Biliproteins or Phycobilins :** This comprise a bile pigment conjugated to a protein moiety. They are of three types namely **phycocyanin, phycoerythrin** and **allophycocyanin**. While **c–phycocyanin** and **c–phycoerythrin** occurs in Cyanophyceae, **r–phycoerythrin** and **r–phycocyanin** are found in Rhodophyceae. The allophycocyanin is found in both the groups.

(6) **Reserve food :** The food is reserved in different forms in various algal groups, some of which are summarised here under :

(i) Chlorophyceae : Starch and Oils.

(ii) Xanthophyceae : Chrysolaminarin (carbohydrate) and Oils.

(iii) Bacillariophyceae : Chrysolaminarin and Oils.

(iv) Phaeophyceae : Laminarin (carbohydrate), Mannitol (alcohol) and Oils.

(v) Rhodophyceae : Floridean Starch and Galactan $-SO_4$ polymers.

(vi) Cyanophyceae : Cyanophycean Starch (glycogen) and Cyanophycin (protein).

(7) **Reproduction :** The algae reproduce **vegetatively, asexually** and **sexually**. Various method involved in reproduction are discussed in the following account.

(i) **Vegetative reproduction :** It occurs by following types.

(a) **Fragmentation :** It occurs due to breakage of filament or thallus into fragments, each of which behaves as an independent organism *e.g., Ulothrix, Spirogyra* etc.

(b) **Fission :** The unicelled forms like diatoms, desmids multiply by fission *i.e.,* simple cell division.

(c) **Budding :** A bud arises as a papilla on the parent cell. It enlarges and finally separates *e.g., Protosiphon.*

(d) **Propagules or Gemmae :** They arise as modified branches. They are rich in food and germinate into new plant on detachment *e.g., Sphacelaria*.

(e) **Hormogonia :** In certain blue-green algae *e.g., Oscillatoria, Nostoc,* the filament breaks up into hormogonia due to the formation of separation disc (**necridia**) or at the junction of intercalary heterocysts.

(f) **Tubers :** In certain forms like *Chara,* tubers are formed on the lower nodes as also on the rhizoids. They germinate into new plants.

(g) **Akinetes :** Due to deposition of food material followed by thickening of the parent wall, a cell is transformed into an akinete. They may be formed in a chain. On the arrival of favourable conditions, they germinate to forms a new plant *e.g., Cladophora, Ulothrix, Nostoc* etc.

(ii) **Asexual reproduction :** It occurs by the formation of various types of spores in sporangia. Except the zoospores, all other types of spores are non-motile.

(a) **Zoospores :** These are thin walled motile spores. They are anteriorly biflagellate and the two flagella are similar in *Cladophora*. In *Vaucheria* and *Ectocarpus* they are laterally biflagellate and the two flagella are dissimilar. Multiflagellate zoospores are formed in *Oedogonium* and *Vaucheria*. In *Vaucheria* the flagella are present all over the surface in pairs and hence it is called as **synzoospore**.

(b) **Aplanospores :** They are thin walled and non-motile spores commonly formed in *Chlamydomonas, Ulothrix* etc.

(c) **Autospores :** They are also thin walled, non-motile spores which resemble the parent cell *e.g., Chlorella*.

(d) **Hypnospores :** These are thic walled non-motile spores formed to tide over unfavourable condition. They germinate on the arrival of favourable conditions *e.g., Chlamydomonas, Ulothrix.*

(e) **Exospores :** These are specialised type of aplanospores formed externally by pinching off the exposed protoplast *e.g., Chamaesiphon*.

(f) **Endospores :** In many blue-green algae, one or more endospores are formed inside an endosporangium by fragmentation of the protoplast *e.g., Dermocapsa, Pleurocapsa*.

(g) **Carpospores :** In red algae, carposporangia are formed at the tip of gonimoblast filaments which produce a single haploid or diploid carpospore *e.g., Batrachospermum, Polysiphonia*.

(h) **Tetraspores :** Four non-motile tetraspores are formed inside a tetrasporangium as a result of mitosis in brown algae (*e.g., Dictyota*) or by meiosis in red algae (*e.g., Polysiphonia*).

(i) **Monospore :** The juvenile stage of *Batrachospermum*, a red alga, multiplies by forming a single monospore formed in side a monosporangium.

(iii) **Sexual reproduction :** The sexual reproduction in algae is broadly of three types as under :

(a) **Isogamy :** It involves fusion of gametes which are morphologically and physiologically similar. They are called as isogametes *e.g., Chlamydomonas eugametos*. In diatoms, there is simplification of isogamous reproduction. Here two nuclei of opposite strains (+ and –) fuse and the phenomenon is called as **autogamy**. In *Chlamydomonas* sp. two vegetative cells may fuse to form a zygospore and the phenomenon is called as **hologamy**. As a result of fusion of two gametes, the zygospore is formed.

(b) **Anisogamy :** It involves fusion of two gametes which are dissimilar *e.g., Chlamydomonas, Ectocarpus, Pandorina* etc. When the two gametes are morphologically dissimilar, the anisogamy is said to be **morphological** *e.g., Chlamydomonas braunii, Ectocarpus secundus*. Here the smaller gamete may be called as male and the large one as female. When the two gametes are morphologically

similar but differ in their behaviour, the anisogamy is said to be **physiological** *e.g.*, *Spirogyra*, *Ectocarpus siliculosus.*

(c) **Oogamy :** In this process there is formation of unicelled sex organs. The male sex organ is called as **antheridium** and the female as **oogonium**. The antheridium forms the male gametes called **antherozoids** which are generally flagellate. The oogonium forms a non-motile female gamete called **egg**. The oogamy involves fusion of antherozoids with egg. The simplest type of oogamy is seen in *Chlamydomonas coccifera*.

In *Sargassum* the sex organs are formed in special pitcher shaped depressions called **conceptacles** formed on **receptacles**. In red algae (*Polysiphonia*) the male gametes called **spermatia** are non-motile. The female sex organ called carpogonium is formed on a specialized filament. The highest degree of specialization is seen in *Chara* where the antheridia and oogonia appear to be surrounded by sterile cells. The structures so formed are called as **globule** and **nucule**, respectively. As a result of fertilization, the zygote is formed which secretes 1 – 2 thick walls and undergoes a period of rest. On the arrival of favourable conditions, it germinates. Usually it undergoes meiosis to forms meiospores. In some forms, it forms the diploid plant *e.g.*, *Cladophora, Ectocarpus*.

(8) **Classification :** Linnaeus (1754) differentiated a group of plant and called as **'algae'** where he included lichens and liver worts also. This group was delimited to its present form by de Jussieu (1789).

Endlicher (1836) proposed the term **Thallophyta** where he included algae along with fungi. Fritsch (1935) classified algae into the eleven classes as under :

(i) Chlorophyceae (Green algae)

(ii) Xanthophyceae (Yellow-green algae)

(iii) Chrysophyceae

(iv) Bacillariophyceae (Diatoms)

(v) Cryptophyceae

(vi) Dinophyceae (Dinoflagellates)

(vii) Chloromonadineae

(viii) Euglenineae (Euglenoids)

(ix) Phaeophyceae (Brown algae)

(x) Rhodophyceae (Red algae)

(xi) Myxophyceae or Cyanophyceae (Blue green algae)

(9) **Salient features of some selected classes**

(i) **Chlorophyceae**

(a) Plants fresh water or marine.

(b) Forms unicelled to parenchymatous.

(c) Cells showing eukaryotic orgnaization.

(d) Chief pigments – Chlorophyll a, b; α, β, γ– carotenes, lycopene; lutein, violaxanthin.

(e) Reserve food – Starch and oils.

(f) Zoospore formation occurs.

(g) Male gametes flagellate.

(h) Flagella identical.

(i) Sexual reproduction – Isogamous, anisogamous or oogamous.

(ii) **Xanthophyceae**

(a) Plants generally fresh water.

(b) Forms unicelled to siphonous.

(c) Cells showing eukaryotic organization.

(d) Chief pigments – Chlorophyll a, e; β–carotene, violaxanthin, neoxanthin.

(e) Reserve food – Chrysolaminarin and oils.

(f) Zoospore formation occurs.

(g) Male gametes flagellate.

(h) Flagella non-identical (unequal).

(i) Sexual reproduction – Isogamous, anisogamous or oogamous.

(iii) **Phaeophyceae**

(a) Plants marine.

(b) Forms unicelled to parenchymatous.

(c) Cells showing eukaryotic organization.

(d) Chief pigments – Chlorophyll a, c; β–carotene, fucoxanthin, lutein, violaxanthin, diatoxanthin.

(e) Reserve food – Laminarin, mannitol and oils.

(f) Zoospore formation occurs.

(g) Male gametes flagellate.

(h) Flagella unequal.

(i) Sexual reproduction – Isogamous , anisogamous or oogamous.

(iv) **Rhodophyceae**

(a) Plants generally marine.

(b) Forms filamentous to parenchymatous.

(c) Cells showing eukaryotic organization.

(d) Chief pigments – Chlorophyll a, d is present but chlorophyll *c* is absent; α, β–carotene, lutein, violaxanthin, fucoxanthin, myxoxanthin, γ–phycoerythrin, γ–phycocyanin and allophycocyanin.

(e) Reserve food – Floridean starch, galactan $-SO_4$ polymers.

(f) No zoospore formation.

(g) Male gametes non-flagellate.

(h) Sexual reproduction by specialized type of oogamy.

(i) Life cycle haplobiontic or diplobiontic.

(v) **Myxophyceae (Cyanophyceae)**

(a) Plants generally fresh water, a few forms marine.

(b) Forms unicelled to filamentous.

(c) Cells showing prokaryotic organization.

(d) Chief pigments – Chlorophyll a; β-carotene; luteins, myxoxanthin, oscillaxanthin, c-phycocyanin, c-phycoerythrin, allophycocyanin.

(e) Reserve food – Cyanophycean starch (glycogen) and cyanophycin (protein).

(f) No zoospore formation.

(g) No flagellate bodies.

(h) No sexual reproduction.

(10) **Green algae as a ancestors of land plants :** There are sufficient evidences which suggest that the land plants have originated and evolved from algae. Morphological, cytological and biochemical similarities between the green algae and the land plants suggest that the ancestral algae was green, flat and fleshy with heterotrichous filamentous habit similar to *Fritschiella* (Smith). The various evidences which suggest algal origin of land plants are :

(i) Presence of similar type of photosynthetic pigments – Chlorophyll *a*, Chlorophyll *b* and carotenoids in both green algae and land plants.

(ii) Presence of cellulose and pectose as constituents of cell wall in both the groups.

(iii) Accumulation of starch as reserve food material.

(iv) Similar structure of flagella in green algae and land plants.

(11) **Economic importance**

(i) **Useful aspects**

(a) **Nitrogen fixation :** Some fifty species of blue-green algae are capable of fixing atmospheric nitrogen in the soil *e.g., Anabaena, Aulosira, Cylindrospermum, Calothrix, Gleotrichia, Nostoc, Scytonema, Stigonema, Tolypothrix* etc. Under aerobic conditions, nitrogen is fixed by heterocysts only. The fixation is brought about by the enzyme *nitrogenase*. Under anaerobic condition the vegetative cells also show *nitrogenase* activity.

(b) **Algae as food :** Many green algae such as *Chlorella, Ulva, Caulerpa, Enteromorpha,* etc. are used as food. *Chlorella,* a unicellular green alga, possesses a high quality of food value. It has about 50% protein and 20% of lipid and carbohydrates. The *Chlorella* protein contains all the amino acids essential for human nutrition. Besides, it contains vitamins A, B, C, K and various other essential elements. *Ulva* is collected and processed as food product. *Ulva lactuca* has formerly used in salad and soup in Scotland.

(c) **Green algae in space research :** In recent years biologists have realized that unicellular green algae (*e.g., Chlorella*) could be used to provide O_2 during space flight trips. The alga can reuse CO_2 during the process of photosynthesis and release O_2 for the use by Astronauts.

(d) **Antibiotics :** The genus *Chlorella* yields an antibiotic **chlorellin**, which is used against Gram +ve and Gram –ve bacteria, especially *Escherichia coli, Shigella dysenteriae* and *Staphylococcus aureus*. The genus *Caulerpa* also yields antibiotics.

(e) **Alginates :** Alginic acid is a polymer of carbohydrate. It occurs in the cell wall and middle lamella. The alginates particularly ammonium, *Fe, Na* and *K*, salts are water soluble. They are obtained from *Laminaria, Ascophyllum, Fucuc, Nereocystis, Turbinaria* etc. They are viscous, gel-forming and non-toxic. Hence they are used in pharmaceuticals as emulsifiers and stabilizers as well as for making pills, antibiotic capsules etc. They are also used in the preparation of soups, jellies, cosmetics, toothpastes, polishes, hair dyes, compact powders, lotions, shampoos etc.

(f) **Carrageenin :** It is a polysaccharide colloid (phycocolloid) obtained from the red algae *Chondrus crispus* and *Gigartinia stellata*. It is widely used in soups, sauces, milk shakes, cheese, jellies, cream and fruit juices. It is also used in painting and printing.

(g) **Kieselguhr or Diatomite :** The fossil deposits of unicelled alga, diatoms are formed due to their highly siliceous cell wall (frustules). This is called as diatomite or diatomaceous earth. It is used in making sound proof buildings, lining furnaces and boilers, as insulating material and also as a filter.

(h) **Agar-agar :** It is a non-nitrogenous carbohydrate consisting of two polysaccharides namely **agarose** and **agaropectin**. It is obtained from several red algae *e.g., Gracilaria, Gelidium, Gigartinia, Pterocladia, Chondrus, Furcellaria, Phyllophora* etc. It is insoluble in cold water but soluble in hot. It is used as a base for a variety of culture media.

(i) **Source of minerals and elements :** The members of brown algae called **'kelps'** have been the source for obtaining iodine *e.g., Laminaria, Macrocystis, Fucus*. About 25% of total iodine is extracted

from kelps. Besides iodine, the kelp also contain Bromine, Boron, Copper, Cobalt, Chromium, Iron, Manganese, Molybdenum and Zinc.

(j) **Sewage disposal :** Green unicellular algae such as *Chlorella* and *Chlamydomonas* are used in sewage disposal ponds. They remove CO_2 and restore O_2 by the process of photosynthesis and makes the sewage water habitable for many fishes and aerobic bacteria.

(ii) **Harmful aspects**

(a) **Algal toxicity :** Some dinoflagellates like *Prymnesium, Gymnodinium* are extremely poisonous to fishes. The blue-green alga *Microcystis* secretes hydroxylamine which not only kills aquatic life but also the birds and cattles who care to drink that water. While *Lyngbya* and *Chlorella* may cause skin allergies in human beings.

(b) **Algal parasitism :** The red alga *Cephaleuros virescens* causes red rust of tea thus destroying the tea leaves. Similar disease are caused by the species of *Cephaleuros* to coffee plant, *Piper* and *Citrus* sp.

(c) **Fouling of marine vessels :** Some brown and red algae grow on the metallic and wooden submerged parts of naval vessels. As a result, their surfaces are corroded. This creates problems in their navigation.

(d) **Spoilage of drinking water :** Forms like *Anabaena, Microcystis* not only spoil the taste of drinking water but also produces toxic effect. The water filters are blocked due to growth of diatoms, *Spirogyra, Oscillatoria* etc. Forms like *Chaetophora*, *Anacystis* grow inside the water pipes and boilers, and thus corrode their surface by their secretion. The growth of algae is controlled by using **algicides** such as dichlorophen, sodium perborate, phygon XI, exalgae, delrad, cuson etc. Besides, cyanophages (LPP-1) are also used for the destruction of *Lyngbya*, *Phormidium* and *Plectonema*.

(e) **Water blooms :** Algae grow abundantly in water reservoirs where excess of nutrients are available to them. This algal growth floats on the water surface and look like foam or soap lather. It is called water bloom. *e.g.*, Member of cyanophyceae (*Microcystis, Anabaena, Oscillatoria etc.*) are common. Water bloom deplete oxygen of water reservoirs and therefore, aquatic animals die of deoxygenation.

Important Tips

- **Thallophytes :** The term was coined by Endlicher (1836) for placing algae, fungi and bacteria in it. Plant body of thallophytes is called **thallus**. It does not show differentiation of stem, leaves and roots. An embryo stage is absent. Sex organs are nonjacketed and basically unicellular. They are most primitive members of plant kingdom.
- **Algae :** The term was coined by Linnaeus (1754) for hepaticae and others but was used for its present meaning by A.L. de Jussieu (1789).
- The element present in thyroxin is obtained from Laminaria.
- In blue green algae photosynthesis process is take place in chromatophore.
- **Father of Indian Phycology :** M.O.P. Iyengar.

- **Zoochlorella :** Chlorella species endozoic and living as symbionts, e.g., C. parasitica (in Spongilla), C. conductrix (in Paramecium and Hydra).
- Red algae secrete and deposite calcium carbonate and appear like corals.
- **Phycocolloid :** It is mucopolysaccharide present in and over the walls of brown and red algae like alginic acid (brown algae), agar and carrageenin (red algae).
- Multicellular algae are evolutionary older than land plants.
- Brown algae bear refracting vessels called as fucosan vesicles.
- Red alga, Rhodymenia is called sheep's weed.
- Eye spot absent in somatic cells of Ulothrix.
- Conducting tubes or trumphet hyphae are present in kelps. They are similar to sieve tubes.
- Red sea is due to excessive growth of blue green alga (Trichodesmium erythrium) over the surface of sea water.
- The algae growing attached to the bottom of a water body is called benthos.
- The first algal antibiotics chlorellin was extracted from chlorella.
- Chondrus (Irish moss) is used in the prepration of various pharmaceuticals including laxatives and cosmetics.
- Balls of Nostoc commune are used as a food by Chinese and South Americans. Food is called Yoyucho.
- Some species of Aulosira and Anabaena are inoculated in ponds to check the development of mosquito larvae.
- Some species of Anabaena and Tolypothrix help in conservation of soil, thus checking soil erosion.
- Cymbella used as a bacterial filter.
- The common names of some important alga are given below :

  Hydrodictyon (water net), Volvox (Rolling alga), Batrachospermum (Frog spawn), Ulva (Sea lettuce), Chara (Stone wor), Spirogyra (Pond scum/ water silk), Sargassum (Gulf weed).

4.10 Bryophyta

(1) **Introduction : Bryophyta** (Gk : *Bryon* = moss ; *phyton* = plants) includes the simplest and primitive land plants. De Jussieu (1789) placed mosses etc. under acotyledons along with algae and fungi. De Candolle (1813) placed liverworts and mosses in the class Aetheogamous of the division Cellulare. Robert Broun include algae, fungi, lichen and mosses under bryophyta. It occupies a position intermediate between algae and pteridophyta. Due to peculiar type of their habitats, they are regarded as 'the amphibians of the plant kingdom'.

(2) **Habitat :** Bryophytes usually grow in moist and shady places. The plants grow densely together and form green carpets or mats on damp soil, rock, walls, barks of trees and on decaying logs in forests, especially during the rainy season.

(3) **Specialized habitats :** Some bryophytes grow in diverse habitats such as – **aquatic** (*e.g., Riccia fluitans, Ricciocarpus natans, Riella*), epiphytes (*e.g., Dendroceros, Radula protensa* and many mosses), saprophytes (*e.g., Buxbaumia aphylla, Cryptothallus mirabilis*), and in **dry habitats** such as dry heaths (*e.g., Polytrichum juniperinum*), deserts (*e.g., Tortula desertorum*) and dry rocks (*e.g., Porella platyphylla*).

(4) **Gametophytic plant body**

(i) The life cycle of bryophytes consists of two distinct phases – the gametophytic phase and the sporophytic phase. The haploid gametophyte is dominant, long lived, green and independent whereas the diploid sporophyte is short lived and dependent upon the gametophyte. The two phases come one after the other in alternating manner and both are morphologically distinct.

(ii) The plants are small, range from few millimetres (*e.g., Zoopsis*) to 30–40 centimetres. The tallest species may reach upto 70 *cm* in length (*e.g., Dawsonia*).

(iii) The gametophytes are either thalloid (*i.e.,* not differentiated into true roots, true stem and true leaves) or **leafy shoot** having stem-like central axis and leaf-like appendages.

(iv) The roots are completely absent and they are replaced by unicellular or multicellular thread like **rhizoids**. In some higher forms the multicellular rhizoids form cords.

(v) The vascular tissue (*i.e.,* xylem and phloem) are completely absent. In few mosses (*Polytricum*) the xylem like hydroids, which conduct water and phloem like leptoids, which conduct the assimilates, have been reported.

(5) **Apical growth :** The apical growth in bryophytes take place by a single apical cell or a group of meristematic cells arranged in a transverse row. In *Riccia, Marchantia* and many jungermanniales the apical growth takes place by a transverse row of apical cell. In mosses, it occurs by single pyramidate apical cell. In *Anthoceros,* on the other hand, there may be a single apical cell or a transverse row of such meristematic cells.

(6) **Reproduction :** The bryophytes reproduce vegetatively, asexually and sexually. Various methods involve in reproduction are discussed in the following account.

(i) **Vegetative reproduction :** The bryophytes reproduce vegetatively by following methods :

(a) **Death and Decay :** Most of these plants reproduce vegetatively by gradual death and decay of the older part of the plant body.

(b) **Adventitious branches :** Many plants like *Riccia fluitans, Reboulia, Asterella, Pellia* etc. reproduce by **adventitious branches**. They separate and produce new plants.

(c) **Tubers :** Several species of *Riccia, Anthoceros, Sewardiella, Asterella* etc. produce **tubers** which give rise to new plants on the arrival of favourable conditions.

(d) **Gemmae :** Several members, reproduce vegetatively by forming multicelled gemmae. In *Marchantia, Lunularia,* the gemmae are produced in **gemma cups**. In some liverworts, 1–3 celled gemmae are prodcued on the axis or on the 'leaves' or on thalli. Gemmae are also produced on the

thallus of *Anthoceros*. Several mosses also produce gemmae on the 'leaves' (*Bryum*), or axis or rhizoids or on the protonema (*Funaria*).

(e) **Leafy propagules :** Some liverworts also reproduce vegetatively by forming leafy propagules.

(f) **Primary protonema :** The mosses generally reproduce vegetatively by breaking of the primary protonema. New gametophores now arise from the buds differentiated on it.

(g) **Secondary protonema :** In several mossess a secondary protonema may arise from the rhizoids or primary protonema or even from the injured sporophyte. It may produce buds which give rise to new gametophores.

(h) **Rhizoids :** Mosses may also reproduce vegetatively from the rhizoids *e.g., Leucobryum*.

(ii) **Sexual reproduction :** The male sex organs is called as **antheridium** and the female as **archegonium**. The antheridial stalk is very distinct whereas the archegonial stalk is generally short. They may be of **embedded type** *e.g., Riccia, Anthoceros* or of **projecting type** *e.g., Marchantia*, mosses.

(a) **Antheridia :** They are generally borne on the dorsal surface of the thallus. While in *Riccia* the antheridial chambers are open, in *Anthoceros* they are closed. The antheridia lie embedded within the thallus in both the plants. In Jungermanniales the antheridia are borne in one or more rows. In Marchantiaceae they are present on a special branches, the **antheridiophores** or the **male receptacles** which may be stalked or sessile. While in most of the members the antheridia are superficial in origin, in *Anthoceros* they are endogenous. Each antheridium is distinguishable into a **stalk** and the **body**. The antheridial body consists of a mass of **androgonial cells** covered by a 1-cell thick sterile **jacket**. The terminal cell of the jacket, when distinct, is called as **operculum**. Each androgonial cell finally behaves as **androcyte mother cell**. The androcyte mother cell then forms two **androcytes** (antherozoid mother cell), each of which is metamorphosed into a biflagellate antherozoid**.**

(b) **Archegonia :** These are also borne on the dorsal surface of the thallus. In *Riccia* and *Anthoceros* they lie embedded in the thallus. In many members of Marchantiaceae they are borne on special branches called **archegoniophores** or the **female receptacles**, that may be stalked or sessile. The archegoniophore or **carpocephalum** has rows of archegonia protected by **involucre** or **perichaetium**. The archegonia are flask shaped structures distinguishable into a long **neck** and a globular, swollen venter. A multicelled **stalk** is also present in mosses but in others it is very short. The neck is one-cell thick. It is generally made up of six vertical rows of cells but in Jungermamnniales it is compose of 4 or 5 vertical rows only. The neck is capped by four **cover cells** and contain varying number of **neck canal cells** inside. While in *Riccia* there are only 4 neck canal cells, the mosses however, possess more than six of them. The venter is also 1-cell thick in most of the plant but in Jungermanniales it is 2–3 layered. In mosses it is double layered. The venter contains an **egg** and a **ventral canal cell**.

(7) **Importance of water in bryophytes :** The bryophytes are fundamentally terrestrial plants but require presence of water to complete their life cycle. The water is needed for dehiscence of antheridia,

liberation of antherozoids, transfer of antherozoids from antheridia to archegonia, opening of archegonial neck, and the movement of antherozoids into the archegonial neck.

(8) **Fertilization :** Before fertilization the walls of androgonial cells disorganise to form a mucilagenous mass. The opercular cell is removed and the antherozoids are liberated. The neck canal cells and the ventral canal cell also disorganise. The cover cells split apart giving a free passage to incoming antherozoids. The antherozoids are attracted towards the egg by chemotactic stimulus, which in bryophytes, is provided in the form of sugars. Antherozoids enter in to archegonia and fertilized the egg.

(9) **Sporophyte**

(i) The diploid fertilized egg (zygote) is the first cell of sporophytic generation. It divides and develops into a sporophytic plant body, called **sporogonium**.

(ii) The wall of venter forms calyptra, which provides a protective covering to the developing **sporogonium**.

(iii) The sporogonium, in most of the cases, is differentiated into foot, seta and capsule.

(iv) The sporogonium is completely dependent on the gametophyte for water and mineral supply and, in most of the cases, partly or wholly for organic nutrition. The sporogonium remains attached to the gametophytic plant body throughout its life.

(v) The sporogonium is mainly concerned with the production of asexually formed haploid spores (or meiospores). The spores are produced inside the capsule of sporogonia as a result of meiosis in the spore mother cells.

(vi) The spores are the first cells of gametophytic generation. They germinate to produce the gametophytic plant body either directly or through a juvenile filamentous stage, called protonema.

(10) **Alternation of generation :** Bryophytes exhibit a distinct and heteromorophic alternation of generations in which two phase gametophytic and sporophytic follow each other in regular sequence. The sporophytic plant body (2 *N*) of bryophytes is dependent on the gametophyte (*N*).

(11) **Classification :** Eichler (1883), Engler (1892), Bower (1935) divided Bryophyta into two classes – Hepaticae and Musci. On the other hand, Campbell (1940), Smith (1955), Takhtajan (1953) divided into three classes namely **Hepaticae, Anthocerotae** and **Musci**. Proskauer (1957) changed the names of these classes in accordance with the recommendations of the code, into Hepaticopsida, Anthocerotopsida and Bryopsida.

(12) **Salient features of classes**

(i) **Hepaticopsida :** The latin word *Hepatica* means liver. Thus the members of hepticopsida are popularly known as **liverworts**. The important characters of hepaticopsida are :

(a) The gametophytic plant body is small, dorsiventral, thallose or leaf axis (foliose).

(b) Chlorophyllous cells contain many chloroplasts and one to several oil bodies.

(c) Pyrenoids are absent.

(d) Rhizoids are unicellular.

(e) Sex organs develop from single superficial cells.

(f) Sporogonium has little or no chlorophyllous tissue and stomata.

(g) The capsule is not linear. It lacks columella and intercalary meristem.

(h) Capsule dehisces by drying of capsule-wall, usually by more than two valves.

(ii) **Anthocerotopsida :** This class is characterised by the following characters –

(a) Gametophyte is thalloid. Thalli are lobed, dorsiventral, internally homogenous without any differentiation of tissues.

(b) Air chambers and air pores are absent but mucilage cavities may be present.

(c) Rhizoids are only smooth walled.

(d) Scales are absent.

(e) Each cell possesses single (some times more) large chloroplast with central pyrenoid.

(f) Oil bodies are absent.

(g) Antheridia are endogenous in origin, borne singly or in groups inside the closed cavities.

(h) Sporogonium is differentiated into foot, meristematic zone and capsule (the seta is absent).

(i) Capsule has central sterile columella.

(j) The capsule dehisces basipetally by two valves and shows hygroscopic twisting.

(iii) **Bryopsida :** The members of bryopsida are commonly known as **mosses**. The class is characterised by the following characters –

(a) Gametophyte is differentiated into two stages – prostrate protonema and erect radial leafy shoot.

(b) Leaf-like appandages are spirally arranged on stem – like axis.

(c) Rhizoids are multicellular with oblique septa.

(d) Sex organs develop from superficial cells.

(e) Sporogonium is differentiated into foot, seta and capsule.

(f) Wall of capsule is several layered with stomata on epidermis.

(g) The capsule has central columella.

(h) Elaters are absent.

(13) **Economic importance**

(i) **Soil conservation :** Mosses grow in dense mats over the soil surface. They bind the soil particles and prevent soil erosion by running water.

(ii) **Formation of soil :** Mosses along with lichens play a very important role in the formation of soil over the bare rocky surface. They grow on rocks and add organic matter to the substratum after their death. It makes the rock surface suitable for the growth of higher plants.

(iii) **Use in nursery :** The *Sphagnum* plants have magnificent property of retaining water. They can with hold water two hundred times more than their own weight. Hence they are widely used by gardeners to keep cut plant parts moist during transportation and propagation.

(iv) **Peat :** *Sphagnum* plants grow as semiaquatic or submerged in acidic marshes. The older portions of plants die but do not decay due to peculier germicidal properties. Constantly increasing mass of dead remains accumulate year after year. These dead remains are slowly compressed and become hardened due to weight and forms a compact dark coloured **peat** rich in carbon. The peat is dried, cut into pieces and used as fuel. It is mixed in clayey soil to keep it porous and mixed in sandy soil to improve its water holding capacity.

(v) **Other uses :** Certain bryophytes are used to obtain a number of **antibiotic** substances. Some bryophytes grow in specialized areas and, therefore, used as **indicator plants**. Some bryophytes have important medicinal uses. For example – The tea prepared from *Polytrichum commune* is used to dissolve kidney and gall bladder stones.

Important Tips

- **Bryophytes :** The term coined by Robert Braun (1864). Nonvascular embryophytes.
- **Bryology :** The science dealing with bryophytes. S.R. Kashyap is father of Indian Bryology**.**
- The golden mine of liverworts is western Himalayas.
- **Sporogonium :** Sporophyte of bryophytes which is parasitic over gametophytic plant body and is mainly meant for producing meiospores.
- **Embryophytes :** The term was used by Engler (1886) to include all plants outside thallophytes which possess an embryo stage in life cycle and jacketed sex organs.
- **Archegoniatae :** The group of embryophytes having archegonia. viz. bryophytes, pteridophytes and gymnosperm.
- **Alternation of generation :** First reported by Hofmeister (1851).
- **Exoscopic :** Embryo in which the apex is towards tip of archegonium.
- **Endoscopic :** Embryo in which the apex is towards the base of archegonium.
- **Sphagnol:** Distillate from peat tar which can treat skin diseases.
- **Elaters** exhibit **xerochasy.**
- **Riccia fluitans, Riella** and Ricciocarpus are aquatic bryophytes.
- **Funaria** is also known as cord moss.
- A capsule of **Marchantia** forms about 3,000,000 spores.
- **Pogonatum** sporogonium is without apophysis.
- Calyptra is loose cap-like portion of capsule.
- **Flat roof** of columella is called **epiphragm**.
- **Central sterile** column of capsule is called columella.
- **Bryophytes** are non-vascular plants with multicellular sex organs.
- **Mature Riccia** sporogonial cells are always haploid.
- **Erect** gametophyte of bryophyte is called gametophore.

- **Sterile** hairs mixed with sex organs are called **paraphyses.**
- Smallest bryophyte is Zoopsis.
- Tallest bryophytes is Dawsonia.
- Dimorphic rhizoids are found in Funaria.
- Sporophyte is completely depend on gametophyte in Funaria.
- Appendiculate scales develops in marchantia.
- Common name of some true mosses are, Funaria (cord moss), Sphagnum (Peat moss/ Bog moss/ Truf moss), Polytricum (Hair cap moss), Andraea (Granite moss), Grimmia (Black moss), Tortula (Twisted moss).

4.11 Pteridophyta

(1) **Introduction :** The **pteridophytes** (Gk. *Pteron* = feather and *phyton* = plants ; means plants with feather like fronds or **ferns**). They are flowerless, seedless, spore producing vascular plant which have successfully invaded the land. Pteridophytes represent an intermediate position between bryophytes and spermatophytes (Gymnosperm and Angiosperm). It is classified by Carolus Linnaeus (1754) under the class cryptogamia. They are also called vascular cryptogams. The group has a long fossil history. It is the most primitive group that flourished in Devonian and Carboniferous periods of Palaeozoic Era.

(2) **Habitat :** The plants of pteridophytes are mostly terrestrial. They prefer shady habitats. Some species of *Selaginella* and *Adiantum* are xerophytes. A fern, *Acrostichum aureum is a halophyte.* Some species *e.g., Selaginella oregana, Psilotum flacidum, Lycopodium squarrosum* and ferns like *Asplenium nidus, Pleopeltis* sp. are epiphytes. *Marsilea* occurs as a terrestrial, amphibious as well as an aquatic plant. There are true aquatics ferns like *Salvinia, Azolla* and *Ceratopteris*.

(3) **Sporophytic plant body**

(i) The main independent plant body of pteridophytes is sporophyte. It is differentiated into true roots, true stem and true leaves.

(ii) The primary root is short lived. It is replaced by adventitious roots. The root has a permanent growing apex.

(iii) The stems are usually herbaceous (except in some woody ferns) and branched monopodially or dichotomously.

(iv) The leaves may be small microphyllous (*e.g., Lycopodium, Equisetum*) or large macrophyllous (*e.g., Pteridium, Pteris* and other ferns).

(v) All the vegetative parts possess vascular tissues (*i.e.,* xylem and phloem) organized in definite groups or steles. Secondary growth does not occur in most of the living pteridophytes (except in *Isoetes*).

(4) **Apical growth :** The pteridophyte generally possess a single apical cell with three cutting faces in the shoot apex. The root tip also has a single apical cell but with four cutting faces.

(5) **Spore producing organs :** The plants of pteridophytes are sporophytes. They reproduce asexually by forming spores in sporangia. They are **homosporous** but a few plants are **heterosporous** also *e.g., Isoetes, Selaginella, Marsilea, Regnellidium, Pilularia, Azolla* and *Salvinia*. In *Selaginella* the sporangia are borne in relation to **sporophylls** which constitute a **strobilus**. In *Equisetum* they are borne on sporangiophores which constitute a **cone**. In ferns the sporangia are borne in **sori** on the sporophylls. The sori are of three types –

(i) **Simple sorus :** Here all the sporangia mature at the same time.

(ii) **Gradate sorus :** Here the oldest sporangium lies in the centre and the sporangia on either side show successively younger stages.

(iii) **Mixed sorus :** It shows mixed arrangement of younger and older sporangia.

In *Marsilea, Azolla, Salvinia* etc. the sori are present in a box like structure called **sporocarp**. The sorus may be naked or covered by an inducium. The inducia may be **true** or **false**. A true inducium is a specially developed structure whereas a false inducium is formed by curving of the sporophyll margin.

(6) **Sporangium :** The sporangia are generally stalked structures. Each sporangium is distinguishable into a **jacket** enclosing a mass of **sporogenous tissue**. The sporangial jacket may be 2-4 layered. The innermost wall layer is the **tapetum**. No tapetum is formed in *Psilotum* and *Tmesipteris*. It is a nutritive layer which degenerates at maturity of the sporangium. The sporangial jacket in some ferns shows distinctions of annulus and **stomium**. On the basis of development the sporangia have been classified by Goebel, 1881 into two categories as under :

(i) **Eusporangiate type :** Such a sporangium develops from a group of superficial initials. They divide periclinally into outer and inner components. The outer cells form the wall whereas the inner cells give rise to sporogenous tissue.

(ii) **Leptosporangiate type :** Such a sporangium arises from a single superficial initial. It divides periclinally into outer and inner components. While the inner cell forms the stalk, the outer gives rise to sporagnium proper. In *Marattia alata*, the sporangia in a sorus may fuse to form a **synangium**.

(7) **Spore :** The plants may be **homosporous**, *i.e.*, produce only one type of spores (*e.g., Lycopodium, Pteridium*) or **heterosporous** *i.e.*, produce two different types of spores, smaller microspores and larger – megaspores (*e.g., Selaginella, Marsilea* etc.). The spore germination is homosporous pteridophytes may be **bipolar** (*e.g., Lycopodium, Equisetum*) or **tripolar** (*e.g., Hymenophyllum*) or **amorphous** (*e.g., Angiopteris*).

The spores germinate to produce haploid gametophyte, called prothallus. The homosporous pteridophytes produce bisexual (monoecious) gametophytes whereas heterosporous one produce unisexual (dioecious) gametophytes.

(8) **Sex organs :** The **archegonia** and **antheridia** are generally of embedded type. The archegonium consists of **neck** which usually projects from the surface of the prothallus. It contains 1-2

neck canal cells. There is no **venter**. The **egg** and the **ventral canal cell** remain surrounded by the cells of prothallus. The antheridia are generally sessile. They have a 1-cell thick **jacket** enclosing a mass of **androgonial cells**. They form the androcytes which are metamorphosed into biflagellate (*Lycopodium, Selaginella*) or multiflagellate (*Equisetum, ferns*) antherozoids.

(9) **Fertilization :** Before fertilization the walls of androgonial cells get dissolved and antherozoids liberated. The neck canal cells and the ventral canal cell disorganise. The neck cells/cover cells separate to give a free passage to incoming antherozoids. Fertilization is affected by water medium (**zooidogamous**). The antherozoids are attracted towards the egg by a chemotactic stimulus provided by the degeneration of neck canal cell and ventral canal cell, in the form of malic acid**.**

(10) **Embryogeny :** As a result of fertilization the zygote is formed. It divides into an upper or anterior **epibasal cell** and a lower or posterior **hypobasal cell**. In *Selaginella, Lycopodium* the epibasal cell forms the suspensor and the hypobasal gives rise to embryo proper. By further segmentation a quadrant and then an octant is formed. Usually the epibasal quadrant forms the stem and root and the hypobasal gives rise to foot and root. The young sporophyte of pteridophytes is dependent upon the gametophyte for food which is drawn with the help of its foot. Like bryophytes, the pteridophytes also show heteromorphic alternation of generations.

(11) **Stelar system :** The **stelar theory** was proposed by Van Tiegham and Douliot (1886). Some important types of steles found in pteridophytes are :

(i) **Protostele :** Solid core of xylem surrounded by phloem, pericycle and endodermis. The types of protosteles are :

(a) **Haplostele :** A protostele having a central smooth core of xylem surrounded by phloem, pericycle and endodermis *e.g., Selaginella* sp., *Lygodium*, etc.

(b) **Actinostele :** A protostele having star-shaped xylem core with radiating ribs *e.g., Psilotum, Lycopodium serratum,* etc.

(c) **Plectostele :** A protostele having xylem broken into parallel plates alternating with parallel phloem plates *e.g., Lycopodium clavatum*.

(d) **Mixed protostele :** A protostele having several xylem groups scattered and embedded in phloem *e.g., Lycopodium cernuum.*

(ii) **Siphonostele :** A stele having central pith. It is formed by medullation (or appearance of pith) in the protostele. The types of siphonosteles are :

(a) **Ectophloic siphonostele :** The central pith is surrounded by xylem, phloem, pericycle and endodermis. The phloem occurs only outside the xylem *e.g., Osmunda*.

(b) **Amphiphloic siphonostele :** The ring of xylem is surrounded on both outer and inner sides by phloem, pericycle and endodermis *e.g., Marsilea rhizome, Adiantum pedatum* rhizome.

Modification of siphonostele

(i) **Cladosiphonic siphonostele :** A siphonostele not perforated by leaf gaps *e.g.*, a few species of *Selaginella.*

(ii) **Phyllosiphonic siphonostele :** A siphonostele perforated by leaf gaps – *e.g., Nephrolepis*.

(iii) **Solenostele :** A siphonostele perforated by leaf gaps which are scattered but not overlapping *e.g.*, Ferns.

(iv) **Dictyostele :** A siphonostele perforated by several overlapping leaf gaps. Each separate strand is called **meristele**. *e.g., Dryopteris, Pteridium, Pteris,* etc.

(v) **Polycyclic dictyostele :** A dictyostele consisting of two or more concentric rings of meristeles *e.g., Pteridium aquilinum.*

(vi) **Eustele :** Much dissected siphonostele having vascular strands separated apart by parenchyma *e.g., Equisetum.*

Polysetelic condition : Presence of more than one stele *e.g., Selaginella kraussiana*.

(12) **Heterospory :** The sporophytes reproduce asexually producing spores in sporangia. When all the spores are alike *i.e.,* almost of the same size, the phenomenon is called **homospory**. However, in some pteridophytes, two types of spores are formed which differ significantly in their size as also in function. This phenomenon is called as heterospory. It is seen in pteridophytes like *Selaginella, Isoetes, Stylites, Marsilea, Regnellidium, Pilularia, Azolla, Salvinia* and *Platyzoma*.

It is believed that during the course of evolution, heterothallism was followed by heterospory. Some homosporous ferns *e.g., Equisetum, Ceratopteris* produced two types of gametophyte, thus representing **incepient heterospory.**

(13) **Apogamy :** The terms **apogamy** was coined by de Bary (1878). It is defined as formation of sporophyte from a gametophytic cell other than egg without fertilization. It was first observed by Farlow (1874) in *Pteris cretica*. Thereafter it was observed in several other plants *e.g., Lycopodium, Selaginella, Nephrodium, Lastrea, Marsilea* etc. The apogamy is of two types, **obligate** and **facultative**. If either both of the sex organs are nonfunctional or absent, the apogamy occurring on account of this is said to be obligate. But if a gametophytic cell is induced to form the sporophyte without fertilization, the apogamy is called as facultative or **induced**.

(14) **Apospory :** The formation of gametophyte from a sporophytic cell without meiosis is called as apospory. This phenomenon was first observed by Druery (1884) in *Athyrium filix-femina*. Thereafter it has been established in several pteridophytes. *e.g., Pteridium aquilinum, Asplenium, Trichomanes* etc. Induced apospory was seen in *Pteris* species.

(15) **Parthenogenesis :** Formation of sporophyte from egg without fertilization is called as **parthenogenesis**. Farmer and Digby (1907) observed that in homosporous, leptosporangiate ferns, apospory was always followed by parthenogenesis. This phenomenon has been observed in several species of *Selaginella* and *Marsilea*.

(16) **Affinities of pteridophytes :** The pteridophytes occupy an intermediate place between bryophytes and spermatophytes. They represent affinities with both the groups.

(i) **Similarities with bryophytes**

(a) Both have terrestrial mode of life.

(b) Water is indispensable for the process of fertilization.

(c) Male gametes are flagellated.

(d) The structure and ontogeny of sex organs *i.e.* antheridium and archegonium is based on similar pattern.

(e) Both the groups have definite alternation of sporophytic and gametophytic generations.

(f) Sexual reproduction is of oogamous type. Zygote is retained within the venter of archegonium to form embryo.

(g) Sex organs are surrounded by sterile jacket.

(h) The young sporophyte is partially or wholly dependent on the gametophyte for nourishment.

(ii) **Similarities with spermatophytes**

(a) In both the cases, sporophytic plant body is large, independently existing and dominant phase of life cycle.

(b) The plant body is differentiated into true stem, leaves and roots.

(c) Vascular tissue is present.

(d) Spores are produced inside the sporangia.

(e) Presence of distinct alternation of generations.

(f) Process of photosynthesis is mainly confined to leaves. Stomata are present on the leaves.

(17) **Fossil history of pteridophytes :** The pteridophyta have a long fossil history. Their first traces were identified in the silurian period of paleozoic age (about 400 million years age). Pteridophytes flourished well during devonian, mississipian and pensylvanian periods of late paleozoic age. This period can be well recognised as "**age of pteridophyta**".

(18) **Classification : Eichler** (1883) classified the plant kingdom into **Cryptogamia** and **Phanerogamia**. The Cryptogamia was further divided into Thallophyta, Bryophytes and Pteridophyta. Engler (1909) included Bryophyta and Pteridophyta under **Embryophyta**. Sinnott (1935) introduced the term **Tracheophyta**. A years later Eames (1936) classified Tracheophyta into four groups namely, Psilopsida Lycopsida, Sphenopsida and Pteropsida, and Pteropsida into Filicinae, Gymnospermae and Angiospermae. Smith (1938) classified pteridophytes into four classes namely Psilophytineae, Lycopodineae, Equisetineae and Filicineae. Oswald and Tippo (1942) classified pteridophytes in to four sub-phyla.

(i) Psilopsida

(ii) Lycopsida

(iii) Sphenopsida

(iv) Pteropsida

(19) **Salient features of sub-phyla**

(i) **Sub-phylum : Psilopsida**

(a) These are the oldest known vascular plants, most of them (except *Psilotum* and *Tmesipteris*) are fossils.

(b) Plant body is relatively less differentiated.

(c) Roots are absent, instead dichotomously branched rhizome is present.

(d) Aerial axis is either naked or have small spirally arranged leaves.

(e) Sporangia are cauline (*i.e.*, directly borne on the axis or stem); they are lateral or terminal in position. *e.g., Psilotum, Tmesipteris*.

(ii) **Sub-Phylum : Lycopsida**

(a) Plant body is differentiated into root, stem and leaves.

(b) Leaves small (*i.e.*, microphyllous) with a single unbranched vein.

(c) Sporangia develop in the axil of the sporophylls.

(d) Sporophylls generally form compact strobili. *e.g., Lycopodium, Selaginella,* etc.

(iii) **Sub-Phylum : Sphenopsida**

(a) Stem differentiated into nodes and internodes.

(b) Leaves microphyllous, present in whorls at each node.

(c) Sporangia are borne on the sporangiophores which form compact cones at the apex of the fertile branches. *e.g., Equisetum*.

(iv) **Sub-Phylum : Pteropsida**

(a) Plant body well differentiated into root, stem and leaves.

(b) Leaves megaphyllous, pinnately compound.

(c) Sporangia develop on the ventral surface of the sporophylls, usually aggregated into sori. *e.g., Dryopteris, Pteris, Pteridium, Polypodium,* etc.

(20) **Economic importance**

(i) **Ornamental value :** Many ferns are grown as ornamental plants in gardens for their large, Show and graceful foliage. *e.g.,* species of *Lycopodium, Nephrolepis, Selaginella, Lygodium, Anemia, Cyathea* etc.

(ii) **Medicines :** An anthelmintic drug is obtained from the rhizomes and petioles of the fern *Dryopteris. Lycopodium clavatum* is used in skin diseases. *Equisetum arvense* has diuretic properties.

(iii) **Food :** The sporocarps of *Marsilea* are rich source of starch and used by tribals for their nutritive value.

(iv) **Soil conservation :** Plants like *Selaginella* are useful in soil conservation.

Important Tips

- The term **Pteridophyta** was first introduced by Haeckel in 1866.
- The term **Cryptogams** was coined by Linnaeus (1737) which means plants without seeds.
- **Tracheophytes :** Sinnott (1935) coined the term to include vascular plants (pteridophytes and seed plants).
- The chloroplasts of Selaginella contain pyrenoids.
- Stem of Selaginella kraussiana shows distelic condition.
- Smallest pteridophyte is Azolla whereas the largest is Cyathea/Alsophila (Tree ferns).
- Adiantum is commonly called 'Maiden hair fern'.
- **Elaters :** Elongated structures which help in spore dispersal. They have spiral bands of thickening for xerochasy. Elaters are epispore appendages in **horsetail** Equisetum. Anthoceros has pseudoelaters.
- **Cormophytes :** Plants with distinction of stem, leaves and roots.
- Selaginella lepidophylla and S. pilifera are **xerophytes** and sold in the market as **novelties**.
- Salvinia is root less pteridophyte.
- Adiantum is commonly known as walking fern because it propagates vegetatively by its leaf tips. Some species of Adiantum are **Xerophytes**.
- Meristeles are found in fern rhizomes.
- Selaginella oregana, Lycopodium squarrosum and Asplenium nidus are **epiphytes**.
- Rudimentry seed habit occurs in selaginella.

- Acrostichum aureum is a **halophyte**.
- Marsilea occurs as terrestrial, amphibious as well as aquatic plant.
- Azolla is an aquatic **water fern** used as biofertiliser. The alga – Anabaena fixes atmospheric nitrogen in symbiotic association with Azolla.
- Salvinia is an aquatic pteridophyte **weed**.
- Equietum is commonly known as **Horsetails** or **Scouring rushes**. A few species of Equisetum contain gold.
- Lycopodium is commonly known as club moss.
- In ferns, young leaves are protected by Ramenta.
- Vernation is arrangement of leaves in bud condition.
- Unbranched erect axis is called **caudex**.
- Brown scale are called **ramenta**.
- Selaginella is also Rnown as 'resurrection plants'.
- Stomium is the area on sporangial wall from which spores dehisce.
- Psilophytes (Cooksonia, Rhynia etc.) primitive pteridophytes of Silurian and Devonian period.
- Ophioglossum (Adder's tongue fern) has maximum number of chromosomes (2n = 1242) in plant kingdom.
- The vascular supply given for a leaf from the main stele is called '**leaf trace**'.
- The parenchymatous region left behind in the main stele after the departure of the leaf trace is called '**leaf gap**'.
- The vascular supply given out for a branch from main stele is called '**branch trace**'.
- The parenchymatous region left out in the main vascular sylender due to departure of branch trace is called '**branch gap**'.

4.12 Gymnosperm

(1) **Introduction :** Gymnosperm (Gk. *Gymnos* = naked ; *sperma* = seed) are the plants with exposed or naked seeds or ovules. These plants represent the most ancient group of seed plants. They have been generally placed in the division spermatophyta (seed bearing plants) along with angiosperms. They were not grouped separately as gymnosperms. But *Robert Brown* (1827) separated them from angiosperms and placed under a distinct group due to presence of unprotected ovules in them. The gymnosperm originated much earlier then angiosperms. However, most of the members of this group have now become extinct and only few living forms are known today. The living gymnosperm are generally grouped under four orders (Cycadales, Ginkgoales, Coniferales and Gnetales).

(2) **Distribution :** Plants of Gymnosperms occur throughout the world. The group is presently represented by only 900 living species. Of these, about 500 species belong to 'Conifers' or cone bearing plants. Several species of conifer occur in north-west America and eastern and central China. In India several members are found in Himalayas, *Podocarpus* and *Cupressus* in the central and *Larix, Tsuga,*

Cephalotaxus in the eastern. The Indian species of *Ephedra* are commonly found in Punjab, Rajasthan, Haryana and from Sikkim to Laddak. *Gnetum* sp. occur in Kerala, Assam, Naga hills, Orissa, Sikkim, Burma, Thailand and China. *Welwitschia* is endemic to south-west Africa. *Ginkgo* is native of South China.

(3) **Habit :** Living gymnosperms are mostly perennials, xerophytic, evergreen, arboreal and woody plants. They grow as wood trees, bushy shrubs or rarely as climbers (*e.g.*, Gnetales). None of them are herbs or annuals.

(4) **External features**

(i) The plant body is sporophyte and differentiated into root, stem and leaves.

(ii) The plant possess well developed **tap root system**. In some cases the roots are symbiotically associated with algae (*e.g.*, Coralloid roots of *Cycas*) or with fungi (*e.g.*, Mycorrhizal roots of *Pinus*).

(iii) The stem is erect, aerial, solid, woody and branched (unbranched in Cycadales) but almost tuberous in *Zamia*.

(iv) The leaves may be microphyllous or megaphyllous.

(5) **Gymnospermous wood**

(i) **Manoxylic wood :** Cambial activity is short lived, cortex and pith are broad, parenchymatous rays are broad, wood is soft and commercially useless. *e.g.*, *Cycas*.

(ii) **Pycnoxylic wood :** Cambial activity is long lived, cortex and pith are reduced, parenchymatous rays are few, wood is hard and compact, wood is commercially most important and used as good quality timber. *e.g.*, *Pinus*.

(6) **Reproduction :** Gymnosperms are heterosporous, *i.e.*, produce two different kinds of spores – the male **microspores** and the female **megaspores**. The spores are borne inside the sporangia. The two types of sporangia are borne on special leaf-like structures, called **sporophylls**. The **microsporangia** (pollen sacs) are born on microsporophylls (= stamens) and the **megasporangia** (ovules) are borne on megasporophylls (= carpels).

The sporophylls are usually aggregated in the form of compact structures called **cones** or **strobili**. The cones are generally unisexual, *i.e.*, the male cones are microsporangiate (pollen cones) and the female cones are megasporangiate (seed cones). The male cones are short lived whereas the female cones are long lived. The female cones remain attached on the plants for several years till the maturity or ripening of the seeds.

(7) **Pollination :** The microsporangium (Pollen sac) produces numerous light **pollen grain**. Pollination is anemophilous (wind pollination). The ovules are orthotropous and remain exposed on the megasporophyll. Each ovule surrounded by integuments. It incloses the nucellus and a female gametophyte formed from the haploid megaspore. The female gametophyte contains archegonia. The pollen grains are captured by the pollination drop secreted by the micropyle of the ovule. When it dries, the grains are sucked in the pollen chamber. The pollen grains now germinate. A **pollen tube** is formed

due to elongation of the tube cell. In *Cycas* and *Ginkgo* the pollen tube is haustorial in nature. The lower end of the tube bursts and releases the male gametes which fuse with the egg to form the **zygote**.

(8) **Fertilization :** Fertilization occurs by siphonogamy, *i.e.* the male gametes are carried to the archegonia through pollen tube (except in *Cycas* where pollen tube functions as haustorium and fertilization occurs by zoodiogamy). Fertilization thus takes place in the absence of external water.

(9) **Embryogeny :** The zygote undergoes free-nuclear divisions in *Cycas* followed by wall formation. There are no free-nuclear divisions in *Sequoia* and *Gnetum*. The embryo is soon differentiated into an upper **haustorial**, middle **suspensor** and lower **embryonal** regions. In *Pinus*, on the other hand, the zygote gets differentiated into four tiers of four cells each, designated as open tier, rosette tier, suspensor tier and embryonal tier**. Cleavage polyembryony** is seen in *Pinus*. The embryonal part shows differentiation of radicle, hypocotyl, cotyledons and plumule.

(10) **Seed :** As a result of fertilization the ovule develops into a **seed**. The integument forms the **seed coat**. The outer fleshy layer of the integument forms the **testa** whereas the middle stony layer gives rise to **tegmen**. The nucellus persists as a cap like **perisperm**. In *Taxus* a fleshy **aril** is also present at the base as a cup like structure. The seeds of gymnosperms comprise tissue of three generations namely **parent sporophytic** (integument and nucellus), **gametophytic** (endosperm) and **second sporophytic** (embryo).

(11) **Living fossils :** When a group of plants is represented by a single genus or species while rest of the other representatives of the group have become extinct and fossilized the long surviving individual is called a living fossil *e.g.*, *Ginkgo biloba*. However, *Cycas* is also regarded as a living fossil because most of the cycad species are confined to tropical and subtropical region and the group is becoming endangered. Therefore, cycads have been referred as **reptiles of plant kingdom** or **panda of vegetable kingdom**.

(12) **Classification :** Robert Brown (1827) recognised the gymnosperms as a group distinct from Angiosperms. However, Bentham and Hooker (1862-83) in their 'Genera Plantarum' placed them between Dicotyledonae and Monocotyledonae, Chamberlain (1934) divided gymnosperms into following two sub-classes.

(i) Cycadophyta

(ii) Coniferophyta

(i) **Sub-class I. Cycadophyta :** These are characterised by the presence of **unbranched stem** and **large foliage leaves**. Internally, the stem has large pith and cortex but the wood is relatively small. It includes following 3 orders.

Order 1. Cycadofilicales : It is a group of fossil plants. These plants resembled with ferns, hence they were given the name **Pteridospermae** (*i.e.*, seed bearing ferns). *e.g., Lyginopteris, Medullosa*.

Order 2. Bennettitales or **Cycadeoidales :** It is also a group of fossil forms. These plants resembled with modern cycads. *e.g., Cycadeoidea, Williamsonia*.

Order 3. Cycadales : It includes both living and fossil forms. *e.g., Cycas, Nilssonia, Zamia*.

(ii) **Sub-class II. Coniferophyta :** These are characterised by long **profusely branched stem** and **simple small leaves**. In stem the amount of wood is much more than cortex and pith. It includes following four orders.

Order 1. Cordaitales : All the members of this order are extinct. *e.g. Cordiates, Dadoxylon*.

Order 2. Ginkgoales : All the members of this order, except for *Ginkgo biloba* are extinct. *Ginkgo biloba* is a medium sized tree with branched stem and bilobed leaves. Because of the resemblance of the leaves of this plant with those of *Adiantum* (maiden hair fern), the name **Maiden hair tree** has been given.

Order 3. Coniferals : The order includes both fossils and present day forms. *e.g., Pinus, Cedrus, Sequoia*.

Order 4. Gnetales : Gnetales are modern group consisting of living forms. The order differs from other gymnosperms in the presence of vessels in the xylem. *e.g., Ephedra, Gnetum, Welwitschia*.

(13) **Economic importance**

(i) **Ornamentals :** Some of the gymnosperms are grown in the gardens in different parts of the world *e.g., Cycas revoluta, Ginkgo biloba, Auraucaria cookii, A. bidwilli, Biota orientalis, Cupressus* sp., *Juniperus* sp., *Thuja* sp., *Taxus baccata, Cryptomeria japonica* etc.

(ii) **Wood :** Several plants of this group yield useful timber. The wood of *Cedrus deodara* is used for making railway sleepers. It is also used as a structural timber and making bridges. The wood of *Callitris verrucosa, Pinus roxburghii, P. wallichiana, P. pinaster, P. lambertiana* etc. is used for making furniture. *Juniperus virginiana* wood is used for making pencils. The gymnosperm *Agathis australis* is perhaps the largest timber producing tree of the world. Soft wood of many gymnosperms is used for making toys.

(iii) **Resins :** Several conifers yield resin which is obtained by tapping. By distilling the oleoresin obtained from pines. The resins are of three types namely **hard resins**, **oleoresins** and **gum-resins.** Several hard resins are obtained from living and fossil conifers which are as under :

(a) **Copals :** Kauri copal is obtained from *Agathis australis* and manila copal from *Agathis alba*.

(b) **Amber :** It is obtained from the fossil conifer *Pinites succinifera*.

(c) **Sondarac :** This pale-yellow resin comes from *Callitris quadrivalis* and *Tetraclinis articulata*. The turpentines are oleoresin which are also contributed by conifers. An important source of turpentine is *Pinus australis, P. ponderosa* and *P. caribeae.* Besides, some of the following products of turpentine nature are also obtained from conifers :

- **Canada balsam :** It is obtained from *Abies balsamaea*.
- **Spruce gum :** It is obtained from *Picea rubens*.
- **Bordeaux turpentine :** It is obtained from *Pinus pinaster*.
- **Venetian turpentine :** It is obtained from *Larix decidua*.

(iv) **Essential oils :** They are obtained from several plants. These oils are used mainly in perfumery, soap industry etc. The important oil yielding plants are *Tsuga canadensis, Picea glauca, Abies siberica* and *Cedrus deodera*. The oil obtained from *Juniperus virginiana* (cedar wood oil) is also used in microscopic work.

(v) **Paper industry :** The wood of several gymnosperms, particularly those of conifers is used in paper industry *e.g., Abies pindrow, Picea smithiana, Cryptomeria japonica, Pinus roxburghii, Tsuga canadensis* etc.

(vi) **Edible :** The seeds of *Pinus geradiana* (*chilgosa*) and *P. roxburghii* are edible. Sago is obtained from *Cycas revoluta*. The seeds of *Cycas* sp. are ground and used in the preparation of many edible products.

(vii) **Medicinal use :** Species of *Ephedra* yield an alkaloid called ephedrine. It is used in the preparation of medicines for the treatment of cough, asthma and bronchitis.

Important Tips

- The term gymnosperm was introduced by Theophrastus.
- Cycas ovules are sessile and **orthotropous**. The ovules of C. circinalis are about 6 cm wide whereas those of C. thouarsii are 7 cm wide. They are largest ovules in the plant kingdom.
- The egg of Cycas is largest among all living plants. It is about 1/2 mm in diameter in Cycas circinalis.
- Sperms of Cycas revoluta are largest in the plant kingdom and measure about 200 to 300μ wide. They are top-shaped, multiciliate with spiral band of cilia. (First observed by lkeno, 1896).
- World's **tallest gymnospermous tree** is Sequoia sempervirens, which measures about 368.5 ft. in height (found in Red wood park of California).
- **The largest gymnospermous tree** (in girth) is Sequodendron, which measure about 13-16 meters in diameter. However, Taxodium mucronatum (the big tree of Tule) is not too tall but sometimes measures about 24 meters in diameters.
- **The longest (oldest) gymnospermous tree** (in age) is Pinus longavaea, which is about 4900 years old.
- **The smallest gymnosperms** is Zamia pygmia, which has underground tuberous stem.
- In gymnosperm xylem is generally made up of tracheids (Non-porous) but vessels have been observed in Gnetum, Ephedra and Welwitschia.
- The primitive haplochelic type of stomata are found in Cycas, Pinus, Ginkgo, Ephedra etc.
- The plants of Welwitschia are unique in Gymnosperms.
- The wood formed may be in one ring due to persistent cambium. Such a wood is called as **monoxylic**. e.g., Pinus.
- The wood is formed in more than one ring due to ephimeral nature of cambium. Such a wood is called as **polyxylic**. e.g., Cycas.
- The female cone of Pinus takes three years for complete maturity.

- The pollen grain of Cycas are shed at three celled stage while in Pinus pollen is shed at four celled stage.
- Prothallial cell absent in pollen grains of Welwitschia.
- Dwarfism is seen in many gymnosperms perphaps due to wind velocity. e.g., Picea engelmannaii (15 cm).
- In Pinus, pollen grains are winged.
- All gymnosperms bear unitegmic orthotropous ovules.
- Cycas wood is **mano** and **monoxylic**, where wood of Pinus is **pycnoxylic**.
- In gymnosperm endosperm is haploid and develops before fertilization.
- About two hundred million years ago, the gymnosperms formed the dominant vegetation on the earth.
- The only gymnosperm showing limited growth is Welwitschia (45 cm. tall).
- The ramnent nucellar tissue present within the seed covering of embryo is called **perisperm**.
- Cycas revoluta is commonly called 'sago palm'.
- Pinus gerardiana is commonly called **'chilgoza pine'**.
- Embryo sac of gymnosperm is haploid.
- Monkey's puzzle is a common name of Araucaria embricata.
- In gymnosperm, the arrangement of megaspore tetrad is linear.
- Archegonia are not formed in Gnetum and Welwitschia.
- Neck canal cell absent in archegonia.
- Sulphur shower is due to pollen of Pinus/Cedrus.
- In gymnosperms phloem lacks companian cells.

4.13 Angiosperms

(1) **Introduction :** The angiosperms, or flowering plants, constitute the most dominant and ubiquitous vascular plants of present day flora which changed the green and yellow melancholy of the earth's vegetation by the colourful brightness and fragrance of their flower. The term **angiosperm** means 'enclosed seed' because the ovules or potential seeds are enclosed within a hollow ovary. In this respect they are considered most highly evolved and advanced as compared with the naked seeded gymnosperms.

(2) **Characteristic features**

(i) Angiospermous plants grow in almost every kind of habitats. In the deserts, these plants grow, flower, shed seeds and complete their life cycle in a few weeks of rainy season. Some flowering plants like *Zostera*, occur in shallow seas. A small orchid even lives underground. It survives as a saprophyte on decaying organic matter because of the mycorrhizal association which helps to obtain nourishment. In rain forests, some plants grow on the branches of other plants but do not obtain water or food from them. They are called epiphytes (*e.g., Vanda*).

(ii) The angiospermous leaves show reticulate or parallel venation forming areoles. The libriform fibres are present in the xylem and the companion cells are present in the phloem. The true vessels are present in the xylem of angiosperms.

(iii) The angiosperms produce flowers which normally consist of 4 whorls of appandages – the two outer accessory and reproductive structure such as sepals and petals and the two inner essential parts – stamens and carpels.

(iv) The stamens (microsporophylls) are bilaterally symmetrical. Each stamen consists of a filament and an anther.

(v) The anthers produce tectate pollen grains with exine differentiated into rod-like columellae covered by a tectum.

(vi) In angiosperms, the insects and animals also act as pollinating agents. For this purpose the flowers possess bright and showy petals, edible pollen and nectar.

(vii) The carpels (= megasporophylls) are rolled and partly sterile so that they enclose the ovules within a hollow ovary that is connected with the stigma and style.

(viii) The female gametophyte is highly reduced and consists of single egg cell, two synergids, three antipodals and two polar nuclei. The archegonia are absent.

(ix) The most characteristic feature of angiosperms is double fertilization.

(a) The male gamete fuses with the egg producing diploid zygote that develops into embryo or new sporophyte.

(b) Another male gamete fuses with the polar nuclei (triple fusion) resulting in the formation of triploid endosperm.

(x) After fertilization, the ovules ripens into seeds and ovary ripens into fruits.

(3) **Size**

(i) **The smallest** angiosperm is *Wolffia*. The plant body of *Wolffia* consists of tiny flat oval green stem (phylloclade) having a few small roots. The plants are about 1 *mm* in diameter and found free floating in aquatic habitats like ponds, etc.

(ii) **The tallest** angiosperm is *Eucalyptus*. Their trees may attain a height upto 100 *meters* or more.

(iii) **Banyan** (*Ficus bengalensis*) tree covers a large area. It's slanting aerial branches spread in all directions. The tree spreads with the help of prop or pillar roots.

(4) **Longevity :** Based on the duration of life, the plants are divided into following 4 categories :

(i) **Ephemerals :** This category includes the plants which live only for a few weeks because of a very short growing season. Such plants are found near deserts or in very cold countries. For example, *Arabidopsis* species have a life span of 20–28 days.

(ii) **Annuals :** The plants of this category live and complete their life-cycle in a single favourable season. During this period, they grow in size, produce flowers, shed their seeds, undergo senescence and die. They pass the unfavourable period in the form of seeds. Many crop plants (*e.g.*, wheat, rice, maize, etc.) are annuals. The smallest angiosperm – *Wolffia* is an aquatic annual.

(iii) **Biennials :** The plants of this category complete their life-cycle in two favourable seasons (*i.e.*, in two years). They grow vegetatively in the first season and produce flowers and set seeds in the

next. Often they produce some storage organs, as in the sugar beet, where food is stored in their swollen roots.

(iv) **Perennials :** Plants of this category live for more than two years. Generally they live for many years and bear the flowers and fruits during specific seasons. Some perennials continue their vegetative growth for several years and produce fruits and seeds only once in their life time, *e.g.*, *Agave*, Bamboos, etc. They are called **monocarpic**. Others produce flowers and fruits every year after attaining a definite stage of maturity, *e.g.*, Mango, Lemon, Apple, etc. Such plants are called **polycarpic**.

(5) **Habit :** Depending upon the habit of plants, the angiosperms belong to following categories –

(i) **Herb :** These are small, soft, non-woody plants without persistent parts aboveground. The height of plants usually reaches upto 1 *m*. The plants may be annual (*Brassica*), biennial (Sugar beet) or perennial (*Canna*). The perennial herbs usually possess underground rhizomes which form the new aerial shoots every year. The plants of banana are perennial herbs.

(ii) **Shrubs :** These are woody plants of relatively low height (1-4 *m*). They typically branch at or near the base and do not have a main trunk, *e.g.*, Rose. They are mostly perennial.

(iii) **Trees :** These are perennial woody plants with one main trunk. The trunk may or may not be branched. These are of the following types :

(a) **Caudex :** The stem is unbranched and usually bears a crown of leaves at the apex. *e.g.*, Date-palm.

(b) **Excurrent :** The lower part of stem is thicker which gradually tapers above. Branches arise from the main stem in acropetal succession and plant appears conical *e.g.*, *Pinus*.

(c) **Deliquescent :** The apical bud of the main stem dies after some time and branches and sub-branches spread in different directions. *e.g.*, *Tamarindus*, *Ficus*.

(iv) **Culms :** In these plants, nodes and internodes are extremely clear. Internodes of such plants are usually hollow. These plants are grasses but cannot be considered as herb or shrub or tree. *e.g.*, *Bambusa* (Bans).

(6) **Habitat :** Warming (1895) divided the plants, on the basis of their adaptation to water, into four major groups – hydrophytes, mesophytes, xerophytes and halophytes. A fifth group epiphytes can also be included.

(i) **Hydrophytes :** The plants which grow in aquatic habitats are called hydrophytes. They are further grouped as –

(a) Submerged (*e.g.*, *Hydrilla*)

(b) Attached floating (*e.g.*, *Nymphaea*)

(c) Free-floating (*e.g.*, *Eichhornia*, *Wolffa*)

(d) Amphibious or partly emerged hydrophytes (*e.g.*, *Sagittaria*).

(ii) **Mesophytes :** These are the plants which grow under moderate moisture and temperature conditions. They have no special adaptations to grow either in very dry or in very wet conditions (*e.g.*, Sun flower, *Brassica*). These plants do not possess special adaptations to reduce transpiration.

(iii) **Xerophytes :** The plants which grow in dry or xeric habitats (*i.e.,* under deficient supply to available water) are called xerophytes. These plants face acute shortage of water and therefore, develop morphological, structural and physiological adaptations in order to survive under such habitats. The adaptations in plants are mainly to check the transpiration and survive under acute shortage of water. *e.g., Cynodon* (Doob grass), *Casuarina, Euphorbia tirucalli, Asparagus,* etc.

(iv) **Halophytes :** Halophytes are those plants which grow in saline habitats, *i.e.,* in salt marshes, alkaline soils, river estuaries, saline ponds near seashore or sandy and heavy soils having excess of salts. In such habitats, the water is present in sufficient amount but due to high osmotic concentrations it is physiologically not available to normal plants. Such conditions are said to be physiologically dry. *e.g., Spartina, Atriplex, Portulaca* etc.

(v) **Epiphytes :** These are the plants which grow on other plants for space only. The plants are autotrophic and occur both in aquatic and terrestrial habitats. *e.g., Vanda* (an orchid).

(7) **Modes of nutrition :** On the basis of modes of nutrition plants are classified as follows –

(i) **Autotrophs :** These plants manufacture their organic matter from inorganic matter.

(a) **Photoutotrophs :** These are green coloured due to the presence of chlorophyll. In the presence of light they are capable of synthesizing their food from CO_2 and H_2O. *e.g.,* Mango, Mustard etc.

(b) **Chemoautotrophs :** Those plants which synthesize their food from CO_2 and H_2O by using energy product in the chemical reactions. *e.g.,* Many bacteria.

(ii) **Heterotrophs :** They are either unable to photosynthesize their food or are unable to take their water and minerals directly from the soil or unable to synthesize protein.

They are classified as follows :

(a) Parasites

(b) Saprophytes

(c) Symbionts

(d) Insectivorous plants

A detailed discussion of these group is given in chapter "Plant nutrition".

(8) **Reproduction :** (See in embryology).

(9) **Classification :** The plants of Angiosperms divided into two major groups as – Dicotyledons and Monocotyledons.

(i) **Dicotyledons :** They are show following distinguished characteristics.

(a) Tap roots found in the members of this group.

(b) The leaves in members of these class exihibit reticulate (net like) venation.

(c) The flowers are tetramerous or pentamerous having four or five members in the various floral whorls, respectively.

(d) The vascular bundles arranged in a ring, numbering 2–6, open and with cambium.

(e) The seeds of dicotyledons are with two cotyledons as the name indicate.

(ii) **Monocotyledons :** They are show following distinguished characteristics :

(a) Adventitious roots found in the members of this group.

(b) The leaves are simple with parallel venation.

(c) The flowers are trimerous having three members in each floral whorl.

(d) The vascular bundles scattered in the ground tissue, many in number, closed and without cambium.

(e) The seeds of monocotyledons are with one cotyledons as the name indicate. *e.g.*, Cereals, bamboos, sugarcane, palms, banana, lilies and orchids.

(10) **Economic importance**

(i) **Food :** Flowering plants are the major sources of food. They produce **cereals** such as wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*), barley (*Hordeum vulgare*), oat (*Avena sativa*), etc. **pulses** such as pigeon pea or Arhar (*Cajanus cajan*), gram (*Cicer arietinum*), pea (*Pisum sativum*), Soyabean (*Glycine max*), green gram (*Vigna radiata,* vern. mung), black gram (*Vigna mungo,* vern. urd), etc ; **Vegetables** such as potato (*Solanum tuberosum*), tomato, carrot, cabbage, cauliflower, etc ; **Fruits** such as apple ; mango, grapes, banana, guava, pears, melons, etc. and **nuts** such as cashewnut, walnut, almond, etc.

(ii) **Edible oils :** Flowering plants are the main source of edible oils used for cooking. These are obtained from ground nut (*Arachis hypogea*), mustard (*Brassica campestris*), sunflower (*Helianthus annus*), coconut (*Cocos nucifera*), etc.

(iii) **Spices :** Common spices are obtained from various parts of flowering plants such as coriander (*Coriandrum sativum* vern. dhania), chillies (*Capsicum frutescens*), cinnamon (*Cinnamomum zeylanicum,* vern. dalchini), cloves (*Syzygium aromatica,* vern. laung), cara way (*Carum carvi,* vern. jeera), fennel (*Foeniculum vulgare*, vern. saunf), black pepper (*Piper nigrum,* vern. Kali mirch), etc.

(iv) **Timber :** Many angiospermous tree, particularly dicotyledons, yield valuable **hard wood** which is used as timber. The important timber producing plants are – teak (*Tectona grandis*), sal (*Shorea robusta*), oak (*Quercus alba*), sisso or sisham (*Dalbergia sisso*), sandal wood (*Santalum album*), etc.

(v) **Fibres :** Fibres of different qualities are obtained from various species of flowering plants for *e.g.* :

(a) Textile fibres are obtained from cotton (*Gossypium barbadense, Gossypium herbaceum,* etc.)

(b) Rough fibres are obtained from flax (*Linum usitatissimum*), hemp (*Cannabis sativa*), sunn hemp (*Crotolaria juncea*), etc. These fibres are used for making ropes and gunny bags.

(c) Jute is obtained from *Corchorus* sp.

(d) Husk of unripe coconut (*Cocos nucifera*) is used to obtain coir.

(vi) **Beverages :** Tea (*Camellia sinensis = Thea sinensis*), coffee (*Coffea arabica*) and cocoa (*Theobroma cacao*) are the common beverages obtained from the flowering plants.

(vii) **Medicines :** Our Indian system of medicine (Ayurveda) utilises many flowering plants for the cure of various ailments. Even today a large number of advanced medicines are prepared from these

plants. Some of the important medicinal plants are – *Aconitum napellus* (aconite), *Atropa belladona* (belladona), *Cinchona* sp. (quinine), *Withania somniferum* (asvgandha), etc.

(viii) **Others :** There is a long list of useful articles such as paper, rubber, volatile oils, tobacco, etc., which we get from flowering plants. sugar is obtained from sugarcane (*Saccharum officinarum*) and sugarbeet (*Beta vulgaris*). A large number of plants are grown in the gardens as ornamentals.

Important Tips

- Bamboo or Agave are monocarpic perennial plants.
- A small archid grows underground as a saprophytes.
- Vessels are major water conducting cell in angiosperm.
- Double fertilization is a unique character of angiosperm.
- It is believed that Bodhi tree at Gaya is about 2000 years old.
- **Anthophytes :** Plants with flower/ flowering plants.
- **Marine angiosperm :** Zostera, Thalassia.
- **National tree :** Ficus bengalensis (Banyan).

LIFE HISTORY OF LOWER PLANTS

4.14 RHIZOPUS/MUCOR

Systematic position

Kingdom	–	Plantae
Sub kingdom	–	Thallophyta
Division	–	Mycota
Sub division	–	Eumycotina
Class	–	Zycomycetes
Order	–	Mucorales
Family	–	Mucoraceae
Genus	–	*Rhizopus*
		Mucor

(1) **Habitat :** They are cosmopolitan and saprophytic fungus, living on dead organic matter. *Rhizopus stolonifer* occur very frequently on moist bread, hence commonly called **black bread mold** *Mucor* is called **dung mold**. Both are called **black mold** or **pin mold** because of black coloured pin shead like sporangia. Besides, it appears in the form of white cottony growth on moist fresh organic matter, jams, jellies, cheese, pickles, etc.

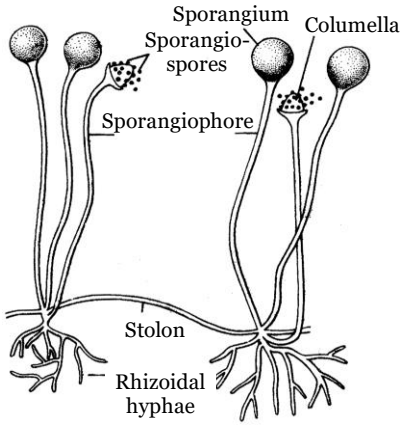


Fig : *Rhizopus* – Habit sketch showing stolon, rhizoidal hyphae and

(2) **Structure :** The vegetative body or thallus consist of well branched, aseptate and multinucleate (coenocytic) mycelium on the surface of substratum. The mycelium is almost white when young but becomes blackish during reproductive phase. The mature mycelium is distinguishable into three types of hyphae :

(i) **Stoloniferous hyphae :** These hyphae grow horizontly on the surface of substratum. They are relatively stout and less branched than other hyphae. Certain portions of the stolons called nodes, give out rhizoids and sporangiophores.

(ii) **Rhizoidal hyphae :** They arise in clusters from the lower side of each node and are repeatedly branched. The rhizoids penetrate the substratum and serve as anchors for the superficial mycelium. These hyphae secrete enzymes like amylase and maltase into the substratum and absorb the digested food.

(iii) **Sporangiophores :** They are erect, aerial, unbranched reproductive hyphae that arise in clusters from the upper side of each node. Each sporangiophores develops single terminal sporangium which is filled with spores.

In *Mucor* there is no such distinction. In *Mucor*, the *hyphae* develop singly. There is no holdfast or apparant node. The hyphal wall is made up of chitin-chitosan and other polysaccharides. Inner to the chitin wall is a thin layer of plasma membrane. The granular protoplasm has many nuclei, glycogen and oil droplets, mitochondria, endoplasmic reticulum and ribosomes.

(3) **Reproduction :** They reproduces by vegetative, asexual and sexual methods.

(i) **Vegetative reproduction :** It takes place by fragmentation. If stolon breaks accidentally into small segments, each part grows into a new mycelium.

(ii) **Asexual reproduction :** It occurs by three types of non-motile mitospores, sporangiospores, chlamydospores and oidia.

(a) **Sporangiospores :** The sporangiospores are also called **aplanospores**. They are thin walled, non-motile, multinucleate spores formed in a sporangium. A vertically growing mycelium acts as sporangiophore. Its tip now shows accumulation of food and nuclei. The tip swells up into a vesicle which gradually enlarges. Soon the protoplasm gets demarkated into an outer dense region having many nuclei and inner vacuolated region having only a few nuclei. A septum now appears separating the **outer sporangium** from the **inner columella**. The protoplasm of the sporangium now shows formation of spores by cleavage which starts from the periphery. The sporangium dehisces irregularly due to collapse of columella and the spores are dispersed. The spores germinate under favourable conditions to form the new mycelium.

(b) **Chlamydospores :** These are the perennating spores formed when the fungus starts facing dry conditions. The protoplasm of hyphae collects at certain places, rounds off accumulates a lot of food materials and develops thick wall to become chlamydospores. They tide over the unfavourable conditions and germinate to produce new mycelia as soon as they get favourable conditions.

(c) **Oidia :** In liquid, sugary and acidic medium the hyphae form small rounded cells called oidia. They multiply by budding like yeast. The budded state is called torula stage. It takes part in alcoholic fermentation. On transfer to a suitable solid medium, each oidium forms a new mycelium.

(iii) **Sexual reproduction :** Sexual reproduction takes place by conjugation between two multinucleate but single celled gametangia. The gametes are isogamous and non-motile.

The species of *Rhizopus* may be **heterothallic** (*R.Stolonifer*) or **homothallic** *(R. sexualis*). But mostly heterothallic in both *Mucor* and *Rhizopus*. In homothallic species sexual union in brought about between two hyphae of the same mycelium whereas in heterothallic species it occurs between two hyphae derives from different compatible strains *i.e.*, positive (+) and negative (–).

In *R. stolonifer* the sexual reproduction occurs between two hyphae of opposite strains. It has been suggested by Burgeff (1924) and Mesland *et al*. (1974), that when two compatible strains approach each other, the following three reactions occur in members of Mucorales :

(a) **Telemorphic reaction :** The hyphae which form the progametangia are called zygophores. In this reaction club shaped zygophores are formed. The zygophore formation is induced by the hormones trisporic acids B and C.

(b) **Zygotropic reaction :** It involves the growth of zygophores from +ve and –ve strains towards each other. The growth of zygophores occurs as a result of some chemotropic response.

(c) **Thigmotropic reaction :** The changes taking place as a result of fusion or contact between the two zygophores, such as gametangial fusion and septation, are controlled by this reaction.

The two mycelial branches growing towards each other are called **progametangia**. Their tips become rich in food and nuclei. They enlarge and come in contact each other. A septum is laid down separating the terminal **gametangium** from the proximal **suspensor**. The gametangium has dense cytoplasm and many nuclei whereas the suspensor has vacuolated cytoplasm with fewer nuclei. Each gametangium behaves as an aplanogamete or coenogamete. The two gametangia fuse with each other. **Plasmogamy** is followed by pairing of nuclei of opposite strains. The unpaired nuclei degenerate. This is followed by **karyogamy**. The **zygospore** so formed develops a dark coloured thick wall and undergoes rest. It is also believed that karyogamy is delayed till the germination of zygospore.

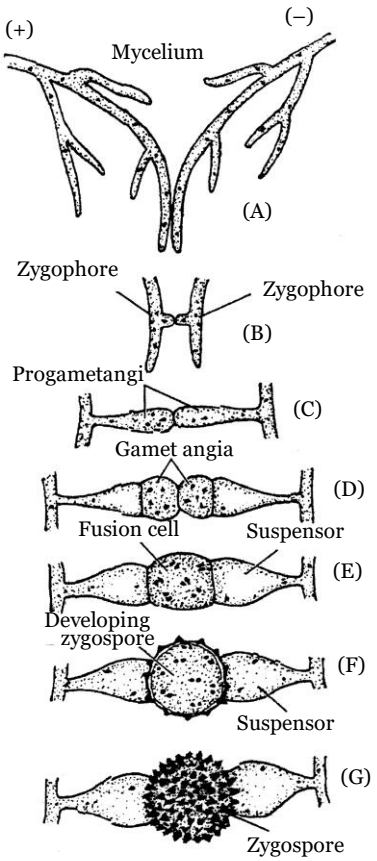


Fig : (A)-(G) Stages in the sexual reproduction upto the formation of zygospore

On the arrival of favourable conditions the zygospore germinate. The outer wall ruptures and the inner protrudes out in the form of promycelium. The promycelium grows vertically upward and forms a terminal **germsporangium**. It is generally believed that meiosis occurs in the germ sporangium. Each diploid nucleus forms four haploid nuclei, of which three degenerate. However, according to Cutter (1942) and Laane (1974), early nuclear divisions in the promycelium are meiotic. The germsporangium shows formation of thin walled spores which are initially uninucleate. Later on, by simple mitotic divisions they become multinucleate. The germsporangium ruptures irregularly releasing the spores which germinate to form a new mycelium. Occasionally, failure of gametangial copulation results in parthenogenous development of zygospores which are called **azygospore** (parthenospores).

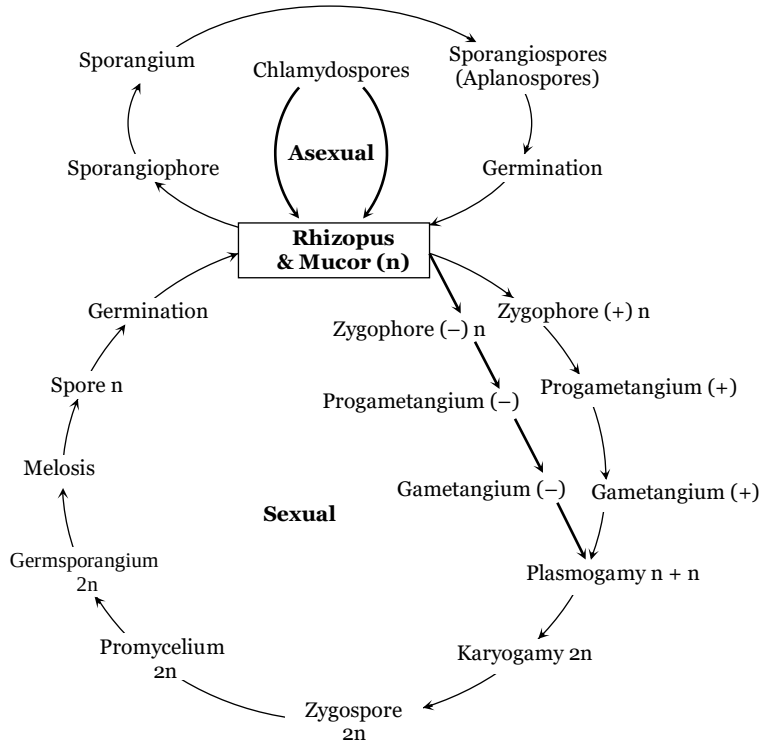


Fig : Graphical representation of life cycle of rhizopus and mucor sp.

(4) **Economic importance**

(i) **Spoilage of food** : Exposed bread and other food particles are spoiled by *Rhizopus* and *Mucor* sp.

(ii) **Soft rot :** *Rhizopus* species attack sweet potato, apple and strawberry producing soft rot or leak disease. Germinating maize grains are also attacked.

(iii) **Mucormycosis** : *Mucor pusillus* and *M. ramosissimus* may attack internal human organs including lungs alimentary canal and nervous system

(iv) **Fermentad foods** : They are prepared from rice and soyabean with the help of *Rhizopus* and *Mucor e.g* Sufru,

(v) **Chemicals** : Citric acid prepared by *Mucor* from molasses, fuimaric acid and cortisone by *Rhizopus stolonifer*, Lactic acid by *R. stolonifer* and *R.nodosus* and alcohol by *R. oryzae* and *M. javanicus*.

(vi) **Antibiotic** : Ramysin is produced by *Mucor ramannianus*.

(vii) **Waste water treatment** : Growth of *Mucor arrhizus* removes heavy metal contamination of water.

4.15 Yeast

Systematic position

Division	–	Mycota
Sub division	–	Eumycotina
Class	–	Ascomycetes
Order	–	Endomycetales

Family – Saccharomycetaceae

Genus – *Saccharomyces* (Yeast)

(1) **Habitat :** Yeast is a saprophytic fungus found on substratum which is rich in sugars *e.g.* sugarcane, juice, fruits (palms, grapes), milk, etc. Some species are found on animal excreta.

(2) **Structure :** Yeast was first described by Antony Von Leeuwenhock in 1680. The yeast plant consists of a single cell which is very small and either spherical or oval in shape. However, under favourable conditions they grow rapidly and form **false mycelium or pseudomycelium**. Individual cells are colourless but the colonies may appear white, red, brown, creamy or yellow. The single cell are about 10 μm in diameter. It is enclosed in a delicate membrane which is not made up of fungal cellulose but is a mixture of two polysaccharides known as mannan and glycogen.

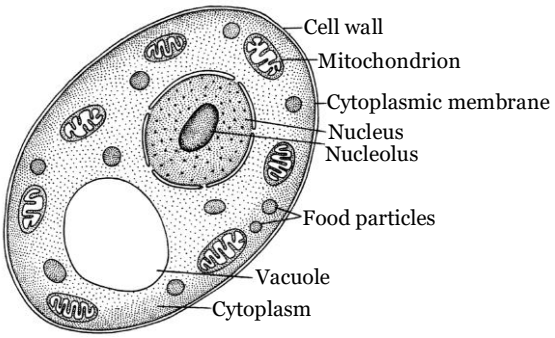


Fig : Electron micrograph of single yeast cell

The cytoplasm in granular in appearance due to the presence of droplets or granules of fat, glycogen and volutin. The volutin is nothing but nucleic acid. The glycogen is the chief reserve food material and its bulk increases during alcoholic fermentation and at times it may form as much as 30% of the weight of the yeast cell.

Yeasts are facultative aerobes *i.e.* they are anaerobes but can also survive under aerobic conditions and respire aerobically as well. The yeast cells secrete extracellular enzyme **zymase** which converts complex sugars into simple soluble sugars that can easily be assimilated.

(3) **Reproduction :** Yeast reproduces by vegetative or asexual and sexual methods.

(i) **Vegetative reproduction :** Yeast reproduce vegetatively either **by fission** or **by budding**

(a) **Budding :** It is the common method of reproduction in budding yeasts (*e.g.*, *Saccharomyces*) under favourable conditions (*i.e.*, when growing in sugar solution). During this process a small bud like out growth appears at one end of the parent cell which gradually enlarges in size (unequal division of cytoplasm takes place) The nucleus enlarges and divides **amitotically** into two daughter nuclei. One daughter nucleus goes into the bud and the other remains in the parent cell. The nuclear membrane persists throughout the nuclear division.

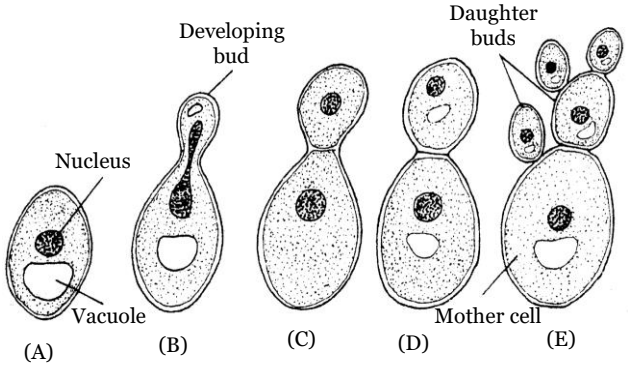


Fig : Budding in yeast

The vacuole almost disappears at this stage. Gradually the bud becomes almost of the same size as the parent cell. Then a constriction appears at the base of bud and a separating wall (made up of chitin) is laid down. Sometimes a bud may produce another bud over it which is still attached to parent cell forming a false mycelium or pseudomycelium.

(b) **Fission :** It is a common method of reproduction in fission yeasts (*e.g.*, *Schizosaccharomyces*). During fission the parent cell elongates and its nucleus divides into two daughter nuclei. The two nuclei separate apart. It is followed by a transverse cytokinesis by formation of a transverse septum which develops centripetally. The two cells separate apart and behave as uninucleate vegetative thalli.

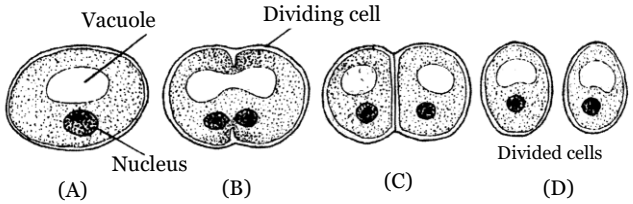


Fig : Fission in yeast

(ii) **Sexual reproduction :** Sexual reproduction in yeasts takes place during unfavourable conditions, particularly when there is less amount of food.

The sex organs are not formed in yeasts and the sexual fusion occurs between the two haploid vegetative cells or two ascospores which behave as gametes. The two fusing gametes are haploid and may be **isogamous** or **anisogamous**. Such kind of sexual reproduction is called **gametic copulation**. It is the best example of **hologamy** *i.e.*, the entire vegetative thallus is transformed into reproductive body. The sexual fusion leads to the formation of diploid zygote. The zygote behaves as an ascus and forms 4 – 8 haploid ascospores. These liberate and function as vegetative cells.

Guilliermond (1940) has recognised three types of life cycle in yeasts.

(a) **Haplobiontic life cycle :** This type of life cycle is common in *Schizosaccharomyces octosporous,* a homothallic species. It's cells are haploid and they multiply by fission. Two haploid cells now act as gametangia and produce tiny protuberances towards one another. They fuse with each other to form a small **conjugation canal** or **copulation tube**. The nuclei of the two gametangia move into the tube and fuse to form a diploid zygotic nucleus. The zygote so formed behaves as ascus mother cell. It undergoes meiosis and then mitosis to form eight haploid nuclei which organise into eight ascospores. The ascus ruptures releasing the ascospores. They enlarge and behave as independent organisms.

(b) **Diplobiontic life cycle** : This type of life cycle is found in *Saccharomyces ludwigii*. The cells of this yeast are diploid and they multiply by budding. Ultimately a diploid cell functions as ascus, forms four ascospores which fuse in pairs. Each zygote grows into sprout mycelium from which vegetative cells develops as buds.

(c) **Haplodiplobiontic life cycle :** This type of cycle is found in *Saccharomyces cerevisiae* in which haploid and diploid both types of generations are found. The haploid nucleus of the ascus

divides in two by mitosis and then followed by meiosis resulting in four small nuclei, the two of which being of (+) strain and the remaining two of the (-) strain. Thus four haploid ascospores are formed. The ascus wall ruptures releasing the four ascospores which start budding and produce new yeast cells. These cell are of (+) and (–) strains and function as gametes. When the two cells of different strains come together they fuse to form large yeast cell. Thus the alternation of generation takes places between the haploid – diploid generations.

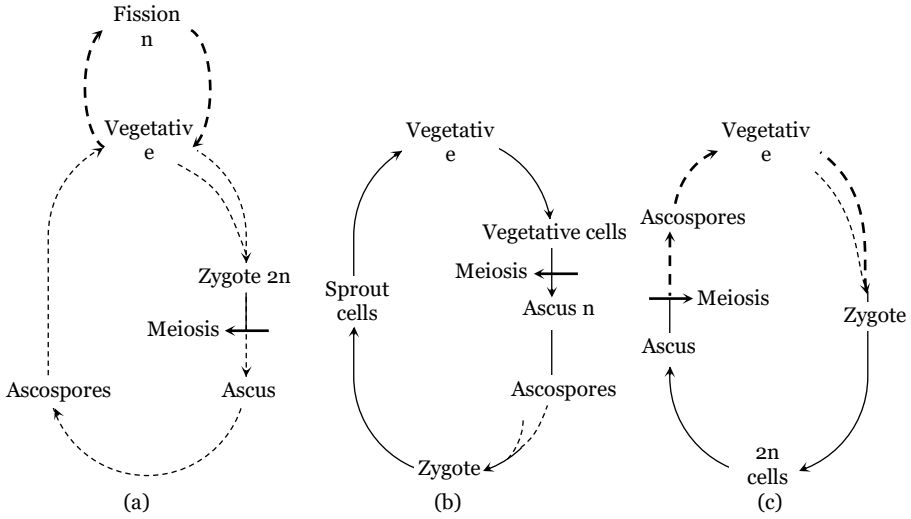


Fig : Yeast graphical representation of life cycles
(A) Haplobiontic, (B) Diplobiontic, (C) Haplodiplobiontic

In addition to above, in *Schizosaccharomyces pombe*, two adjoining sister cells fuse and this phenomenon is called **adelphogamy**. In some yeasts *e.g. Debaryomyces*, the mother and daughter cells fuse to form the zygote and this phenomenon is called pedogamy.

(4) **Economic importance**

(i) **Useful activities**

(a) **Baking industry :** Yeast are used in manufacture of bread. Kneaded flour is mixed with yeast and allowed to ferment. Yeast convert starch into sugars and sugar into CO_2 and alcohol with help of enzyme zymase CO_2 is released when effervescence takes place due to which bread become spongy and gets swollend and is of light weight.

(b) **Brewing industry :** Brewer's/Beer yeast is *Saccharomyces cerevisiae* and wine yeast is *Saccharomyces ellipsoidens*. They perform alcoholic fermentation.

$$\underset{Glucose}{C_6H_{12}O_6} \xrightarrow[Zymase]{Yeast} \underset{ethyl\ alcohol}{C_2H_5OH} + 2CO_2$$

(c) **Food yeast :** Yeast from brewing industry is harvested and used as food yeast. It is rich in protein and B-vitamins (Riboflavin) Special food yeasts are Torulopsis (protein), Endomyces (fat) and Cryptococus (both).

(ii) **Harmful activities**

(a) Fermentation of fruits and fruit juices by yeast cells makes their taste unpleasent.

(b) Parasitic species of yeast like *Nematospora* causes diseases in tomato, cotton and bean.

(c) Parasitic yeast cause diseases in human beings (*e.g.* cryptococcois, blastomycosis and torulosis).

4.16 ALBUGO

Systematic position

Kingdom	–	Plantae
Sub kingdom	–	Thallophyta
Division	–	Mycota
Subdivision	–	Eumycotina
Class	–	Oomycetes
Order	–	Peronosporales
Family	–	Albuginaceae
Genus	–	*Albugo*

(1) **Habitat :** *Albugo* is an **obligate parasite** and grows in the intercellular spaces of host tissues. It is parasitic mainly on the members of families Cruciferae, Compositae, Amarantaceae and Convolvulaceae, The disease caused by this fungus is known as **white rust or white blisters** which is prevalent all over the world. The fungus forms shiny white patches on the leaves, mostly on their lower surfaces, stems and petioles. The fungus also causes hypertrophy and deformation in affected parts.

The most common and well known species is *Albugo candida* which attacks the members of the mustard family (Cruciferae). It is commonly found on **Capsella bursa – pastoris** (Shepherd's purse) and occasionally on radish mustard, cabbage, cauliflower, etc. The reserve food is oil and glycogen.

(2) **Structure :** The plant body of the fungus is mycelial and eucarpic. The mycelium is intercellular, branched, aseptate and **multinucleate** (coenocytic). The mycelium produces finger like or globular **haustoria** which enter into the host cells to absorb the food material. The mycelial wall is made up of **cellulose-glucan**. The cells show characteristic fungal eukaryotic organization. The parietal layer of cytoplasm also contains oil globules.

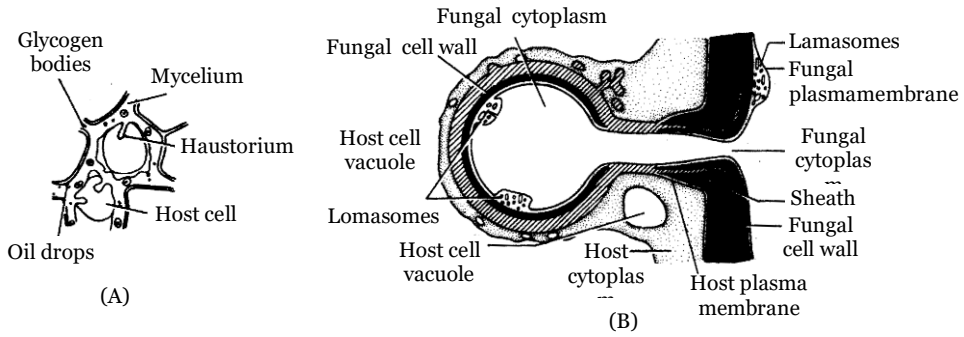


Fig : *Albugo* – (A) Intercellular mycelium with knob like haustoria, (B) Ultra structure of haustorium (diagrammatic)

(3) **Reproduction :** The fungus *Albugo* reproduces asexually as well as sexually.

(i) **Asexual reproduction :** Asexual reproduction take place by the formation of **sporangia** or **conidia**. The fungal mycelium collects below the host epidermis and forms **sporangiophores** (conidiophores). These are club-shaped and multinucleate. The sporangiophores cut sporangia in basipetal manner, that is, the oldest and first formed are at the top and the youngest and last formed are at the base. The sporangia remain attached in the form of chains .The walls between the sporangia fuse to form a gelatinous disc-like structure called **disjunctor**. Due to formation of numerous sporangia, the epidermis of the host is raised in the form of a **postule**.

Finally the disjunctors are dissolved in water and sporangia are set free. They appear as white powdery mass on the host tissue. These smooth, rounded structures are disseminated by wind. Germination of sporangia occurs when they reach a suitable host. The mode of germination depends on the availability of water or even moist air.

- If water is available sporangia forms About 4 – 12 (usually eight) zoospores within two minutes of their formation. The zoospores are kidney shaped and laterally biflagellate (unequal). The zoospores move into a vesicle before they are released. After a swimming period, the zoospores come to rest, encyst and germinate by germ tubes. The germ tubes enter into the host and produce an intercellular mycelium.
- If water is not available, the sporangia germinate directly by forming germ tubes.

(ii) **Sexual reproduction :** The sexual reproduction is **oogamous type** and takes place with the help of **antheridia** and **oogonia**. The antheridia and oogonia are multinucleate in the beginning but become uninucleate by disorganization of nucleri. the antheridia are club- shaped and the oogonia are globular. Both sex organs develop terminally on the hyphae. There is a single egg (oosphere) surrounded by periplasm. At the time of fertilization, a **receptive papilla** develops on one side of the oogonium through which the fertilization tube enters into the oogonium. Inside the oogonium the male nucleus fuses with the egg nucleus. The diploid zygote develops a warty wall and becomes the **oospore**. The diploid nucleus undergoes meiosis, followed by several mitotic divisions. After a period of rest, the oospore germinates and produces reniform, biflagellate zoospores. The zoopores are first released into a vesicle and then to the outside. They swim for some time, encyst and then germinate to form germ tubes. Most part of the life cycle of *Albugo* is **gametophytic**. The sporophytic phase is limited only to the oospore stage.

According to Sansome and Sansome (1974), the species *A. candida* is heterothallic and meiosis occurs inside the gametangia (antheridia and oogonia) and not in the oospore. Thus the vegetative mycelium of *Albugo* is **diploid**.

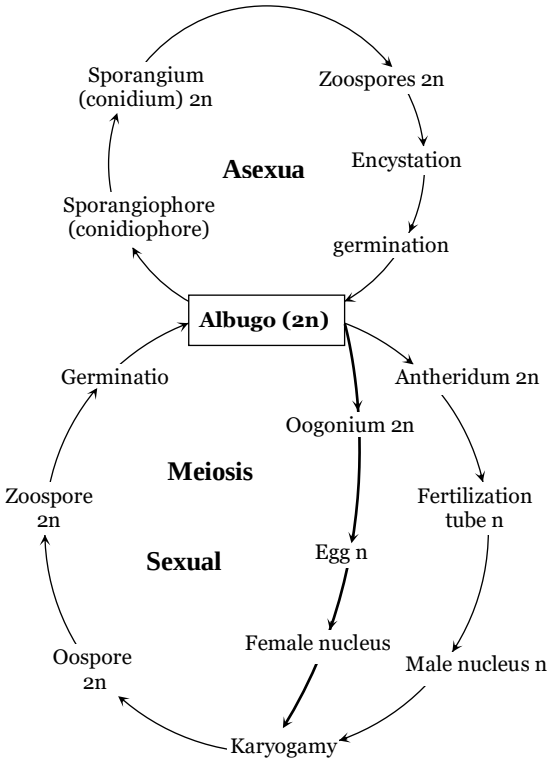


Fig : Graphical representation ofl ife cycle of rhizopus and mucor sp.

4.17 LICHEN

A lichen is structurally organised entity consisting of the permanent association of a fungus and an alga. The fungal component of a lichen is called **mycobiont** (mostly ascomycetes) and the algal component is called phycobiont (mostly blue green alga). Both mycobiont and phycobiont are associated in **symbiotic** union in which the fungus is more predominant and alga is subordinate partner. The fungus provides the structural covering that protects alga from unfavourable conditions, *i.e.*, drought, heat etc. It also traps moisture from the atmosphere and anchors the lichens to a rock, tree bark, leaves and other similar supports. The alga prepares organic food (*e.g.*, mannitol) by the process of photosynthesis from carbon dioxide. If the algal component is a cyanobacterium (blue green alga), it fixes atmospheric nitrogen in addition to preparation of food. The relationship between the two is that of consortium, symbiosis or mutualism. Ahmadjian (1963) considers fungus to be a controlled parasite. The phenomenon is called **helotism**.

(1) **Habitat :** Lichens are cosmopolitan in distribution.Their growth is very slow. Some lichens growing in arctic regions are believed to be 4500 year old. The lichens which grow on stones are called **saxcoles** (e.g., *Dermatocarpon*) and those growing on barks are called **corticoles** (*e.g., Usnea*). A few liches are aquatic (*e.g., Peltigera, Verrucaria margacea*). The lichens generally do not grow near smoky industrial areas where atmosphere is polluted. *Cladonia rangiferina*, commonly known as **reindeer-moss** grows luxuriantly in tundra region and form the food of animals like the reindeer and caribou (musk ox). Some of the common Indian genera are: *Cladonia*, *Parmelia*, *Usnea*, *Physcia*, *Anaptychia*, *Lecidia*, etc. Lichens are highly pigmented. They may be bluish, green, grey, yellow, orange, red and brown in colour. Some are white (*Gyrophora*).

(2) **Classification :** Hole (1967) divided lichens into 3 classes :

(i) **Ascolichen** : When fungal partner belongs to ascomycetes. Most lichens are ascolichens. Ascolichens are further divided into :

(a) **Gymnocarpeae :** Fruiting body is apothecium

(b) **Pyrenocarpeae :** Fruiting body is perithecium.

(ii) **Basidiolichen :** When the fungal partner belongs to basidiomycetes.

(iii) **Lichen Imperfecti** : When the fungal component belongs to fungi imperfecti.

(3) **Structure**

(i) **External structure :** The lichens vary in their size and shape. However, sthree main types are recognised on the basis of their habit, growth, form and mode of occurrence.

(a) **Crustose or Crustaceous lichens :** These lichens occur as crust over rocks, soil or tree barks, *e.g., Graphis, Haematomma.*

(b) **Foliose or Foliaceous lichens (Leafy lichens) :** They are leaf like lobed structure which attached to substratum by rhizoid like organs, *e.g., Parmelia,, Paltigera.*

(c) **Fructicose or Filamentous lichens :** They are branched shrubby lichens but small base *e.g., Cladonia, Usnea*.

(ii) **Internal structure :** The bulk portion of lichen thallus is formed by fungal partner. The alga constitutes about 5% of the lichen body. Internally the lichens are of two types

(a) **Homoiomerous Thalli :** Algal cells and fungal hyphae are uniformly dispersed throughout the thallus, *e.g., Collema*.

(b) **Heteromerous thalli :** The algal cells are restricted to algal zone only. In these forms fungal component is dominant. Usually the heteromerous thalli show 4 distinct zones.

Upper cortex : Formed by compactly interwoven hyphae either without interspaces between them or interspaces filled with gelatinous substances. A cuticle like layer is present on the surface. In some species *e.g., Parmelia* breathing pores are present.

Algal layer : Present just below the upper cortex forming **photosynthetic zone** of the thallus. This layer is also called **gonidial layer**.

Medulla : Occurs nearly in the middle of the thallus beneath the algal layer the hyphae are loosely interwoven in this layer.

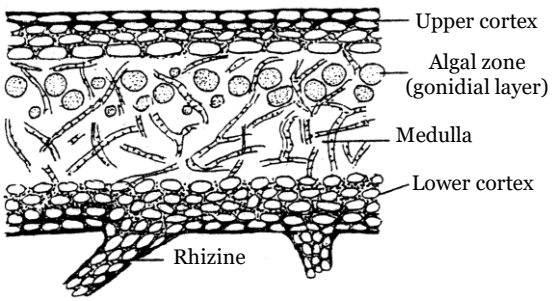


Fig : Transverse section of a foliose lichen

Lower cortex : Comprising of closely packed dark coloured hyphae Rhizoids arise from this layer.

(4) **Special structures and propagules :** The following specialized structures and propagules are associated with lichen thalli :

(i) **Breathing pores :** The upper surface of some lichens, particularly the foliose lichens is provided with pores. Here the fungal hyphae are loosely arranged. They help in aeration.

(ii) **Cyphellae :** These are small, almost circular depressions present on the lower side of the thallus. The medullary hypae are not exposed through these depressions due to the presence of corticating hyphae. They are meant for exchange of gases *e.g., Sticta*. Similar structures without any cortical border are called **pseudocyphellae.**

(iii) **Cephalodia :** These are gall like outgrowths present on the upper surface of the thallus. They are distinguishable into cortex and medulla with similar fungal but different algal components from that of the main thallus. Lichens having two algal and one fungal partner are called **diphycophilous**. The cephaloida are meant for retaining moisture *e.g, Peltigera.*

(iv) **Isidia :** These are coral like, simple or branched outgrowths present on the upper surface of the thallus. They have the same algae and fungal component as that of the main thallus. They help in photosynthesis as also in vegetative propogation *e.g., Parmelia, Peltigera*.

(v) **Soredia :** It is a powdery mass comprising both algal and fungal components formed in a postule like structure called **soralium**. The soralia arise from the algal zone lying just below the upper cortex *e.g., Physia, Parmelia*.

(5) **Reproduction :** Lichens reproduce both by asexual and sexual methods.

(i) **Asexual reproduction**

(a) **Fragmentation :** The main thallus breaks into small pieces which grow as independent thalli.

(b) **Rejuvination :** Plants like *Cladonia* show this unique phenomenon. It becomes young again. The older parts of the thallus die whereas the young branches continue to grow.

(c) **Isidia :** These are small superficial outgrowths on the surface of lichen thallus. They enclose the same alga as present in the thallus and covered by continuous cortex. Their function is to increase the photosynthesis by increasing the surface area. They get detached from the thallus, disseminate by wind and grow into new thalli.

(d) **Soredia :** This is a powdery mass formed in a postule like structure called soralium. Each soredium forms a new thallus under favourable conditions.

(e) **Conidia :** In serveral lichens the fungal component forms conidia on conidiophores. They form new fungal mycelium which with suitable algal component form the lichen.

(f) **Pycniospores :** The conidia formed in a flask shaped structures lying embedded in the thallus (pycnidia) are called as pycniospores. The pycniospores form new fungal mycelium which consitute the lichen on coming in contact with suitable algal component.

(ii) **Sexual reproduction :** Sexual reproduction in lichen is performed only or mainly by its fungal component. So, the structure of the reproductive organs is dependent upon the type of their fungal partner.

The ascolichens reproduce sexually by forming sex organs. The female sex organ is called **ascogonium** and the male, **pycnidium**. The ascogonium is a multicelled structure coiled in its basal region. The terminal region is some what eract and called **trichogyne**. The ascogonium remains embedded in the thallus. The pycnidia acting as male sex organs are called **spermogonia**. They are pitcher shaped structures that lie embedded in the thallus. The conidia formed in the spermogonia act as **spermatia**. Some sterile hyphae also emerge out of the ostiole. The spermatia are colourless tiny structures of varying shapes, they are disseminated by wind. Finally, they attach themselves to the sticky tip of the trichogyne. This is followed by plasmogamy and migration of the male nucleus to the female structure. **Ascogenous hyphae** now develop from the fertilized cell of ascogonium. The **asci** develop by crozier formation and karyogamy occurs inside the ascus mother cell. This is followed by meiosis and mitosis resulting in the formation of eight ascospores inside the ascus. Simultaneously, the surrounding hyphae also develop and as a result fruiting body called **ascocarp** or **ascomata** is formed. The ascocarp may be an **apothecium** or **perithecium**.

Accordingly, the ascolichens are divided into two groups namely **gymnocarpae** and **pyrenocarpae** respectively. While the apothecia are cup- shaped structures *e.g., Physcia*, the perithecia are pitcher shaped *e.g., Acrocordia*. The fruiting body is internally distinguishable into three zones.

(a) **Thecium** : It is the fertile zone comprising fertile asci and sterile paraphyses.

(b) **Epithecium :** It is the zone formed by the tips of paraphyses projecting beyond the asci.

(c) **Hypothecium** : It is the zone formed by loosely packed hyphae lying below the thecium.

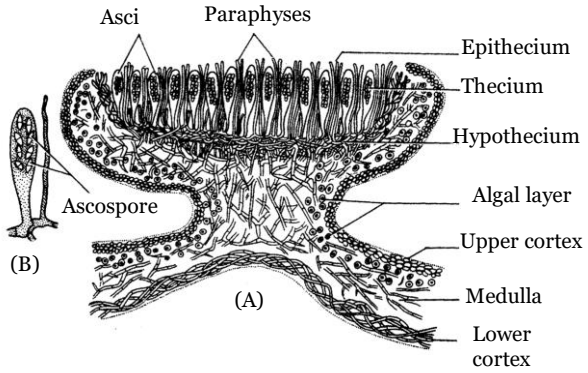


Fig : V.S. of lichen thallus through apothecia, (A) Lecanorine type, (B) Lecideine type

An apothecium has two types of margins, proper and thalline. The proper margin is formed by fungal hyphae only whereas the thalline margin includes the algal component also. Accordingly, we differentiate two types of apothecia.

(a) **Lecideine type** : They have only the proper margin *e.g., Lecidea.*

(b) **Lecanorine type** :They have both proper as well as thalline margin *e.g., Lecanora.*

The sterile tissue lying in between the asci is sometimes called **hamathecium**. The asci dehisce releasing the ascospores. The ascospores germinate to form the fungal hyphae. On coming in contact with the suitable algal component, they constitute the lichen.

(6) **Economic importance**

(i) **Pioneer of vegetation** : Lichens are considered as pioneers in initiating a plant succession on rocks. These are the first plant group which play an important role in the formation of the soil. So

lichens are called as **formers of nature** or **soil builders**. Crustose being the first followed by foliose and finally fructicose lichens.

(ii) **Food and Fodder :** Reindeer moss (*Cladonia rangiferina*) of the arctic region is the used as food for reindeer and cattle. Iceland moss (*Cetraria icelandica*) is ground up and mixed with wheat and made into cakes in Iceland. Rock tripe (*Umbillicaria*) has been eaten by travellers when they face starvation in actic regions. *Evernia* is used by Egyptians for making bread and *Umbilicaria esculenta* is regarded as a delicacy in Japan. Species of *Parmelia* are used as curry powder in India.

(iii) **Medicinal uses :** Dog lichen (*Peltigera canina*) was used as medicine for hydrophobia in ancient days and Lungwort (*Lobaria pulmonoria*) was used for the diseases of lungs. Usnic acid obtained from *Usnea* (old man's beard) and *Cladonia* sp. is used as broad spectrum antibiotic. It is effective against gram positive bacteria. *Lobaria pulmonaria, Cetraria icelandica* are used in respirotory diseases particularly T.B., *Roccella montagnei* in angina, *Peltigera canina* in hydrophobia, *Parmelia sexatilis* in eipilepsy and *Usnea barbata* in urinary troubles.

(iv) **In perfumery :** *Ramalina* and *Evernia*, having sweet scented thalli, are used in the preparation of **Dhup**, **Havan Samagri** and **soap**. Perfumes are extracted from *Evernia prunastri* and *Lobaria pulmonaria*.

(v) **In tanning and dying** : Lichens like *Cetraria icelandica* and *Labaria pulmonaria* are used in tanning. A red dye is obtained from *Ochrolechia* sp. whereas *Parmelia* sp. yield a brown dye. *Litmus* used as acid-base indicator is obtained from *Roccella montagnei* and *Lasallia pustulata*. An **orchill** dye is obtained from *Roccella* and *Leconara* which is purified as orcein and used as a biological stain.

(vi) **In brewing and distilling** : The lichens contain carbohydrates in the form of **lichenin**. *Cetraria islandica* and *Cladonia rangiferina* (yield upto 66% of the polysaccharides) are used to obtain alcohol in Sweden and Russia.

(vii) **Indicators of air pollution** : Lichens are very sensitive to SO_2 and grow only in SO_2 free atmosphere. So lichens like *Usnea* are used as indicators of air SO_2 pollution.

(viii) **As poison** : Some lichens are poisonous also such as *Letharia vulpina* due to **vulpinic acid**, *Cetraria juniperina* due to **pinastrinic acid**, *Parmelia molliuscula* due to **selenium**, *Xanthoria parietina* due to **beryllium** and *Everina furfuracea* due to **chlorine**.

(ix) **Other uses :** Some lichen yield important chemicals *e.g.,* salazinic acid (*Ramalina siliquosa*), **Lecanoric acid** (*Parmelia subrudecta*) and **squamatic acid** (*Cladonia crispata*) etc. In hot season, *Usnea* gets dry and becomes highly inflamable. It easily catches fire and causes forest fires.

4.18 Mycorrhizae

The term 'mycorrhizae' was coined by Frank (1885) It is an association between a fungus and the root of a higher plant *e.g.* Pine, Birch, Eucalyptus, Ficus etc. The actively growing roots of higher plants get infected by fungi. As a result, the roots are modified (*i.e.*, become tuberous, nodulated,

coralloid, etc.) to accommodate fungi. The root cells and fungi directly transmit nutrient substances to each other. Mycorrhiza is a example of **symbiosis** or **mutualism**.

(1) **Types of mycorrhizae :** Mycorrhizae are classified into three categories :

(i) **Ectotrophic mycorrhiza :** It occurs only in about 3% of plant species, majority of which are forest trees, viz. pines, sprues, firs, oaks, beeches, birches, eucalyptus etc. The fungus partner is commonly a basidomycetes. In this type of mycorrhizae, the fungus completely encloses the rootlet in a sheath or mantle of tissue formed of compact hyphal cells and penetrates only between the cells of root cortex. The ectomycorrhizal fungus cannot exist saprotrophically in nature without a plant host association. Such roots are devoid of root hair, root cap and may become unforked, bifurcate, nodular or coralloid.

(ii) **Endotrophic mycorrihiza :** In this kind of mycorrhizae the fungus does not form an external mantle but lines within the root. The ectomycorrhizae are further divided into three groups :

(a) **Ericaceous mycorrhizae :** The fungus forms dense intracellular coils in the outer cortical cells.

(b) **Orchidaceous mycorrhizae :** These are associated with orchid roots. The fungus forms association from the time when the orchid seeds germinate.

(c) **Vesicular-arbuscular mycorrhizae (VAM) :** The fungi of this group mostly belong to zygomycetes. This type is significant in agriculture because it occurs in a large number of crop plants. The fungal hyphae develop some special organs, called **vesicles** and **arbuscules**, within the root cortical cells.

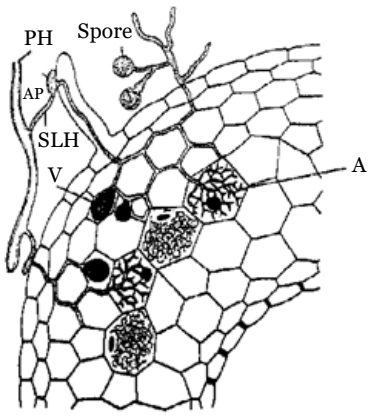


Fig : T.S. of a vesicular-asbuscular mycorrihza (A Asbuscules, Ap. appresorium, Ph. permanent hyphae, SLH. short-lined hyphas V. Vesicle)

(iii) **Ectoendotrophic mycorrhiza :** This type of mycorrhiza sharing characteristics of both ecto and endotrophic mycorrhizas. The fungus forms a hyphal mantle and **Hartig net** as do the ectotrophic mycorrhiza and also establish haustoria and hyphae coils in the epidermal and cortical cells, like the ectorophic mycorrhizas. The external hyphae deliver organic compounds absorbed from the humus to the root cells. One of the best studied examples of ectoendotrophic mycorrhizas is the mycorrhiza of *Monotrapa indica*, the **Indian pipe**.

(2) **Advantages of mycorrhizal association**

(i) Since all fungi are dependent on some kind of foreign organic matter for their survival, the mycorrhizal fungi obtain their nutrient requirement (primarily simple carbohydrates) from the host plant without damaging the function of root tissues,

(ii) The fungal hyphae increase a plant's uptake of certain nutrients from the soil, particularly phosphorus, copper, zinc, nitrogen and potassium.

(iii) The mycorrhizal hyphae permeate the soil and help the absorption of water by host more efficiently,

(iv) The mycorrhizal plants need less fertilizer and can even grow better on the infertile soils. They withstand high doses of heavy metals and acid rain pollution.

(v) The fungi produce various growth promoting substances which help the plants to grow better.

(vi) Due to mycorrhizal association, the higher plants develop resistance to soil borne diseases (due to phytolaxins released by fungi), drought resistance and tolerate salinity, *pH* and temperature extreams.

4.19 Spirogyra

Systematic position

Kingdom	–	Plantae
Subkingdom	–	Thallophyta
Division	–	Algae
Class	–	Chlorophyceae
Order	–	Conjugales (zygnematales)
Family	–	Zygnemaceae
Genus	–	*Spirogyra*

(1) **Habitat :** It is an **unbranched filamentous** green alga of stagnant fresh waters which forms floating masses (supported by bubbles of gases of oxygen) called **pond scum**. A sheath of muscilage occurs on the outside. It gives a silky touch. Hence *Spirogyra* is also called **water silk** or **mermaid's tresses**.

(2) **Structure :** The thallus is an unbranched and uniseriate filament where cells are arranged in a single row. All the cells of a filament are similar. In some species hold fast is present (*e.g., S. fluviatilis*). The cells are elongated and cylindrical. The cell wall is two layered the outer is of pectic substance and the inner of cellulose. The outer part (pectin) dissolves in water to form a muscilaginous sheath. Due to this reason *Spirogyra* filament's are slippery. Transverse or septum can be plane, colligate (with H-shaped piece), **replicate** (ring like ingrowths) and unduliseptate (undulate). The filaments are covered by a layer of mucilage. Each cell of a filament consists of a small amount of protoplast bounded by the cell wall. The protoplast is differentiated into plasma membrane, thin layer of cytoplasm, single nucleus, one (*e.g. S.sahnii* and *S. venkataramanni*) or many (16 in *S.rectispora*) ribbon (spiral) shaped chloroplasts (wavy margin) with pyrenoids and a large central vacuole. Nucleus occurs inside the central vacuole where it is suspended by means of cytoplasmic strands.

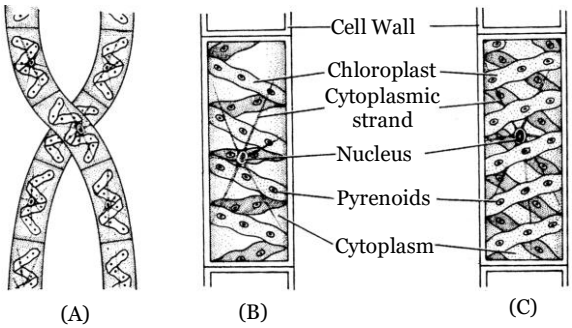


Fig : Spirogyra (A) Two Filaments
(B) and (C) Detaeled structure of a cell

(3) **Reproduction :** *Spirogyra* reproduces by vegetative, asexual and sexual methods.

(i) **Vegetative reproduction :** It takes place by fragmentation of filament. Later on, each segment gives rise to new plant.

(ii) **Asexual reproduction :** Normally asexual reproduction is absent in *Spirogyra*. It occurs only occasionally by the formation of akinetes, aplanospores and azygospores (Parthenospores).

(a) **Akinetes :** Under unfavourable conditions, the cells of the filament develop into thick walled structures, which are known as akinetes. On the onset of favourable conditions, these give rise to new plants. Their wall is made up of cellulose and pectin *e.g., S. farlowi*.

(b) **Aplanospores :** These are formed as a result of contraction of protoplasm and formation of new cellulose wall around it. These nonmotile aplanospores are either round or oval. These later on under favourable condition they give rise to the new individuals. Aplanospores are known to occur in *S. aplanospora, S. articulate* etc.

(c) **Azygospores or parthenospores :** If there is sudden change in the environment, the gametes fail to fuse and each functions as parthenospore. Since the structure of parthenospore is similar to the zygospores produced after sexual reproduction, it is also known as azygospore.

(iii) **Sexual reproduction :** The sexual reproduction in *Spirogyra* is called **conjugation**, It involves the fusion of two morphologically identical, but physiologically dissimilar gametes.

The conjugation is of two types: lateral and scalariform

(a) **Scalariform conjugation :** This is the most common and advanced type of conjugation. It involves two filaments of *Spirogyra* and takes place between two recently formed cells. The participating filaments come closer. The cells of one filament show the formation of **papilla** towards the other filament. It stimulates the formation of similar papilla in cells lying opposite to them. The two papillae fuse by enzymatic dissolution of the wall thus forming a **conjugation canal**.

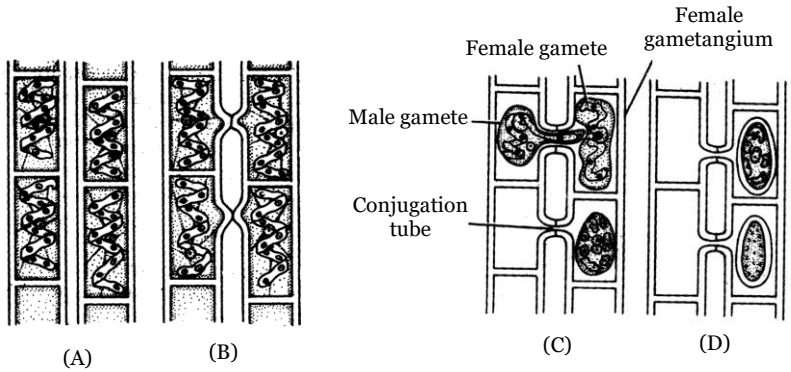


Fig : (A)-(D) Sexual reproduction showing scalariform conjugation in Spirogyra

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. In the beginning, zygospore is greenish but simultaneously chloroplasts of male and female gametes disappear due to which zygospore does not remain green.

The zygospore is differentiated into three layers, the outer **exospore** which is thin, the middle **mesospore** which is a thick layer of cellulose, chitinized and pale yellow to brown in colour, and inner **endospore** which is thin and cellulose in nature.

(b) **Lateral conjugation :** It takes place between two nearest cells of the same filament (homothallic). Both male and female gametes are found in same filament. It is of two types.

Indirect lateral conjugation : Two outgrowths appear on both sides of a transverse septum of two adjacent cells which later on form a conjugation tube. Of the two cells, one behaves as male gametangium from which gamete passes through the tube into female gametangium. By fusion, zygospore is formed. Thus in each second cell of a filament zygospore is formed. It is commonly seen in *S. affinis* and *S. tenuissima*.

Direct lateral conjugation : In this type of conjugation, the male gamete after passing through an aperture in the transverse septum of adjoining gametangium enters the female gametangium and fuses to form a **zygospore**. The two gametes, though morphologically alike but differ in their behaviour. Hence this type of sexual reproduction corresponds to physiologically anisogamy. It is commonly seen in *S. jogensis.*

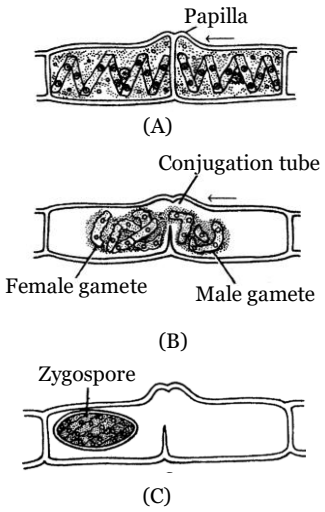


Fig : Sexual reproduction showing lateral (indirect) conjugation in spirogyra

(iv) **Germination of zygospores :** The zygospores on the arrival of favourable conditions germinate. The nucleus undergoes meiosis to form four haploid nuclei (tetra nucleate). Of these three nuclei degenerate and one functions. The exo and mesospores rupture and the endospore protudes out in the form of germling. The new cell undergoes transverse division continuously to form a new filament. Thus in the life cycle of *Spirogyra*, there **is no flagellate phase**.

Life cycle in *Spirogyra* is haplontic as dominant phase in life cycle is haploid (*n*) and diploid phase is represented by only zygospore and it undergose R.D. or meiosis (zygotic meiosis).

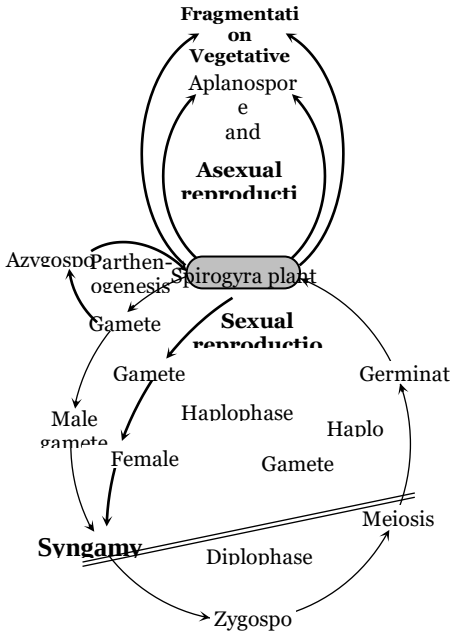


Fig : Graphical representation of the

4.20 ULOTHRIX

Systematic position

Kingdom	–	Plantae
Subkingdom	–	Thallophyta
Division	–	Algae
Class	–	Chlorophyceae
Order	–	Ulotrichales
Family	–	Ulotrichaceae
Genus	–	*Ulothrix*

(1) **Habitat :** It is a green filamentous algae found in running fresh water. *Ulothrix* comprises about 30 species. The common species *U. zonata* occurs in cold water whereas *U. flacca* is marine. *U. implexa* occurs in esturies (where river meats the sea) as **lithophytes**. It is an autotrophic alga and the reserve food is **starch**.

(2) **Structure :** An unbranched filament, consisting of numerous cylindrical cells joined end to end. The filaments remain attached to some substratum by means of rhizoidal cell, *i.e.* showing distinction in base and apex. The basal cell is elongated and colourless known as holdfast while the uppermost cell is rounded. Every green cell is squarish or rectangular and consists of cell wall sorrounding the protoplast.

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. In the centre of the cell is a nucleus and a girdle or ring shaped (*U. zonata*) or collar shaped chloroplast. One (*U. rorida*) or more pyrenoids are present in the chloroplast. A vacuole is present, surrounding it is a thin layer of cytoplasm (primordial utricle).

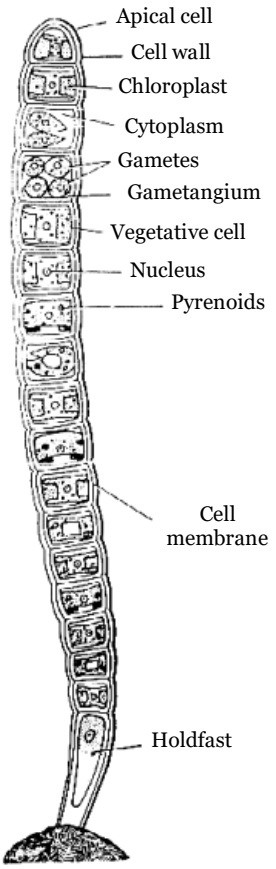


Fig : A vegetative filament

(3) **Reproduction :** The *Ulothrix* reproduces vegetatively, asexually as well as sexually.

(i) **Vegetative reproduction :** It takes place by fragmentation. In this process a filament divides into small parts. These smaller fragments grow and give rise to new filaments of *Ulothrix*.

(ii) **Asexual reproduction :** It takes place by the production of zoospores, aplanospores, hypnospores, akinetes and palmella stage.

(a) **Zoospore formation :** In favourable conditions, each cell produces zoospores except holdfast. Cytoplasm collects in the centre and divides into 2,4,8,16 or sometimes 32 segments. Each segment

develops into biflagellate or quadriflagellate zoospores. Each zoospore is uninucleate, pear-shaped with thin cell membrane (zoospores not having cell wall). The zoospores are of 3 types :

Quadriflagellate macrozoospores : Usually 4 per cell.

Quadriflagellate microzoospores : Usually 8 per cell.

Biflagellate microzoospores : Usually 16-32 per cell.

The zoospores come out into a vesicle, later on the wall disintegrates (forming a pore in lateral wall) and macro and microzoospores are liberated free and float in water. Microzoospores attach to substrate by their anterior ends while macrozoospores attach by their posterior narrow ends. After some time zoospores give rise to new individuals.

(b) **Aplanospores :** Sometimes contents of a cell separate from the cell wall to form one or more rounded aplanospore instead of zoospores. Their wall is thin and they are nonciliated. After liberation, they germinate to produce new plants.

(c) **Hypnospores :** Under unfavourable conditions, the protoplasm is separated from cell wall and develops into a thick- walled structure, the hypnospore. On approach of favourable conditions, the hypnospore gives rise to new individual.

(d) **Akinetes :** During unfavourable cells of the filament develop into thick walled structures known as akinete. Under favourable conditions they give rise to new plants.

(e) **Palmella stage :** When there is shortage of water, filament lies on the moist soil, each cell divides and redivides with the result that some small rounded cells form a colony which is surrounded by mucilaginous substance which protects it from unfavourable conditions and does not allow it to dry. On the approach of favourable conditions, this mucilaginous substance dissolves and these cells either directly or through zoospores develop into new plants.

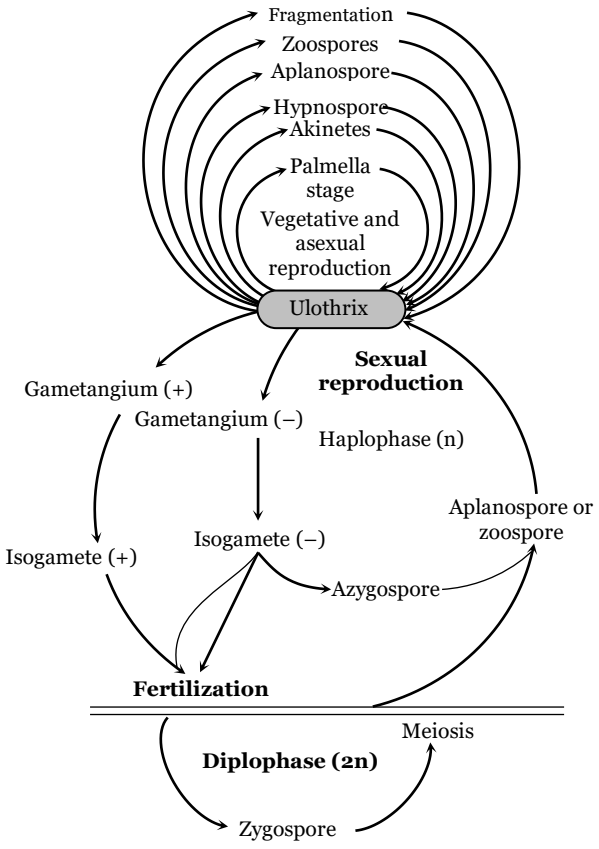


Fig : Graphical representation of life cycle of *Ulothrix*

(iii) **Sexual reporduction :** It occurs at the end of growing season. *Ulothrix* is heterothallic. Sexual reproduction is of isogamous type. The gametes are motile and biflagellate. Except holdfast each cell of the filament can give rise to 64 to 128 gametes. These gametes are smaller than zoospores. On dehiscence of gametangium, the gametes come out in a bag like structure and float on water. When two gametes of (+) and (–) strain come together, they fuse and a quadriflagellate zygospore is formed which after floating for sometime on water, rests on the bottom of the pond. At this time, its four flagella disintegrate and a wall is formed surrounding it from all sides. After taking a rest for long period it divides meiotically and gives rise to 16 aplanospores or zoospores. These come out of the sac and give rise to a new plant of *Ulothrix*.

4.21 Funaria (Moss)

Systematic position

Kingdom	–	Plantae
Sub kingdom	–	Embryophyta
Phylum	–	Bryophyta
Class	–	Bryopsida
Order	–	Funariales
Family	–	Funariaceae
Genus	–	*Funaria*

(1) **Habitat :** *Funaria* is known as **common moss** or **green moss** or **cord moss**. There are 117 species of *Funaria* which are worldwide or cosmopolitan in distribution. 25 species have been reported from India. Most common species are *Funaria hygrometrica, F.obtusa, F. attentua* and *F. fasicularis.*

Funaria grows well in recently burnt grounds rich in plant ashes (alkaline condition). Common places for its growth are moist rocks, moist walls and moist grounds.

(2) **Structure**

(i) **External structure (Gametophytic phase) :** The main plant body of *Funaria* is gametophyte and is of two forms.

(a) Juvenile form (creeping protonema)

(b) Adult form (leafy gametophore)

Protonema is the branched filamentous portion which is produced by germination of spores. It is ephemeral or short lived. Somewhat erect portion of protonema near the substratum, containing chlorophyll is chloronema whereas the deep portion, branched with oblique septa is the rhizoidal portion. It is non- green.

Leafy gametophore develop from buds produced on protonema and is made up of axis with spirally arranged leaves. It is 1 –3 *cm* in height green and is monopodially branched. The main branch

of leafy gametophore bears male reproductive organs, *i.e.*, antheridia and the side branch is female branch. On lower protion the phyllotaxy is generally 3/8 while in upper portion it is 1/3, *i.e.*, crowded.

Leaves : These are small, sessile, ovate with acute apex and broad base. A distinct midrib is present.

Rhizoids : On the lower portion of the leafy gametophore, there are present branched, multicellular rhizoids with oblique septa. Initially the rhizoids are colourless and hyaline but at maturity they become dark in colour due to dark cell walls. If rhizoids are exposed to light they become green.

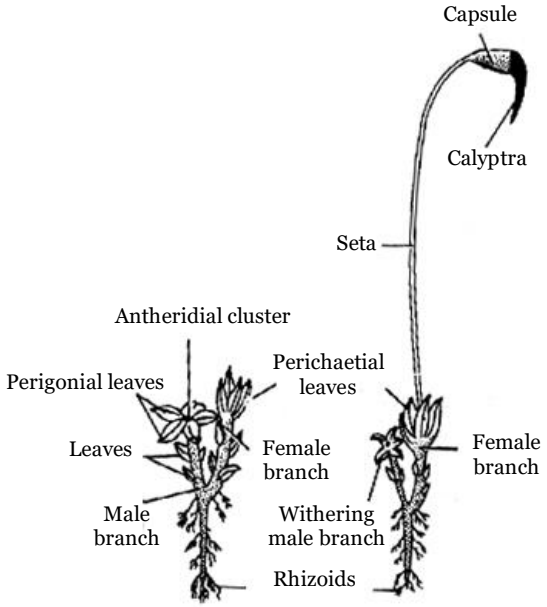


Fig : (A), (B) Funaira plant showing male and female branches

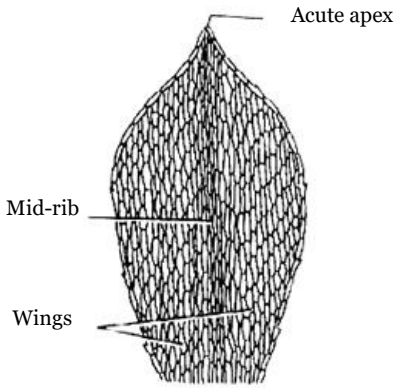


Fig : A leaf

(ii) **Internal structure**

(a) **Stem :** The axis is distinguishable into epidermis, cortex and conducting strands (central cylinder). The epidermis is a one cell thick zone whose cells generally contain chlorophyll but no stomata and cuticle. The cortex is made up of thin walled cells which contain chloroplasts in younger parts but not in older parts. The central cylinder is made up of long. narrow, thin walled, colourless cells which lack protoplasm. These cells performing the function of conduction.

(b) **Leaf :** Internally a 'leaf' is distinguishable into a several cells thick 'midrib' and a 'lamina' of one cell thickness. The midrib contains a few conducting strands of narrow, Thin walled cells. The cells of 'lamina' and some outer cells of midrib contain numerous chloroplasts.

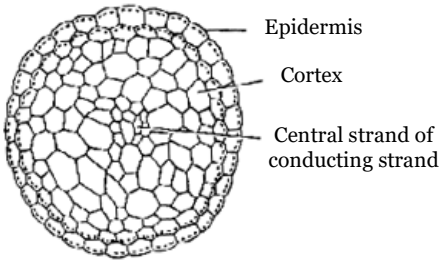


Fig : T.S. axis of *Funaria* (young)

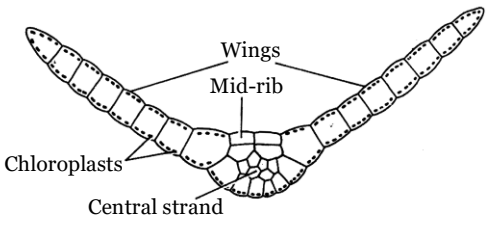


Fig : T.S. of leaf of *Funaria*

(3) **Reproduction :** *Funaria* reproduces both by vegetative and sexual methods.

(i) **Vegetative reproduction :** Vegetative reproduction takes place by the following methods

(a) **Fragmentation of primary protonema** : Protonema formed by germination of spores is called primary protonema. Sometimes this primary protonema breaks up into small fragments accidentally and these fragments give rise to leafy gametophores.

(b) **Secondary protonema** : Sometimes other portions, *e.g.* rhizoids antheridia, etc., also give rise to protonema called secondary protonema, which develop buds and give rise to leafy gametophores.

(c) **Bulbils** : Bulbils are resting buds produced on rhizoids and protonema. They get detached from the parent plant and under unfavourable conditions gives rise to new plants.

(d) **Gemma** : At the apices of the leaves multicellular called gemmae are produced which on separation give rise to new plants.

(e) **Apospory** : Some cells from any part of sporophyte separate from the parent, fall on the soil and form a protonema. Buds of leafy gametophore are produced on the protonema and give rise to a gametophyte- like plant but the cells have diploid set of chromosome ($2n$). In this way a gametophyte like plant is produced from diploid sporophyte without reduction division.

(ii) **Sexual reproduction** : The *Funaria* plants are monoecious and autoecious, *i.e.*,male (antheridia)and female (archegonia) reproductive organs are produced on the same plant but on different branches. Male organs mature first and hence *Funaria* plants are Protandrous.

(a) **Antheridium** : Main branch is male branch which is called antheridiophore. The antheridia are borne at the tip of antheridiophore. The antheridial cluster remains surrounded by a rosette of leaves called Perigonium. In between antheridia are present club shaped green multicelled sterile hair called paraphyses (singular paraphysis). An antheridium is distinguishable into stalk and the body. The stalk is multicelled and biseriate. The antheridial body is club-shaped. It has a 1-cell thick jacket. The terminal cell of the jacket is called operculuum. The jacket encloses a mass of androgonial cells. The androgonial cells divide and redivide and ultimately behave as androcyte mother cells which undergo an oblique division to form two androcytes. A blepharoplast appears and each androcyte is metamorphosed into a sickle shaped, biflagellate antherozoid. The proximal part of the antherozoid consists of nuclear part and the distal represents the blepharoplast part that bears two flagella.

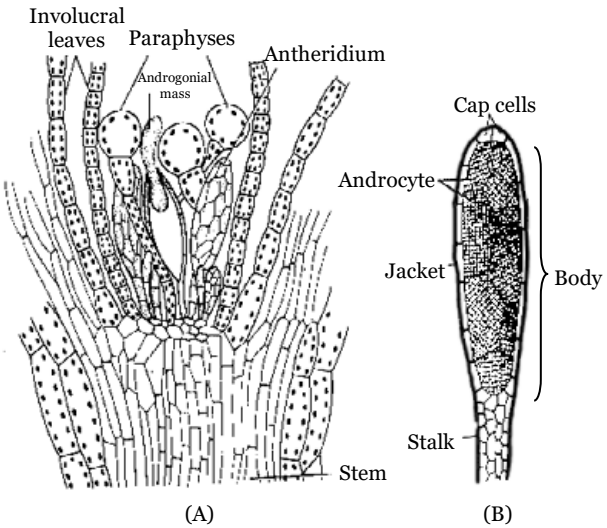


Fig : Moss (A) L.S. of antheridial head
(B) L.S. of one antheridium (young)

(b) **Archegonium** : The archegonia are also borne in a cluster at the tip of archegoniophore. They are also surrounded by ordinary foliage leaves. In between archegonia are present a large number of paraphyses. The terminal cells of paraphyses in female branch is not globular. Besides many leaves

called perichaetial leaves are present at periphery surrounding the group of archegonia forming a cup-like structure perichaetium. The archegonium of moss is distinguishable into a stalk, venter and a neck. The stalk is multicelled and multiseriate. The venter is double layered and contains an egg and a ventral canal cell inside. The neck is several cells high and is made up of six vertical rows of cells. It contains six or more neck canal cells. It is capped by four cover cells or lid cells. The sterile jacket is two layered around venter while single layered around neck. At the base of venter, small massive stalk is present. At maturity the venter canal cell and neck canal cells degenerate to form mucilaginous mass along with sugars. It absorbs water and swells up and the lid cells are blown away. So the mucilaginous mass oozes out of the tip of the neck.

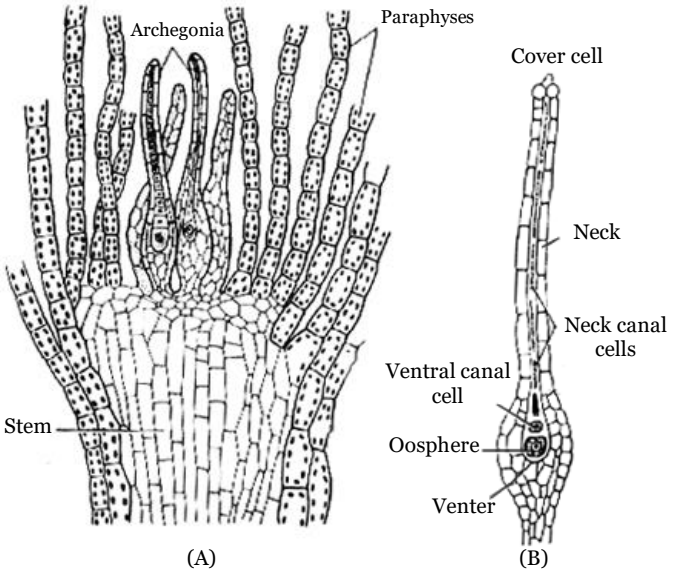


Fig : Moss – (A) L.S. of archegoinal head (B) One archegonium

(c) **Fertilization :** Before fertilization the opercular cell is disorganised and the antherozoids are liberated in a mucilagenous mass into the perichaetial cup. The neck canal cells and the ventral canal cell also degenerate and the cover cells split apart giving a free passage to incoming antherozoid. The antherozoids are attracted towards the neck of the archegonium by some chemotactic substance, possible sugars, produced by the archegonium. The fertilization is affected by water medium. Out of many antherozoids, only one of them is able to fuse with the single egg to produce zygote ($2n$). The zygote without any resting period enlarges and divides to form sporophyte or sporogonium. The first division in zygote is transverse. The epibasal (upper) portion forms capsule and upper half of seta while hypobasal (lower) portion forms foot and lower half of seta.

Sporogenous tissue develops from outer layer of endothecium. The venter wall forms calyptra which is present initially around the sporophyte but later on it breaks.

(d) **Sporophytic phase** : Fully developed sporophyte or sporogonium is made of three regions, *i.e.*, basal foot, seta and capsule. Sporophyte is semiparasite on moss plant taking water, minerals and some growth factors.

Basal foot : Basal foot is embedded in the apex of female branch and is conical in shape. Its function is to absorb nutrients and to provide support for sporophyte.

Seta : It is a long, slender, reddish brown stalk like structure which bears capsule at the top. Internally it is differentiated into a central cylinder of small thin walled cells surrounded by a thick walled cortex and epidermis. The central cylinder helps in the conduction of water and the thick walled cells of the cortex provide mechanical strength to the slender seta.

Capsule : Capsule is the terminal pear shaped portion. Initially it is surrounded by calyptra but later on this calyptra breaks up. Stomata are present on the lower part of capsule. The capsule consists of three portions, *i.e.*, basal apophysis, central theca and terminal operculum.

Apophysis : Apophysis is basal sterile portion of capsule in continuation with seta. The outer layer of apophysis is epidermis which has stomata (primitive type) for gaseous exchange. In capsule of *Funaria* stomata are present only in apophysis. Inner to epidermis there are chlorophyll containing cells which are assimilatory in function. These cells surround a central zone having vertically elongated cells lacking chloroplast. Central zone performs the function of conducting strand.

Theca : Theca is the fertile middle zone of capsule, situated between apophysis and operculum. The outer layer of theca is epidermis, inner to which is 2-3 layered hypodermis. Central sterile portion of theca is called columella, outer to which is spore sac containing spores. Columella is the supporting tissue. The wall of spore sac is single layered on inner side and 2-3 layered on outer side.

Outer to spore sac there are present air spaces traversed by many portions of assimilatory cells called trabeculae.

Operculum : The upper region of capsule is slightly oblique having upper cap-like portion called operculum. Which covers the peristome. The opercular region is separated from the theca region by two rings. The lower ring is the rim or diaphragm and the upper is annulus. The annulus consists of 5-6 superimposed layers of cells. Its upper cells are thick but two lower cells are thin. The peristome is distinguishable into two whorls of radially arranged peristomal teeth. In each whorl, there are sixteen teeth. Each tooth is a triangular structure. Outer ring of these teeth called exostome is thick red affected by changes in moisture content, *i.e.*, hygroscopic in nature. Inner ring, *i.e.*, endostome is thin colourless, without thickening and non-hygroscopic in nature.

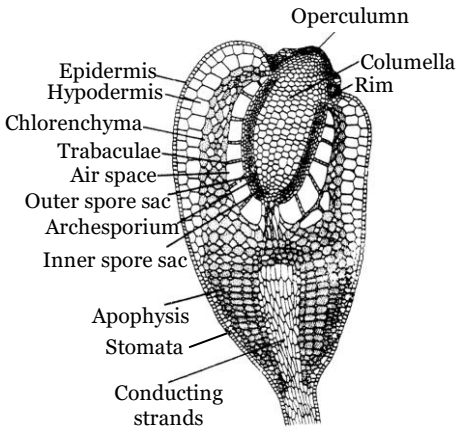


Fig : L.S. of capsule

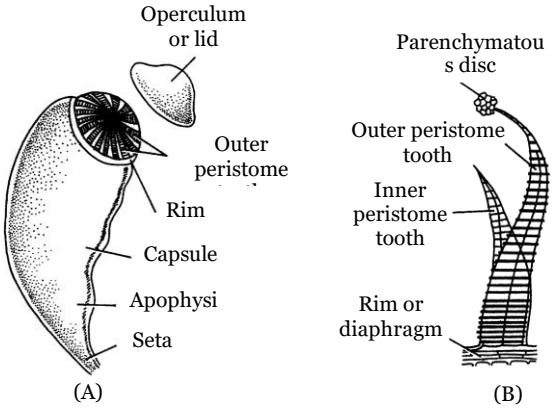


Fig : (A) Capsule with operculum removed to show peristomial teeth (B) Outer and inner peristomial teeth

(e) **Dehiscence of capsule :** As the capsule matures the thinwalled cells including columella dry up. The thin walled cells of operculum break away. The operculum is thus separated along the annulus exposing the peristome. The hygroscopic action of the peristomal teeth also help in the removal of operculum. The capsule becomes inverted due to epinasty. It also shows hygroscopic action. The

lengthening and shortening of peristomal teeth help in the dispersal of spores. The inner peristome acts as a sieve allowing only a few spores to escape at a time. Spores have a long viability, *i.e.*, 8-15 years.

(f) **Germination of spores :** The spore is the first cell of gametophytic generation. Each spore is spherical with two walls, outer one is smooth and coloured called exosporium and inner colourless smooth endosporium. Inside the spore is a single haploid nucleus, numerous chloroplasts and oil globules.

On approach of favourable conditions the spore absorbs water, outer thick exine ruptures and intine comes out in the form of a germ tube which is cut off by means of a septum (oblique). Then it divides and enlarges to form a branched alga –like, filamentous, primary protonema.

There are two generations in life cycle of *Funaria*, *i.e.*, gametophytic generation (*n*) which is independent and complex and sporophytic generation (2*n*) which is partially dependent upon gametophytic generation. These two generations follow each other in regular sequence. This is called heteromorphic or heterologous alternation of generations.

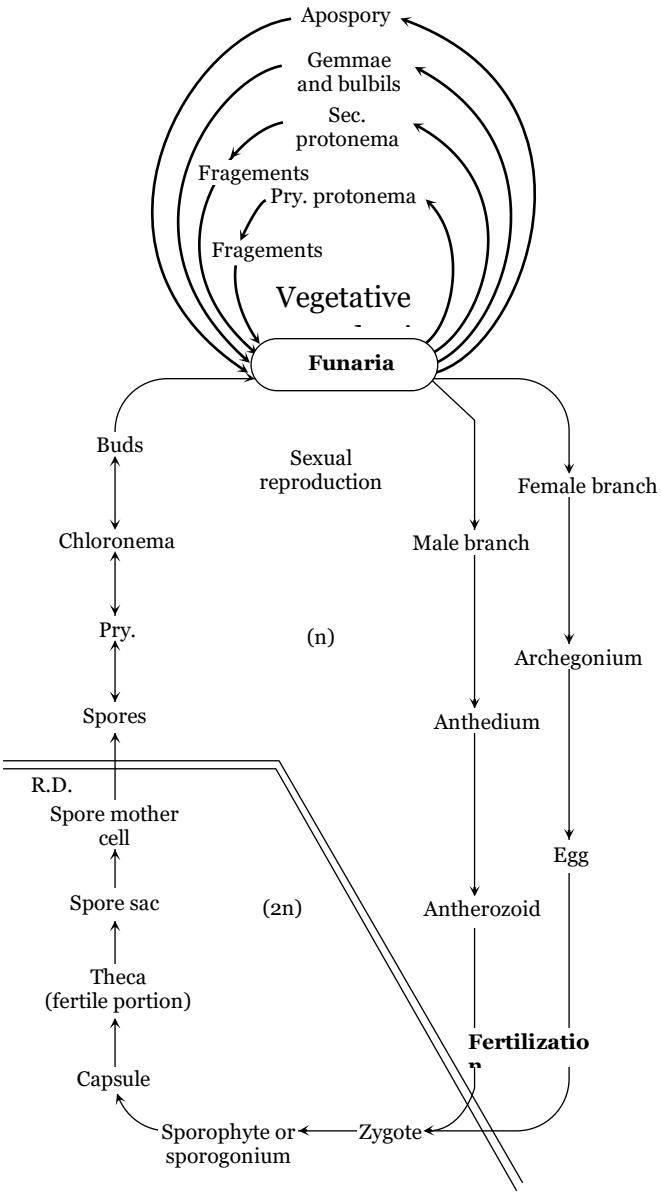


Fig : Graphical representation of life cycle of *Funaria*

4.22 Riccia

Systematic position

Kingdom	–	Plantae
Sub kingdom	–	Embryophyta
Phylum	–	Bryophyta
Class	–	Hepaticopsida
Order	–	Marchantiales
Family	–	Ricciaceae
Genus	–	*Riccia*

(1) **Habitat :** It is a cosmopolitan genus comprising 200 species and about 30 species have been reported from India. The plants occur on moist soil or rocks. Most of the species are terrestrial (on damp soils) except *Riccia fluitans*, which is aquatic in nature. *Riccia himalayensis* (*R. discolor*) is the most common Indian species, which is present in plains and also upto height of 9,000 ft above sea level. It occurs during july to october. The plants show rossette habit on damp soil.

(2) **Structure**

(i) **External structure (Gametophytic phase) :** The main plant body of *Riccia* is gametophytic (*n*)**,** which is thallose, *i.e.*, having no true roots, stem and leaves. It is small, green, flat and fleshy. The thallus is dorsiventral and dichotomously branched. The thalli are present in the form of patches called **rossettes**. The dorsal surface of thallus is smooth and shows mid-dorsal groove, whereas the ventral surface is having unicellular rhizoids and multicellular scales. Scales are found on the margins, while rhizoids are present in the mid-rib region of thallus. Rhizoids are unicellular and unbranched and are of two types- smooth and tuberculate. Rhizoids attach the plant to the substratum and absorb soil water. Scales are minute, violet coloured (due to anthocyanins in their cell sap) multicellular structures which protect the growing point. In submerged species, (*e.g. R. Fluitans*) scales and rhizoids are not present.

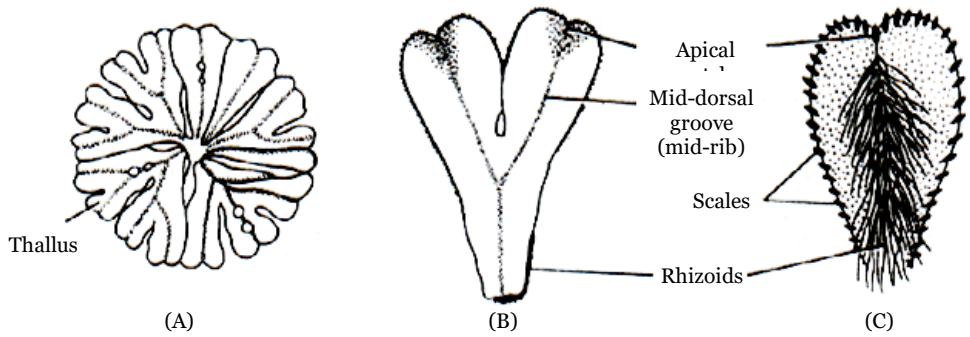


Fig : Riccia (A) Rossette habit (B) Dorsal view of thallus (C) Ventral view of thallus

(ii) **Internal structure :** The thallus is internally differentiated into

(a) An upper or dorsal photosynthetic region.

(b) A lower or ventral storage region.

(a) **Photosynthetic region :** It consists of vertical rows of chlorenchymatous cells. In between these vertical rows are present very narrow air canals or air chambers. The canals communicate with the outside through air pores. The uppermost cell of each row is enlarged and non-green. These non green cells of vertical rows form a discontinuous and poorly-defined upper epidemis.

(b) **Storage region :** The lower portion consists of closely packed parenchymatous cells without intercellular spaces. The cells do not contain chloroplasts. They store water and food. The lowermost row of cells form the lower epidermis. Rhizoids and scales develop from the lower epidermis.

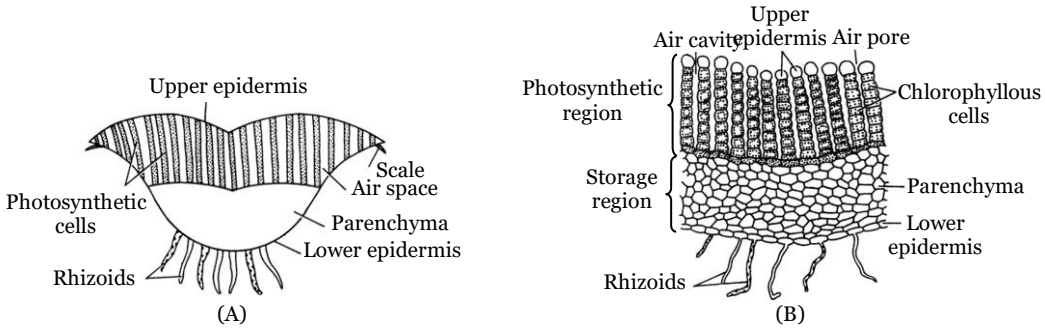


Fig : (A) A V.T.S of *Riccia* thallus (B) A portion magnified

In *R. fluitans* and *R. crystallina,* the photosynthetic region is made up of chlorophyllose photosynthetic lamellae running in various directions. They enclose tiny air chambers in between them.

(3) **Reproduction :** *Riccia* reproduces by both vegetative and sexual method.

(i) **Vegetative reproduction** : The plants of *Riccia* reproduce vegetatively by the following methods and new thalli may arise.

(a) By gradual death and decay of the older part of the plant body.

(b) By the formation of adventitious branches *e.g. , R. fluitans*.

(c) By the perennation of the apical region. *e.g., R. discolor.*

(d) By the formation of tubers which tide over unfavourable conditions *e.g., R. billardieri, R. discolor, R. perennis.*

(e) By segmentation of a rhizoid *e.g. R. glauca*.

(ii) **Sexual reproduction** : Sexual reproduction is oogamous type in *Riccia*. Antheridia and archegonia are the male and female sex organs respectively. Most of the species are monoecious or homothallic, *i.e.*,male and female sex organs are present on the same thallus. A few species are dioecious or heterothallic, *i.e.*, antheridia and archegonia are present on different thalli. Common dioecious species of *Riccia* are *R.himalayensis* and *R. frostii*.

The sex organs are produced singly on mid-dorsal groove of *Riccia* thallus in acropetal succession, *i.e.*, oldest at the base and youngest at the apex. Antheridia and archegonia are present singly in

antheridial cavities and archegonial cavities respectively. In homothallic species, antheridia are produced earlier than archegonia.

(a) **Antheridium (Male sex organ)** : It consists of a small stalk and an oval body. It is situated in a deep pit, called antheridial chamber. The antheridium is surrounded by an outer jacket of sterile cells. The sterile jacket encloses androcyte mother cells. Each androcyte mother cell divides to form two androcytes. The protoplast of each androcyte is metamorphosed into a single antherozoid. Each antherozoid is a narrow, curved structure with two anterior flagella. Moisture is essential for dehiscence of antheridium. Antherozoids come out through the narrow canal of antheridial chamber and swim freely in a thin film of water in the dorsal furrow.

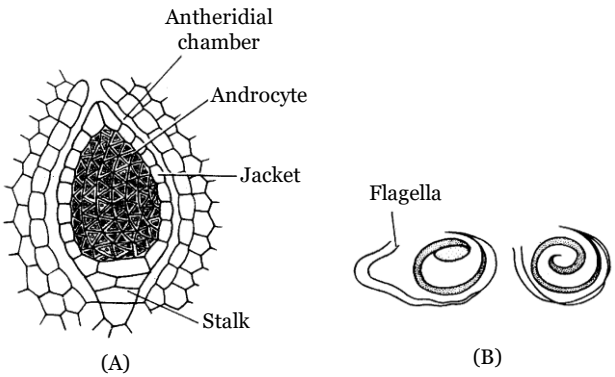


Fig : (A) Structure of an antheridium (B) Two antherozoids

(b) **Archegonium (Female sex organ)** : Archegonium is a flask-shaped structure. It consists of two parts the basal swollen venter and the long narrow neck. The archegonium is surrounded by a layer of sterile cells forming a protective jacket. The neck consists of a vertical row of four cells, the neck canal cells. The tip of the neck is made up of four large cap or cover cells. The venter has two cells, the lower large egg cell and the upper small ventral canal cell. The upper portion of the neck usually projects above the surface of the thallus. On maturity the neck canal and ventral canal cells of the archegonium degenerate forming mucilage. It imbibes water and swells forcing the cover cells to separate from one another.

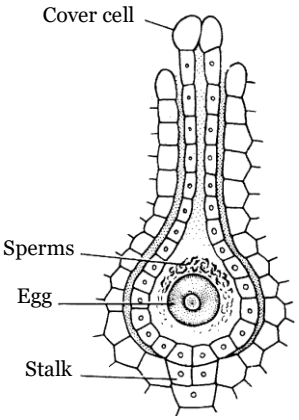


Fig : A mature archegonium

(c) **Fertilization :** Before fertization the neck canal cells and the ventral canal cell disorganise to form a mucilagenous mass. The cover cells now split apart to give a free passage to the incoming antherozoid. The antherozoid are attracted towards the egg by chemotactic mechanism. The chemical stimulus is provided in the form of sugars. The fertilization is affected by water medium (zooidogamous). Many antherozoids may enter into the archegonium, but only one of them is able to fuse with single egg to form zygote (2*n*), which is beginning of sporophytic phase.

(d) **Sporophytic phase :** Soon after formation of zygote, it enlarges in size and fills up the cavity of venter. The zygote also secrets a wall around it. Without any resting period zygote undergoes many divisions and forms a spherical mass of undifferentiated cells called embryo. The venter becomes two cell layers thick and is known as calyptra. The neck of the archegonium disorganizes.

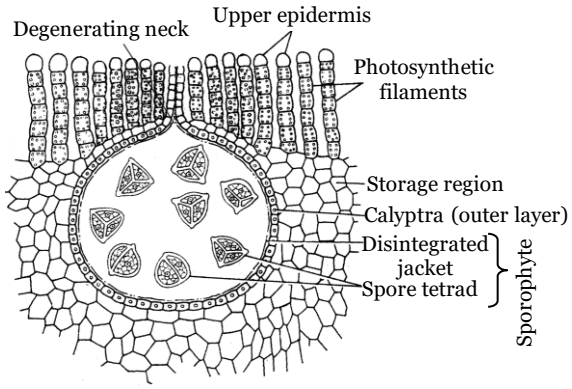


Fig : V.T.S. of Riccia thallus showing mature sporophyte

By cell divisions in embryo two layers are formed, the outer amphithecium and the inner endothecium. The endothecuim forms the spore mother cells, each of which undergoes meiosis to form tetrahedral tetrad of four spores (*n*).

A few spore mother cells, although remain sterile and act as nurse cells, which are having vacuolated cytoplasm and disorganize to provide nutrition to developing spores. Fully developed sporophyte or sporogonium is simple structure, having only capsule or spore sac. There is no foot and seta.

Sporophyte or sporogonium of *Riccia* is simplest among bryophytes. Sporophyte is photosynthetically independent. The capsule is having a single layered wall, *i.e.*, outer layer of calyptra only (Inner layer of calyptra and sterile jacket formed by amphithecium also disorganize).

(e) **Germination of spores :** Spores are the first cells of the next gametophytic generation. Spores are dispersed by the decay of the surrounding thallus tissue. The wall of the spore is thick and sculptured, and is differentiated into three layers- the outer exosporium the middle mesosporium and the inner endosporium which is made of pectose and callose. The surface is having clear triradiate mark. In the mass of cytoplasm, stored food is present in the form of oil – globules. After liberation, the spores germinate in about 6-10 days in presence of light, low temperature and sufficient moisture contents. After absorbing water, the spore swells up. The endosporium grows out in the form of a germ tube which, after further divisions, develops into a new thallus (gametophyte).

Thus there are 2 generations in life cycle of *Riccia*. The main plant body is gametophytic (*n*). The gametophytic phase starts with formation of spores and ends with fertilization. The second phase is sporophytic phase (2*n*), which starts with zygote and ends with reduction division of spore mother cell. The sporophytic phase is dependent upon gametophyte. Thus there is heteromorphic or heterologous alternation of generations in *Riccia*. So life cycle in *Riccia* is diplohaplontic.

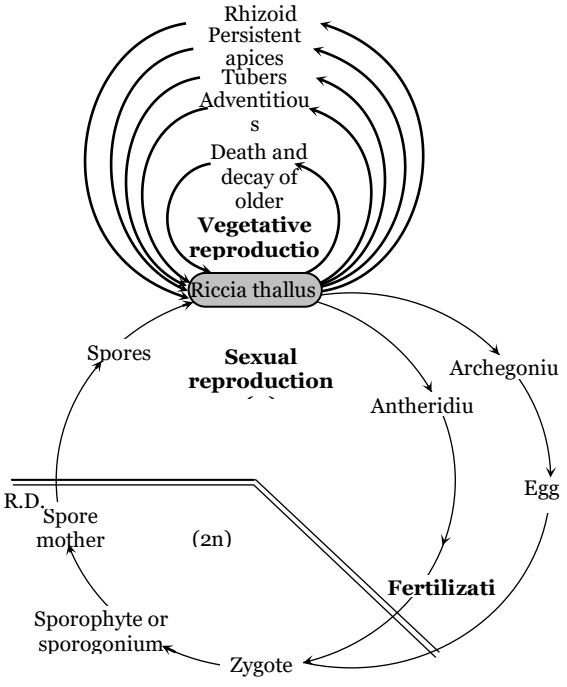


Fig : Graphical representation of life cycle of *Riccia*

4.23 Pteris, Dryopteris and Pteridium (Fern)

Systematic position

Kingdom	–	Plantae
Sub kingdom	–	Embryophyta
Phylum	–	Tracheophyta
Class	–	Leptosparangiopsida
Order	–	Filicales
Family	–	Polypodiaceae
Genus	–	*Pteris, Dryopteris, Pteridium*

(1) **Habitat :** Ferns live in moist, cool and shady places. They are perennial and evergreen. *Fern Dryopteris filix-mas* is commonly known as **Beech fern** or Male shield fern or **Hay scented fern**. There are about 150 sps. and 25 sps. have been reported in India. It is found in sub-tropical regions as well as warm temperate regions.

(2) **Structure**

(i) **External structure :** Fern plant is sporophytic (*2n*) with an underground rhizomatous stem, large aerial leaves or fronds and adventitious roots. Rhizome is sparingly branched in *Dryopteris*, moderately branched in *Pteris* and *Adiantum* and profusely branched in *Pteridium*. Young leaves show *circinate ptyxis*. Younger parts of leaves and rhizome are surrounded by brown hairy structures called **scales** or ramenta. Leaf bases are persistent. Leaves are pinnately compound unipinnately *Pteris vittata*, incompletely bipinnate *Dryopteris filix mas*, bipinnate in *Pteris, biaurita, Dryopteris rigida,* tripinnate in *Pteridium aquilinum*. The leaves show open dichotomous type of venation.

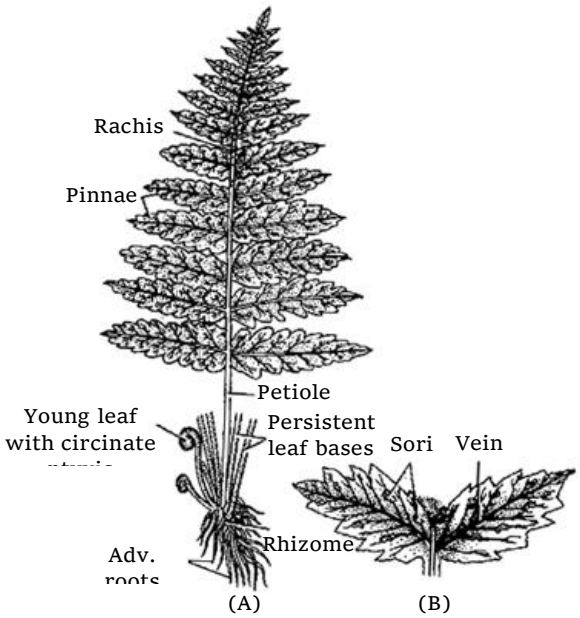


Fig : *Dryopteris* (A) Plant showing habit (B) Fertile pinnule

(ii) **Internal structure**

(a) **Root :** The epiblema is provided with unicelled root hair. It followed by thin walled outer cortex. The inner cortex is thick walled (lignified). The cortex is followed by endodermis with characteristic **casparian strip**. The pericycle may be 1-2 cells thick. It is also made up of thin walled cells. The xylem is diarch and exarch with two phloem groups alternating the protoxylem.

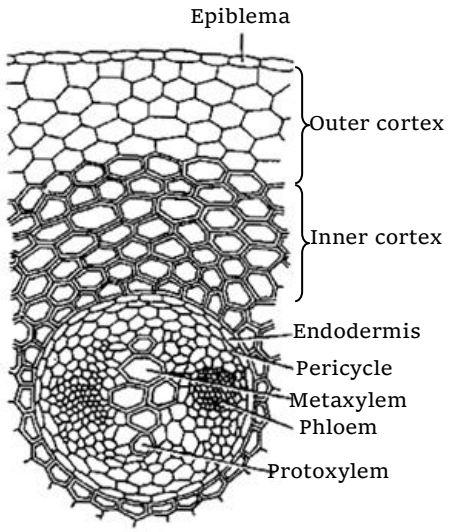


Fig : T.S. of *Dryopteris* root

(b) **Rhizome :** It *Pteridium aquilinum* the epidermis is followed by **sclerenchymatous** hypodermis and the thin walled ground tissue. The young portion has a

siphonostele, but this later forms two concentric cylinders of vascular tissue. The outer ring corresponds to a **dictyostele** (*e.g. Dryopteris and Pteris)* or dicyclic or polycylic dictyostele (*e.g.*, *Pteridium*) which is distinguishable into small **meristeles**. The inner ring comprises generally two medullary meristeles. The two rings are separated by two patches of thick walled tissue. Each meristele has its own endodermis followed by thin walled pericycle. It is **amphicribal** (ectophloic) with mesarch xylem.

The phloem lacks companion cells. In *Dryopteris filix-mas* the vasculature comprises a dictyostele consisting of a ring of meristele. In *Pteris*, however, the vasculature ranges from solenostele to polycyclic dictyostele.

Rachis : The epidermis is followed by thick walled hypodermis. The ground tissue is thin walled. In *Pteridium aquilinum* several *meristeles* lie irregularly scattered in the ground tissue. In *Dryopteris filix-mas* there are 6–8 meristeles arragned in a horse-shoe like manner and single arched with hooked xylem in *Pteris*. The structure of the meristele is similar to that of rhizome.

(d) **Leaf lamina :** The pinnule of *Pteridium aquilinum* shows distinct upper and lower epidermis. The lower epidermis is provided with stomata. The mesophyll is differentiated into an upper zone of palisade parenchyma and a lower of spongy paranchyma. The spongy parenchyma has large intercellular spaces. The vascular strands lie embedded in mesophyll. Each strand is generally amphicribal with its own endodermis and pericycle but sometimes they are bicollateral also. The bundles in minor veins are collateral.

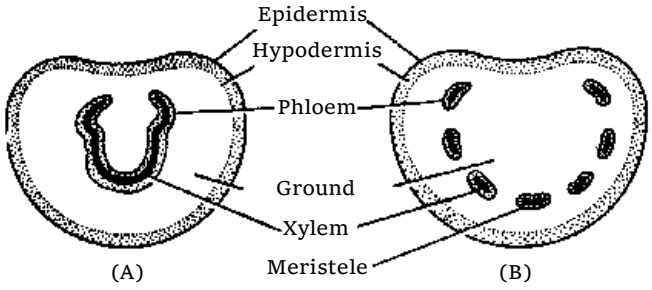


Fig : Dryopteris (A) T.S. rachis (basal portion) (B) T.S. rachis (Upper portion)

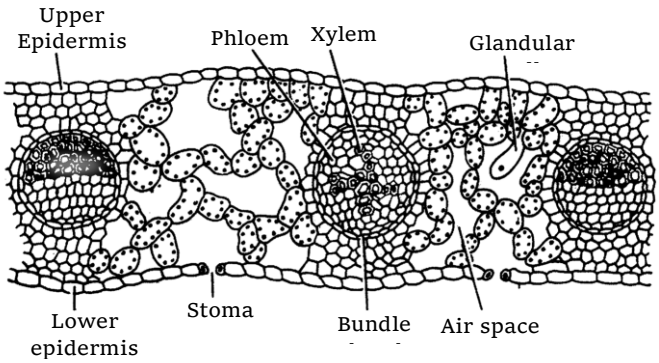


Fig : V.T.S. of pinnule or sterile leaflet (leaf lamina) of *Dryopteris*

(3) **Reproduction**

(i) **Vegetative reproduction :** Vegetative reproduction can occur through fragmentation or rhizome and adventitious buds and these on separation gives rise to new fern plant.

(ii) **Sexual reproduction :** Sexual reproduction takes place through spores. Spores are born in sporangia.

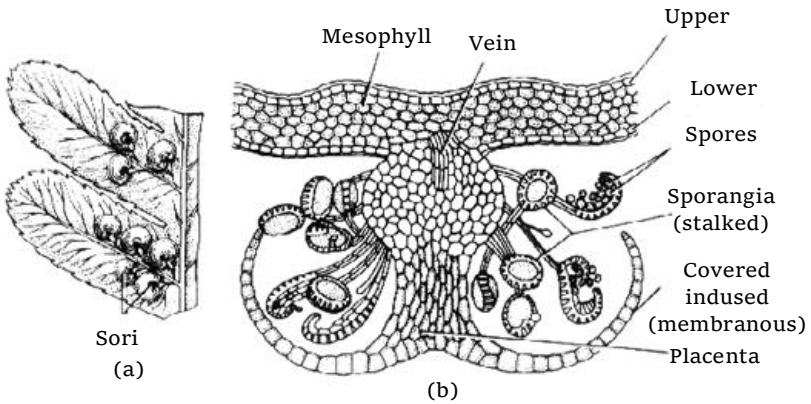


Fig : *Dryopteris* (a) Part of sporophyll with sori (b) T.S. of sorus

The spores are of one kind only (homosporous). When leaves are mature they bear groups of sori on the under surface of fertile *pinnae*. Such fronds are called sporophylls. The sori are borne in two rows on two sides of median vein of pinnule in between the margin and the midrib.

Sori are linear and submarginal in *Pteris* and *Pteridium* and median abaxial in *Dryopteris*. Each sorus is surrounded by a kidney-shaped covering called indusium. In *Dryopteris*, **true indusium** is present because this arises from placenta or placental tissue, from which sporangia arise. (In *Pteris* **false indusium** is there because it is formed by leaf margins).

In sorus of Pteridium is covered by two flap like appendages that protect the sporangia. The upper flap is called false indusium and lower is called the true indusium. In the centre of sorus, the vein ends into placental tissue from where arise a number of sporangia. The sorus is mixed in *Dryopteris* (*i.e.*, no definite arrangement of sporangia).

Sporangium : The sporangial development is leptosporangiate *i.e.*, it develops from a single superficial initial. (In eusporangiate type the sporangium arises from a group of initials.) A sporangium is distinguishable into a **stalk** and a **capsule**. The stalk is multicelled and biseriate. The capsule is oval or elliptical and biconvex in shape. It consists of a single layered wall followed by **double layered tapetum** that encloses the archesporium. The archesporial cells divide and redivide to form a mass of **sporogenous tissue**. Most of the sporogenous cells behave a spore mother cells. They undergo meiosis to form tetrahedral tetrads of (haploid) spores. As a result 32–64 spores are formed in each capsule. The tapetal layer is nutritive. It degenerates at maturity of the sporangium.

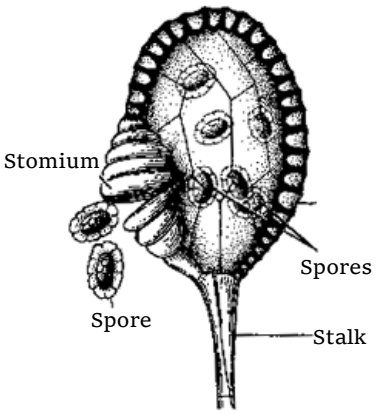


Fig : *Dryopteris* – One sporangium

At the capsule matures, about four lower median cells of the jacket stretch tangentially. Of these, two median ones identify the place from where the capsule opens. This is called **stomium**. The remaining cells of the same median row of the jacket covering about three fourths of the perimeter become specialised.

They develop a thickening along their radial and inner tangential walls. This layer is called annulus. At maturity the inducium dries exposing the sorus. The cells of the *annulus* loose water. Due to presence of thickening along the radial and inner tangential walls, their upper walls contract and the inner ones straight and the annulus coils. Thus, it exerts pressure on the wall resulting in breaking of the capsule between the cells of stomium thereby releasing the spores.

Gametophytic generation

(a) **Spores :** It is the first cell of gametophytic generation. Spores are double layered. The outer wall **exospore** is much thicker than inner **endospore**. On

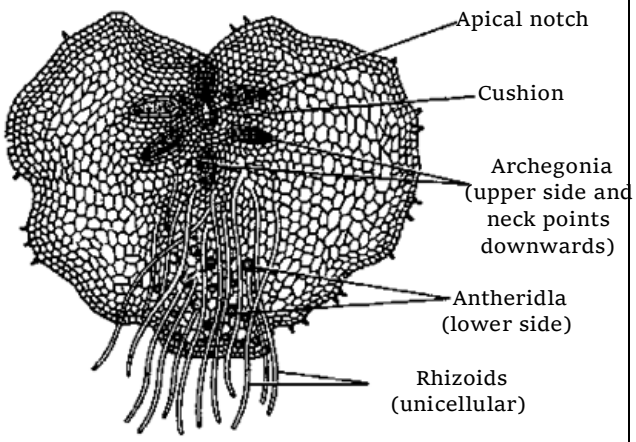


Fig : Mature prothallus of

approach of favourable condition spore germinates to form a filamentous gametophyte which develops into green and heart shaped prothallus.

(b) **Prothallus :** It lies flat on the soil surface, attached by means of numerous delicate **rhizoids**. The fern prothallus is single celled thick. Although at maturity, the portion below the notch becomes many celled thick, i.e. **cushion**. Prothallus shows polarity and dorsiventrality. The dorsal surface is smooth and the ventral is provided with unicelled rhizoids and sex organs. Diameter of fern prothallus is 5 or 6 *mm* to 13 *mm* and each cell of prothallus is having single nucleus and many **discoid chloroplasts**.

Fern prothallus is monoecious but protandrous (antheridia mature first). *Antheridia* are present in between the rhizoids while archegonia are present near the apical notch.

- **Antheridium :** It consists of a three celled jacket enclosing a mass of **androgonial cells**. The two lower jacket cells are ring like (first and second ring cells), and the terminal cell is called as **opercular cell** or **cover cell** or **cap cell**. Sometimes, there may be two cap cells and in that case the jacket is four celled. The last generation of androgonial cells forms the androcytes. There may be 20–25 androcytes in an antheridium, each of which is metamorphose into a spirally coiled, multiflagellate antherozoid.

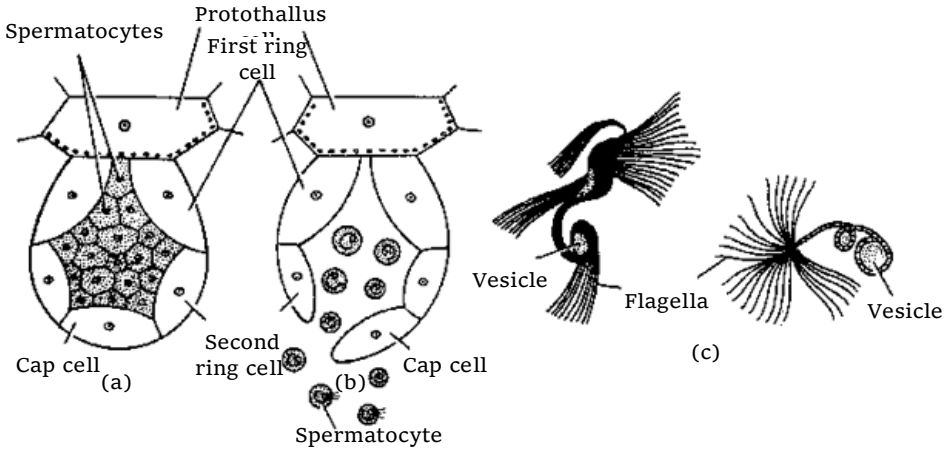


Fig : *Dryopteris* (a) L.S. antheridium (b) dehisced antheridium (c) Multiflagellate spermatozoids

- **Archegonium :** It is a flask-shaped structure having venter and neck. Neck is projected out of the prothallus and is curved posteriorly. Venter is having basal large egg cell and upper small venter canal cell. The neck is having single neck canal cell but is binucleate. Venter is not having any covering or jacket but neck is surrounded by jacket of 4 ventrical rows of cells.

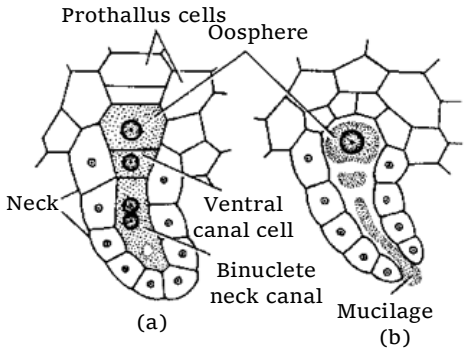


Fig : Dryopteris (a) Mature archegonium (b) Before

(c) **Fertilization and development of sporophyte :** Before fertilization the walls of androgonial cells disorganise to form a **mucilagenous mass**. The opercular cell is removed when it comes in contact with external water. The neck canal cell and the ventral canal cell degenerate. The cover cells split apart giving a free passage to incoming antherozoids. The antherozoids are attracted by **chemotactic stimulus** which is probably provided in the form of **malic acid**. A single antherozoid is able to fuse with egg to form zygote (2*n*), which is beginning of sporophytic generation. Zygote divides first by vertical division, followed by another vertical division and quadrat stage is formed. Then **octant stage** is formed by transverse division. The foot and root develop from four hypobasal cells and cotyledons as well as stem develop from epibasal cells and thus sporophytic plant is formed. At maturity foot is hemispherical mass of gametophyte from which it absorbs food. Generally a single sporophytic plant develops from single gametophyte or prothallus. The fern sporophyte is initially dependent upon gametophyte but later on becomes independent.

The life cycle is diplohaplontic with **heteromorphic** alternation of generation.

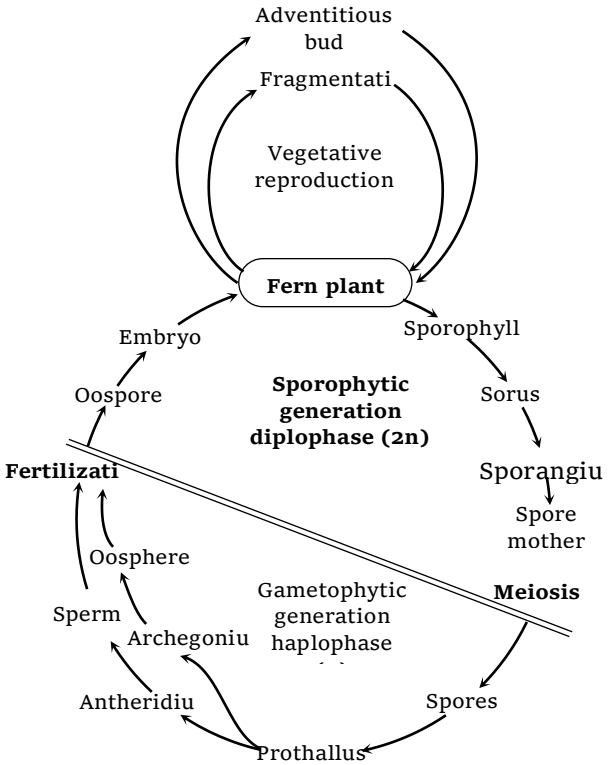


Fig : Graphical representation of life cycle of

4.24 Selaginella

Systematic position

Kingdom	–	Plantae
Sub kingdom	–	Embryaphyta
Phylum	–	Tracheophyta
Class	–	Ligulopsida
Order	–	Selaginellases

Family – Selaginellaceae

Genus – *Selaginella*

(1) **Habitat :** *Selaginella* is commonly called **the little club moss** or **spike moss** and is having about 760 species, out of which 70 species have been reported from India. *Selaginella* is mainly found in damp shaded places. A few species are xerophytic and can withstand the dry conditions for months together. In dry conditions, the plant rolls up into a compact ball and root system is disorganized. During the rainy conditions the ball on absorbing moisture, becomes green again. Such plants are called **resurrection plants** or **bird's nest moss**, *e.g.*, *S.lepidophylla*, *S.bryopteris* (Sanjeevani) and *S.rupestris* (ornamental).

The **epiphytic** species grow on the branches and trunks of moss covered trees. The common epiphytic species are *S. chrysocaulos, S. kraussiana, S. oregana, S. chrysorrhizus*.

(2) **Structure**

(i) **External structure :** The plant body is sporophytic (2*n*), which is an evergreen and delicate herb having adventitious roots. The plants show great variation in their morphology. Some species are **prostrate** growing upon the surface (*e.g.*, *S.kraussiana)*, some are **suberect** (*e.g.*, *S.trachphylla*) and others are **climbers** (*e.g.*, *S.allegans)*. Plants are many *meters* long in *S.willdenovii* and only few centimetre long in *S.spinulosa*. The stem is covered with four rows of small leaves, out of these two rows are of smaller leaves and two of large leaves species with dimorphic leaves such as *S.kraussiana, S.helvetica, S.lepidophylla, S.chrysocaulos* etc. are grouped in subgenus heterophyllum. Species having leaves uniform in size are grouped in the subgenus homeophyllum. These species are *S.spinulosa, S.rupestris, S.pygmaea* and *S.oregana* etc.

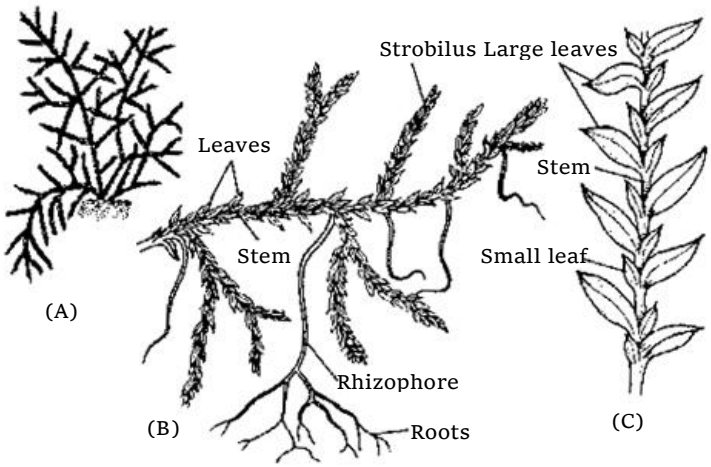


Fig : *Selaginella kraussiana* : (A) General habit (B) A part of the plant (C) Small portion of (B) showing arrangement of leaves

Leaves are sessile, ovate or lanceolate with acute apex. Unbranched midrib is present in the centre of each leaf. The leaves are **ligulate**, *i.e.*, a flap-like outgrowth is present at the base on adaxial side called ligule. It may be fan-shaped or tongue-shaped or lobed or fringed. At the base of ligule, there is present a sheath of elongated cells called glossopodium (secretory).

The leaves possess a midrib but there is **no venation**. At the place of bicuraction of stem, a leafless, colourless, positively geotropic, elongated, cylindrical structure grows downwards. This is called the **rhizophore** and is quite different from the root in that it has **no root cap**. Rhizophores are not present in *S.cuspidata*. Rhizophores typically develops of adventitious roots at its apex.

(ii) **Internal structure**

(a) **Root :** The root is distinguishable into a single layered epidermis having root hair. This is followed by a 3–4 layered thick walled hypodermis representing outer cortex. The inner cortex is thin walled. The endodermis delimits the cortex. It is generally not distinct but in *S.willdenovii* it is very clear. The endodermis is followed by 1–3 layered pericycle. The stele is a **protostele**. It has a central core of xylem surrounded by phloem which is **horse shoe shaped**. It has a single protoxylem element (monarch). The xylem is exarch.

(b) **Stem :** The stem is internally distinguishable into a single layered epidermis having no stomata. This is followed by cortex. The outer cortex is thick walled (hypodermis) followed by thin walled inner cortex. The hypodermis is very well developed in xerophytic species. The stele is suspended by unicelled (rarely multicelled) trabaculae (modified endodermal cell). This layer, due to presence of casparian strips is regarded as endodermis. The stele is a protostele (haplostele) surrounded by a pericycle with a central core of xylem enclosed by phloem. Protostele is **diarch** and **exarch**.

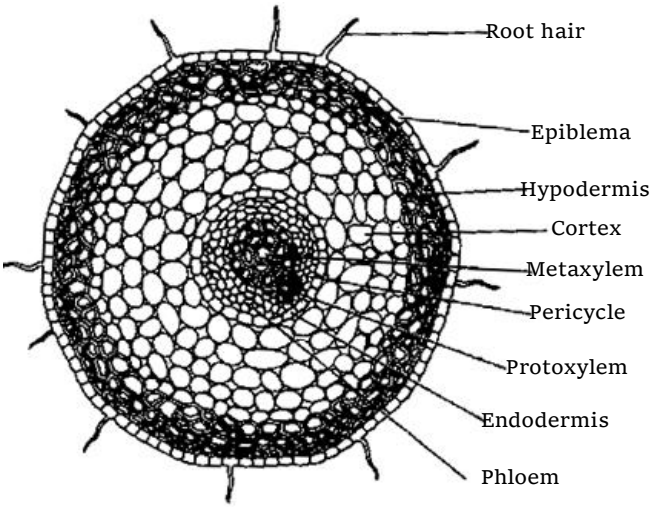


Fig. T.S. root of *Selaginella*

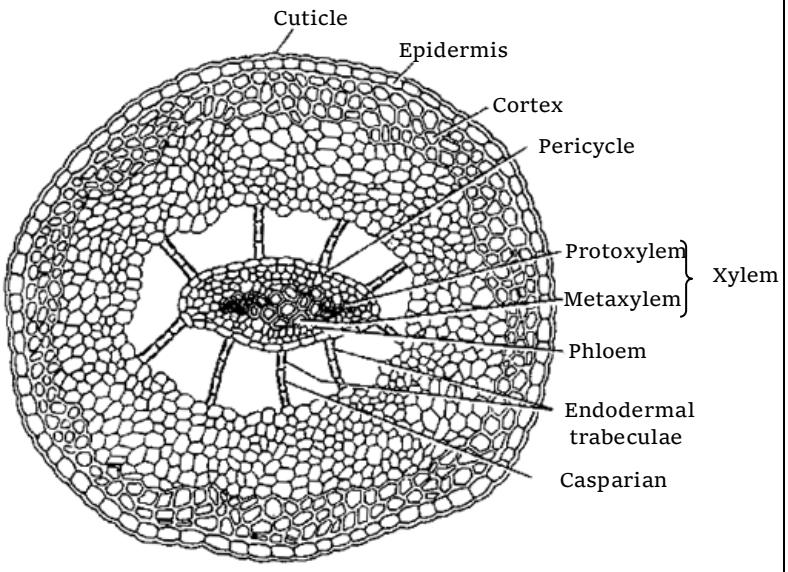


Fig. T.S. stem of *Selaginella*

(c) **Leaf :** The leaf displays a simple structure. It is distinguishable into upper and lower epidermis enclosing mesophyll tissue in between. The upper and lower epidermal layers are 1-cell thick each. The lower epidermis is provided with stomata. The mesophyll is uniform, being composed of elongated chlorenchymatous cells with large intercellular spaces. Each measophyll cells has one (*S.martensii*), two (*S.kraussiana*) or eight (*S.willdenovii*) chloroplasts. Each chloroplast has several pyrenoid-like bodies

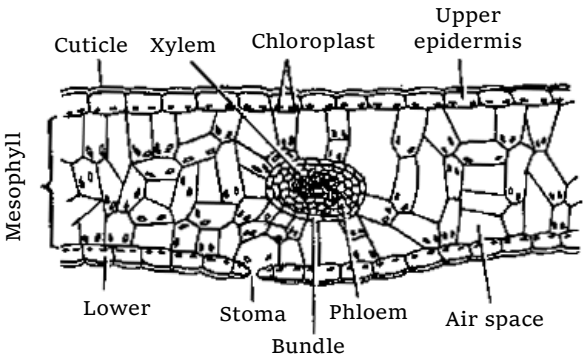


Fig : V.S. of leaf of *Selaginella*

similar to Anthocerotales. The single midrib bundle is concentric, amphicribal (ectophloic) with annular or spiral tracheids surrounded by a few sieve elements.

(d) **Rhizophore :** The anatomy of rhizophore is almost similar to root. The epidermis is cutinised and it is followed by cortex. The outer cortex is thickwalled (hypodermis) whereas inner one thin walled. The innermost layer of the cortex is endodermis which is followed by pericycle. The stele is a **protostele**. The xylem is exarch with several protoxylem groups. In *S.kraussiana,* **centroxylic** condition (having protoxylem in the centre surrounded by metaxylem elements) has been recorded.

(3) **Reproduction :** Reproduction takes place by vegetative and sexual (by spores) method.

(i) **Vegetative reproduction :** It is of rare occurrence and may takes place by following methods :

(a) **Fragmentation :** It occurs during very humid conditions. Some branches act as **adventitious branches**, which get separated from the plant and give rise to new *Selaginella* plants, *e.g.*, in *S.rupestris*.

(b) **By resting buds :** In some cases, terminal leaves get overlapped and become fleshy and form resting buds, which are means of vegetative reproduction, *e.g.*, in *S.chrysocaulos.*

(c) **By tubers :** In *S.chrysorrhizus*, some branches penetrate into substratum and at terminal ends swell to form tubers, which give rise to new plants.

(d) **By apogamy :** In some cases, development of sporophyte occurs directly from gametophyte without intervention of sex organs, it is called apogamy and such plants are genetically **haploid**.

(ii) **Sexual reproduction :** The reproductive structure in *Selaginella* is **strobilus** or **spike**. It is a sessile structure and develops at the terminal ends of the branches and its length varies from $1/4^{th}$ of an *inch* to 2–3 *inches* in different species.

A strobilus is having many ligulate sporophylls arranged in cluster, each bearing a small, short, stalked sporangium on its upper surface. The sporangia are of two types :

(a) **Megasporangia :** Borne on megasporophylls. Megasporangium is pale greenish and contains chalky white, yellow or orange **megaspores**. The megasporangium is **four-lobed** structure with a 2-layered jacket, one layer of tapetum and a large number of microspore mother cell. However, only one megaspore mother cell is functional. After meiosis it produces 4 megaspores out of which 1–3 may degenerate. In *S.rupestris*, there is only a single megaspore.

(b) **Microsporangia :** Borne on microsporophylls having a large number of small

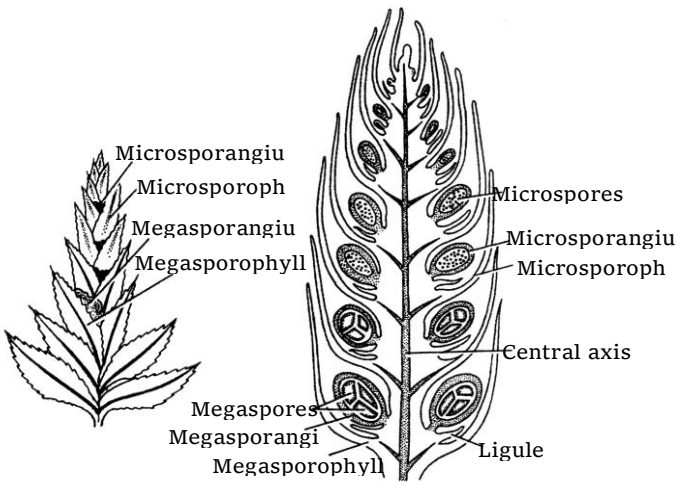


Fig : *Selaginella* : (a) A strobilus showing compactly arranged sporophylls (b) L.S. through strobilus

spores. Thus *Selaginella* is heterosporous. Microsporangium is pale yellow, oval or spherical body, with 2-layered jacket, one layered tapetum and a number of microspore mother cells which undergo meiosis and form haploid microspores. The main body consists of a wall having two layers, inside which are present numerous small microspores (400–2000). Development of sporangium is of eusporangiate type.

In most of the cases, the strobilus or spike bears two types of sporophylls; the lower are megasporophylls and the upper ones are microsporophylls. In *S.kraussiana* there is single megasporophyll at the base of spike and the rest of upper are microsporophylls.

In some cases strobilus contains either micro or megasporophyll, *i.e.*, in *S.gracilis* and *S.astrovirdis*, while *S. martensii* and *S.caulescens* show intermixed micro and megasporophylls. Some sps. possess megasporangia on the ventral side and microsporangia on the dorsal side, *e.g.*, *S.oregana* and *S.inaequalifolia.*

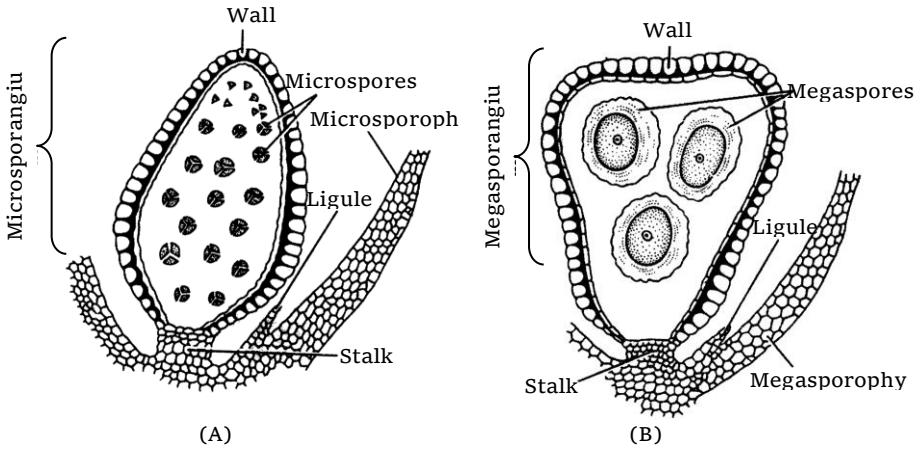


Fig : *Selaginella* : (A) V.S. microsporangium (B) V.S. megasporangium

(c) **Mechanism of sporangial dehiscence :** On maturation, the sporangium splits vertically from the upper end into **two valves** (vertical apical splitting). The lower cup-shaped portion shrinks and the spores come out through apical slits. This is brought about by cohesion owing to **hygroscopic changes** in the apical and lateral part of the sporangial wall. This liberation of spores takes place at intervals in small masses.

The spores starts germinating inside the sporangium before their release; this is known as **precocious germination**. According to Goebel, the violent dispersal of spores is an adaptation for cross fertilization in that it helps to bring spores from different plants near each other. This is further proved by the protandrous nature of the strobilous.

(d) **Germination of microspore :** The microspore is a double layered structure and contains oil droplets. The outer wall **exospore** is much thicker (spiny) than inner **endospore**. It measures 15–50μ in diameter. The microspore on germination forms the male gametophyte. The structure and development of male gametophyte was first described by Slagg (1932). The first division leads to formation of a small prothallial cell and a large **antheridial cell**. The larger antheridial cell, by further divisions, gives rise to central group of **four primary androgonial cells**, surrounded by **eight jacket cells**. At this 13-

celled stage (1 prothallial + 8 jacket cells and 4 primary androgonial cells), the microspore is shed from microsporangium. Each of the central groups of cells divides and redivides and finally forms about 256 spirally coiled antherozoids with two flagella (biflagellated); the jacket cells disintegrate. It takes about three weeks for germination of microspore and formation of antherozoids or sperms.

(e) **Germination of megaspore :** The megaspore has three wall layers namely **exospore, mesospore** and **endospore**. It measures 1.5 – 5.0 *mm* in diameter. The megaspore on germination forms the female gametophyte. Generally the megaspore germinates inside the megasporangium (i.e., in *situ*). In some sps., megaspores are shed after the development of first archegonium, *i.e.*, in *S.kraussiana*, while in *S.apoda* and *S.rupestris*, megaspores are not liberated till a well developed embryo is formed.

During the development of **female gametophyte**, the protoplasm after contraction forms a small sac-like structure. The outer wall bursts into two layers, the exospore and mesospore. At this stage, megaspore contains a haploid nucleus which by division produces many nuclei. Wall formation takes place in the upper beak-like portion and a small-celled cellular tissue is formed. This is one celled thick at the sides and three celled thick in the middle. This is **female prothallus**. Some superficial cells at apex enlarge and act as **archegonial initials** and form the archegonia. The megaspore bursts exposing the female prothallus. Vestigial rhizoids develop.

Archegonium are sessile and embedded type and consists of very short neck having a **single neck canal cell** and a venter, having a single ventral canal cell and an egg.

(f) **Fertilization :** Usually the male gametophytes are shed from the microsporangium on the ground at 13-celled stage. Here they complete their development ultimately producing spermatozoids. These are liberated by the decay of the microspore wall. If the microspore falls near the mature female gametophyte, the sperms swim from the male gametophyte to reach archegonia and one sperm fuses with egg to form **zygote**. Water is necessary for fertilization and sperms are attracted due to **malic acid**.

(g) **Development of embryo or Sporophyte :** The oosphere after fertilization gets surrounded by wall and become oospore. The oospore (zygote) divides transversely into two cells, the upper epibasal cell which forms suspensor cell and the **hypobasal cell** which develops into embryo.

The embryo differentiates into foot, root, primary stem with two rudimentary leaves and rhizophore. By growth of stem and the root, the young sporophyte becomes independent of the gametophyte tissue and falls on the ground where the primary rhizophore forms roots that grow into the soil and the plant starts **independent life**.

In some species of *Selaginella*, the archegonial initial develop apogamously into embryo. In *S.intermedia*, no microspores are formed. Here the embryo develops **parthenogenetically** from the egg. In *S.helvetica*, the archegonia fails to open and here also parthenogenetic development of embryo is seen.

There is distinct **heteromorphic** alternation of generations in *Selaginella*.

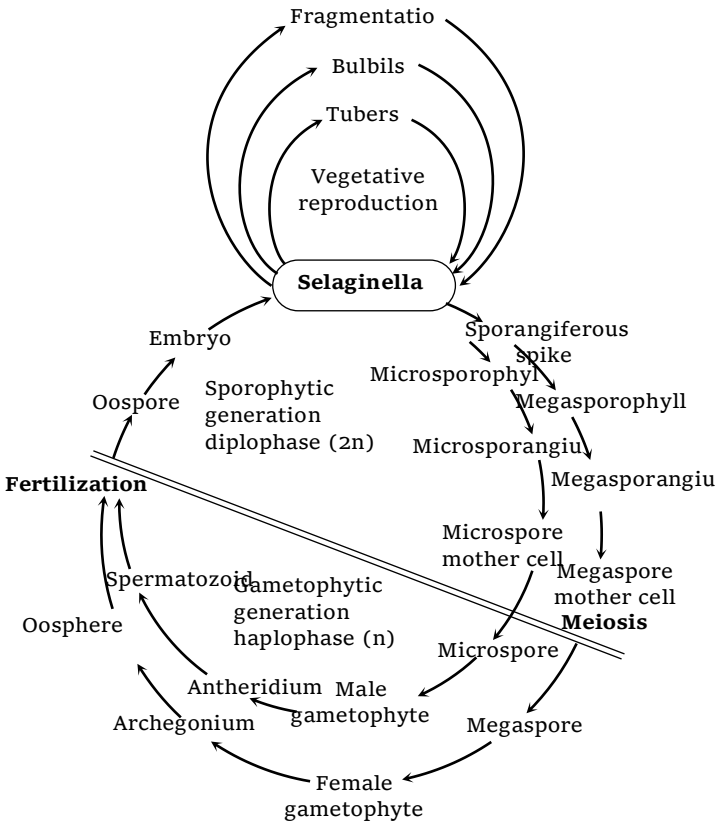


Fig : Graphical representation of life cycle of *Selaginella*

4.25 Pinus

Systematic position

Kingdom	–	Plantae
Sub kingdom	–	Embryophyta
Phylum	–	Tracheophyta
Class	–	Gymnospermae
Order	–	Coniferales
Family	–	Pinaceae
Genus	–	*Pinus*

(1) **Habitat :** It is commonly known as **pine** with about 90 species among which six species are found in India. (N. East and N. West Himalayas) occurring in wild state. These are *Pinus gerardiana* (Chilgoza pine), *P. Wallichiana (*Blue pine or Kail), *P.roxburghii* (Chir pine), *P.merkusii* (Teenasserin pine), *P.insularis (Khasi pine), and P.armandi (*Armand's pine*)*. In addition to these, 4 sps. of exotic pines, *i.e., P.montana, P.laricia and P.sylvestris* (Scotch pine) and *P.strobus* (white pine) have been introduced in India. *P.excelsa* are found at maximum height *i.e.* grow upto 3500 m above see level.

(2) **Structure**

(i) **External structure :** *Pinus* is an evergreen, perennial plant of xerophytic nature. Mostly the species are tall and straight. The whorled branching gives a typical **conical** or **excurrent appearance** to the plant (due to apical dominance). The plant body is **sporophyte** and the plants are monoecious. The plant body is differentiated into roots, stem and leaves.

(a) **Root :** A prominent tap root is present which does not penetrate deep into the soil. Lateral roots which develops later, grow extensively and help in anchoring the plant in the soil. Root hairs are scanty. Ectotrophic mycorrhiza *i.e.* symbiotic association of some fungal hyphae with the ultimate branches of roots, is of common occurrence.

(b) **Stem :** The stem is erect, thick, cylindrical and branched. The branching is **monopodial** type. The main stem is covered by scaly bark. Branches are developed from the buds present in the axil of scale leaves and appear to be in whorls. These branches develop every year and help in calculating the age of the plant.

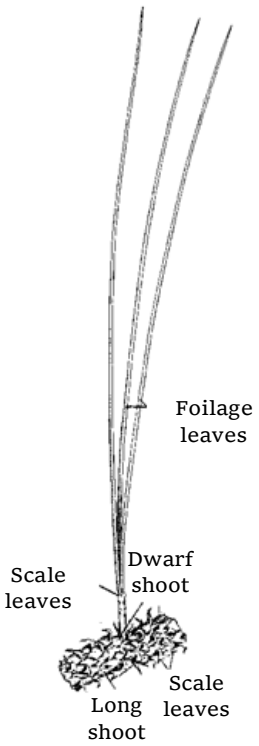


Fig : A part of *Pinus* stem showing two types of branches (long and dwarf) and two types of leaves(scale and foliage leaves)

Branches are of two types :

- **Long shoots or Branches of unlimited growth :** These have apical buds, grow indefinitely in whorls each year from the buds in the axil of scale leaves. These shoots spread out horizontally and bear scale leaves on them.
- **Dwarf shoots or Branches of limited growth :** These branches lack apical buds and grow for a definite or short period. They arise in the axil of scale leaves on long shoots.

(c) **Leaves :** The leaves are of two types *i.e.*, **dimorphic** – scale leaves and foliage leaves.

- **Scale leaves :** The scale leaves are small membranous and brown. They are present on both types of branches (*i.e.* long and dwarf shoots). Scale leaves are non-photosynthetic. These protect the young buds.
- **Foliage leaves :** The foliage leaves are green, needle like and are born at the tips of the dwarf shoots only. Their size and number is different in different species. The dwarf shoot with needles is called a **spur**. On the basis of number of needles, spur is of different types as :

Monofoliar (with one needle), *e.g.*, *P. monophylla*.

Bifoliar (with two needles), *e.g.*, *P. merkusi* and *P. sylvestris*.

Trifoliar (with three needles), *e.g. P. gerardiana* and *P. roxburghii.*

Pentafoliar (with five needles), *e.g.*, *P. wallichiana*, *P. occelsa.*

(ii) **Internal structure**

(a) **Root :** The young root of *Pinus* is identical with the dicot root. A T.S. of root reveals the following structures.

- **Epiblema :** It is the outermost layer of compactly arranged cells. It gives out many thin and unicellular root hair.
- **Cortex :** It is composed of many layered of thin walled parenchymatous cells.
- **Endoermis :** A single layer of suberized cells.
- **Pericycle :** Endodermis is followed by multilayered pericycle.
- **Vascular tissues :** Radial vascular bundles are present.

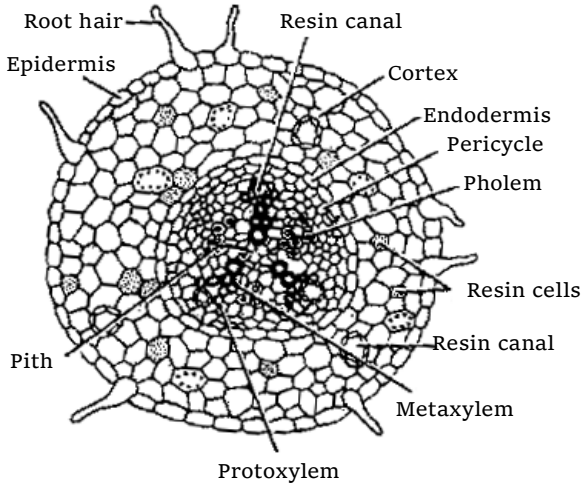


Fig : T.S. of young root of *Pinus*

Xylem : Exarch condition with bifurcated (Y-shaped) protoxylem. Resin canal is present between two arms. Xylem is devoid of vessels.

Phloem : Alternating with the xylem groups are present phloem patches. Companion cells are absent.

Pith : Pith is generally absent. If present, it is very small and made-up of parenchymatous cells.

- **Secondary growth :** In young roots, cambium is absent but at maturity below the phloem patches, arches of cambium are formed. It cuts off secondary xylem on the inner side and secondary phloem on the outer side.

The cells of the outermost layer of pericycle form **cork cambium** (phellogen), which cuts off **phellem** (cork) on the outer side and **phelloderm** (secondary cortex) on the inner side. Finally epiblema ruptures and the cork layer is exposed.

(b) **Stem :** T.S. of a young shoot shows following tissue.

- **Epidermis :** It is the outermost layer made up of small compactly arranged cells (heavily cuticularised).
- **Hypodermis :** Below epidermis are 4–5 layers of **sclerenchymatous cells** constituting hypodermis.
- **Cortex :** Inner to the hypodermis is a wide zone of cortex, some cells are filled with **tanin**.
- **Endodermis :** It is the innermost layer of the cortex, made-up of single layer of cells.

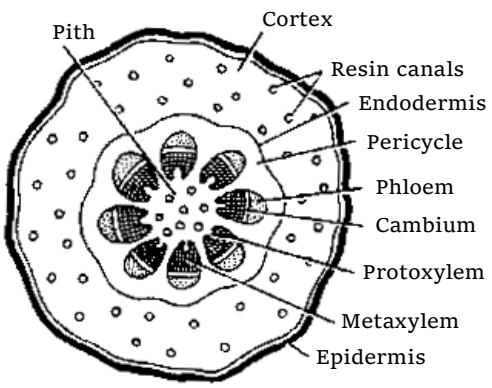


Fig : T.S. of young stem of *Pinus*

- **Vascular cylinder (Stele) :** It is of eustelic type having a ring of 5–8 closely arranged vascular bundles. Vascular bundles are conjoint, collateral and open.

Xylem : It is endarch, consists of only tracheidal cells, **vessels are absent**. Therefore wood is known as non-porous.

Protoxylem consists of annular and spiral tracheids. **Metaxylem** tracheids have uniseriate bordered pits on their radial walls. These are also having **bars of sanio**.

Phloem : It is situated on the outer side of vascular bundle and is made-up of phloem parenchyma and sieve cells. Companion cells are lacking.

Cambium : In between the xylem and phloem of each vascular bundle, there is a strip of intrafascicular cambium.

Medullary ray : In between the vascular bundles is a zone of parenchymatous cells connecting the pith and the cortex.

Pith : In the centre of the stem is a zone of thin-walled parenchymatous cells known as pith. Some of the pith cells are filled with resinous substances.

- **Secondary growth :** Secondary growth is similar to that of dicot root. Wood is pycnoxylic and monoxylic. Vascular rays are linear (uniseriate) but fusiform (multiseriate) area of pasage of resin ducts. Some of the parenchymatous cells in between the adjacent vascular bundles form interfascicular cambium. Both inter and intrafascicular cambium form a complete ring of cambium. These cambium cells cut cells on the inner side forming secondary xylem and on outer side secondary phloem.

The ring of primary cambium remains active only for a year. The activity of the cambium stops in the winter season and again resumes in the following spring. The secondary xylem thus formed clearly shows a number of annual rings. Each annual ring consists of a zone of spring wood and autumn wood.

Autumn wood : It is formed during autumn season and the cells of this wood are smaller, squarish and thick.

Spring wood : It is formed during spring season. The cells of this wood are thinner, large and polygonal. The wood is termed as pycnoxylic (compact and hard).

(c) **Leaf (Needle) :** The outline of foliage leaf varies according to the number of needles in the spur, *i.e.* in monofoliar spur of *P. monophylla*, it is circular, in bifoliar spur of *P.sylvestris*, it is semicircular and is triangular in trifolial spur of *P. roxburghii*. Internal structure of the needle is same in all species of *Pinus*. Needle shows xerophytic characters.

- **Epidermis :** It has a single-layered, thick-walled epidermis, covered with thick cuticle and is interrupted by sunken stomata throughout the surface (amphistomatic).

- **Stomata :** Each stoma has two guard cells and two subsidiary cells. It opens outside into a cavity called vestibule and inside into a substomatal cavity.
- **Hypodermis :** Below the epidermis is present a few layered thick sclerenchymatous hypodermis. It helps in mechanical support.

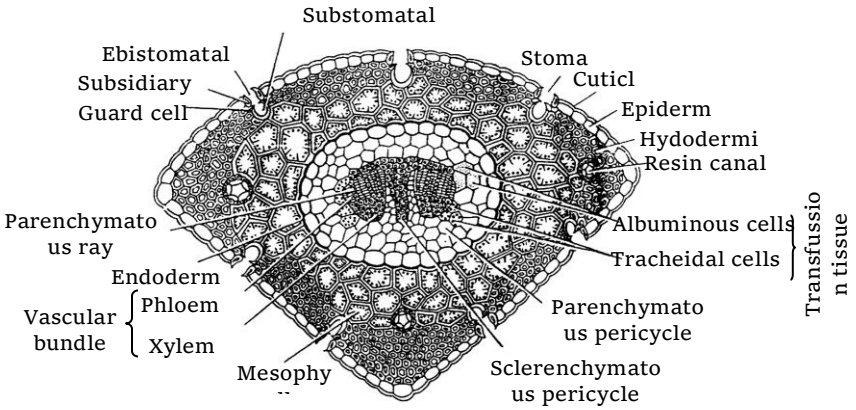


Fig : T.S. neddle of *Pinus roxburghii*

- **Mesophyll :** There is **no differentiation** into palisade and spongy parenchyma. The cells of this region are thin-walled, parenchymatous, polygonal, compactly arranged, having chloroplasts and starch grains. Peg-like infoldings arise from the inner surface.
- **Vascular cylinder :** It is surrounded by single-layered endodermis having barrel-shaped cells with casparian strips.
- **Pericycle :** Just below the endodermis is multilayered pericycle having a "T" shaped mass of sclerenchymatous cells between two vascular bundles. Transfusion tissue occurs on the side. Each bundle is collateral, open and endarch.

The needle of *P.monophylla* has a **single** vascular bundle whereas in *P.roxburghii*, the number is **two**.

(3) **Reproduction :** *Pinus* reproduces only sexually. *Pinus* plant represents sporophytic generation. Unlike *Cycas*, here the micro and megasporophylls form compact male and female cone or strobilus respectively. The megasporangia are produced on **ovuliferous scales** formed along with a bract. The ovuliferous scales and bracts constitute the **female cone**. The cones are generally monosporongiate. Rarely bisporangiate cones are formed in *P. roxburghii*, *P. montana* and *P. maritima*.

(i) **Male cone or Staminate strobilus :** The male cones are borne in a cluster on a branch of unlimited growth behind the apical bud, in the axil of a scale leaf. A male cone is, thus, equivalent to a dwarf shoot. In a cluster, there may be 15–140 male cones. The male strobilus is an ovoid structure measuring 2 to 4 cms. in length and 0.5 to 0.7 *cms*. in diameter. A cone consists of a central axis bearing 60–135 microsporophylls in spiral manner. It is, therefore, comparable to male flower of angiosperms.

(a) **Microsporophyll :** The microsporophylls or 'stamens' are spirally arranged in a compact manner on the cone axis. The microsporophyll is a brown coloured triangular structure consisting of a short stalk or 'filament' and a leaf like flattened structure of 'anther'. Each sporophyll is provided with

two microsporangia on its abaxial surface. The terminal sterile portion of the sporophyll is turned upward to protect the upper sporangia. It is called **apophysis**. Some of the lower microsporophylls are sterile having no sporangia associated with them.

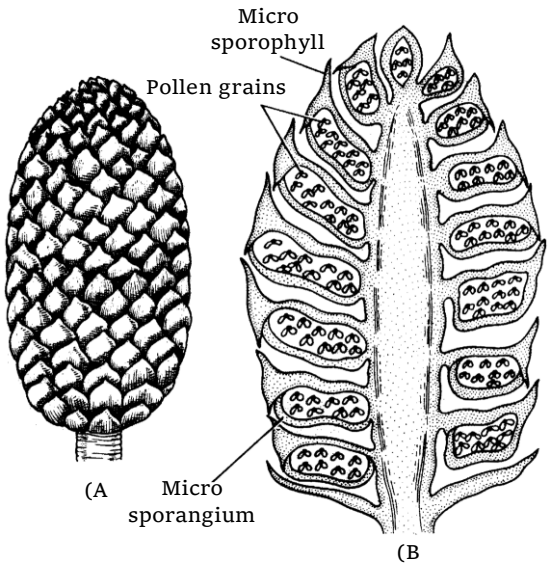


Fig : (A) A young male cone of *Pinus*
(B) Male cone in radial longitudinal section

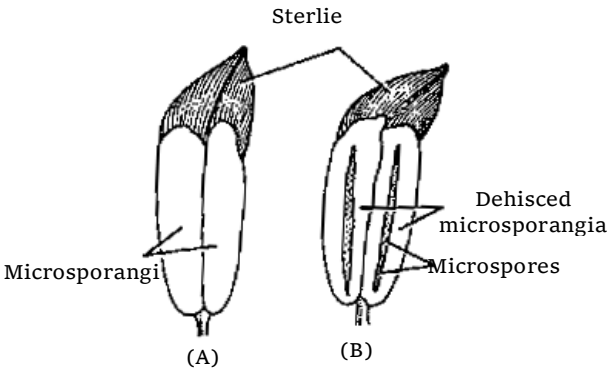


Fig : *Pinus* (A) Ventral view of microsporophyll
(B) Ventral view of microsporophyll with dehisced microsporangia

(b) **Microsporangium :** The microsporangia are sessile elongated, cylindrical, structures. The sporangial development is of **eusporangiate type**. Each sporangium consists of a 2–3 layered wall. The inner most wall layer is called tapetum, which encloses a mass of sporogenous tissue. The sporogenous cells divide and re-divide and finally behave as microspore mother cells or pollen mother cells (PMS). The PMS undergo meiosis to form tetrahedral tetrads of microspores. The tapetum is a nutritive layer which degenerates at maturity of the anther.

(ii) **Female cone :** The female cone is an elongated, ovoid structure comprising a central cone axis on which the ovuliferous scales and bracts are spirally arranged in acropetal order. Usually the cone is 15 – 20 *cms*. long but in *P. lambertiana* they are 60 *cms*. long. The female cones take three years time to develop and mature.

The cones are produced in clusters of 1 to 4 from places where normally dwarf or spur shoots have developed. They arise in a group of 1 – 4 cones on a long shoot in the axil of a scale leaf in place of a dwarf shoot. In the first year, the female cone is reddish-green measuring about 1–2 cms in length having compactly arranged sporophylls. The second year cone is much larger, again with compact sporophylls. In the third year, the cone axis elongated and hence the sporophylls separate from each other.

(a) **Megasporophyll :** Each megasporophyll is differentiated into two parts – Lower part is bract scale and upper part is ovuliferous scale.

- **Bract scales :** These are small, dry, membranous structures attached with the cone axis directly. These are also known as carpellary or cover scales. At the time of maturity, these bract scales become rolled up and thus help in the dispersal of seeds.

- **Ovuliferous scale :** This is a woody, brownish structure borne on the dorsal side of the bract scale. Each ovuliferous scale is triangular with narrow basal part and upper broader part in the form of disc, known as apophysis. The apophysis appears to be rhomboidal and possesses a small point known as **umbo**. On the dorsal side, near the base of each ovuliferous scale, are attached two ovules with their micropyles directed towards the cone axis. Florin gave the term **seed scale complex** to the bract scale along with associated ovuliferous scale.

Fig : Female cone of *Pinus*

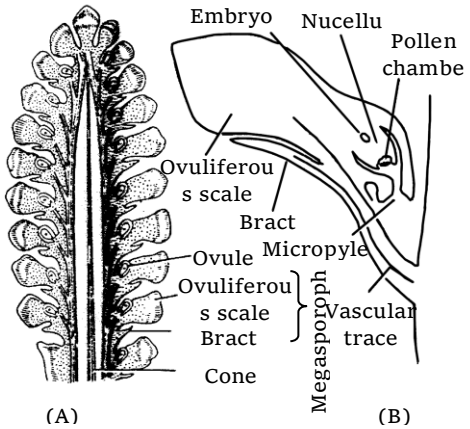


Fig : *Pinus* (A) Longitudinal section of female cone (B) A megasporophyll

(b) **Megasporangium :** Each ovule is an oval and anatropous structure consisting of a central mass of parenchymatous tissue, the nucellus, surrounded by a two lipped protective covering the integument which is united with nucellus except at the micropylar end where it prolongs to form a short tube beyond the nucellus. A small space is left in the upper region of nucellus below the integument, which is known as pollen chamber. Integument is differentiated into 3 layers although differentiation is not so distinct as in *Cycas*.

Outer fleshy layer : Made up of thin walled cells which disappears at maturity.

Middle stony layer : Very conspicious.

Inner fleshy layer : Inner fleshy layer is well developed.

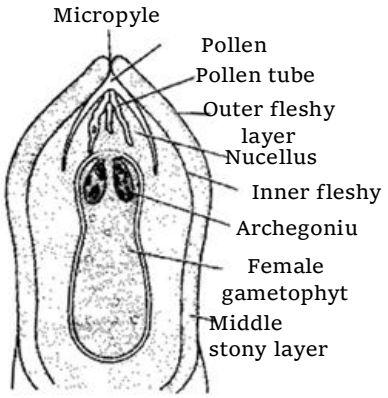


Fig : *Pinus* : L.S. of ovule showing archegonia and pollen

At the apex of the nucellus, a hypodermal cell gets enlarged and differentiated, it is called archesporial cell. The archesporial cell divides periclinally into an upper tapetal cell which forms **tapetum**, the nourishing layer, and the lower megaspore mother cell. This megaspore mother cell (sporogenous cell) divides reductionally to form a linear tetrad of haploid megaspores. Out of the four megaspores, three lying towards the micropyle degenerate. The chalazal one matures into a **functional megaspore**.

(iii) **The gametophyte :** The sporogenesis results in the formation of micro and megaspores representing the first gametophyte cells. They undergo gametogenesis so as to form the male and female gametophytes respectively.

(a) **Male gametophyte :** The unicelled microspore undergoes three divisions of mircogametogenesis, so as to form a four-celled pollen grain or microgametophyte or male gametophyte. There are two prothallial cells, a generative cell and a tube cell. The pollen grains, at maturity are protected by three wall layers. The outermost wall layer, called exine or cappa is cutinised. the second wall layer is called exointine or capulla. It forms two balloon like outgrowths, on either side, called wings or saccus. The third wall layer is thin and called intine or tenuitas. A maturity the microsporangia dehisce by a longitudinal slit and the pollen grains are dispersed at 4 – celled stage. Since, a large number of grains are set free from a cluster of male cones in the form of pale-yellow cloud the phenomenon is often described as **shower of sulphur** or **shower of golden dust**.

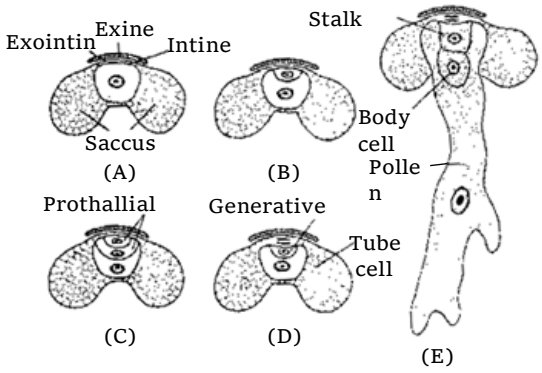


Fig : *Pinus* : (A)-(E) Various stages of microgametogenesis

(b) **Female gametophyte :** The functional megaspore enlarges. A vacuole develops in the centre and then its nucleus divides freely to form about 2000 nuclei. Initially, multinucleate tube like cells are formed called **alveoli**. Later, wall formation starts from periphery and proceeds towards the centre. As a result, cellular female gametophyte or female prothallus or megagametophyte or **endosperms** is formed. The cells of the nucellus surrounding the female gametophyte now get modified and form a nutritive layer called endosperm jacket or spongy layer. The 'endosperm' of *Pinus* is a haploid gametophytic tissue formed before fertilization.

Archegonium : Near the micropylar end, one to five archegonia are differentiated in the prothallus. Each archegonium at maturity consists of eight neck cells arranged in two tiers of four each and a venter having a small ventral canal cell and a large egg. The ventral canal cell disorganizes before fertilization. **Neck canal cells are absent**.

(iv) **Pollination :** The pollination in *Pinus* is anemophilous. The wings of pollen grains are helpful in pollination. Just before pollination the female cone axis elongates separating megasporophyll from each other. This fascilitates pollen grains to reach ovules. There is a long interval of about a year between pollination and fertilization.

(v) **Post pollination changes in the male gametophyte :** The exine ruptures and the intine protrudes out to from the pollen tube that grows through the nucellar tissue. Simultaneously, the generative cell divides to form a stalk cell and body cell. The body cell then divides to form two male gametes, which are non-flagellate.

(vi) **Fertilization :** The mode of fertilization was discovered by Goroschankin (1883). After reaching the neck of the archegonium, the tip of the pollen tube ruptures releasing the two male

gametes. The ventral canal cell degenerates and the neck cell split apart. Out of the two, one male gamete fuses with the egg to form the zygote. The second male gamete along with the stalk and body nuclei degenerates.

(vii) **Embryogeny :** The proembryonal development in *Pinus* was studied by Buchholz (1918). The zygotic nucleus moves toward the base and then divides to form four nuclei. These nuclei organise into four quadrately arranged (diagonally opposite) cells with open upper end. The four cells divide simultaneousing thrice to form four tiers of four cells each. These tiers are designated from top downwards as open tier, rosette tier, suspensor tier and apical tier. Since only a part of the oospore is involved in the formation of the embryo, the development is said to be meroblastic.

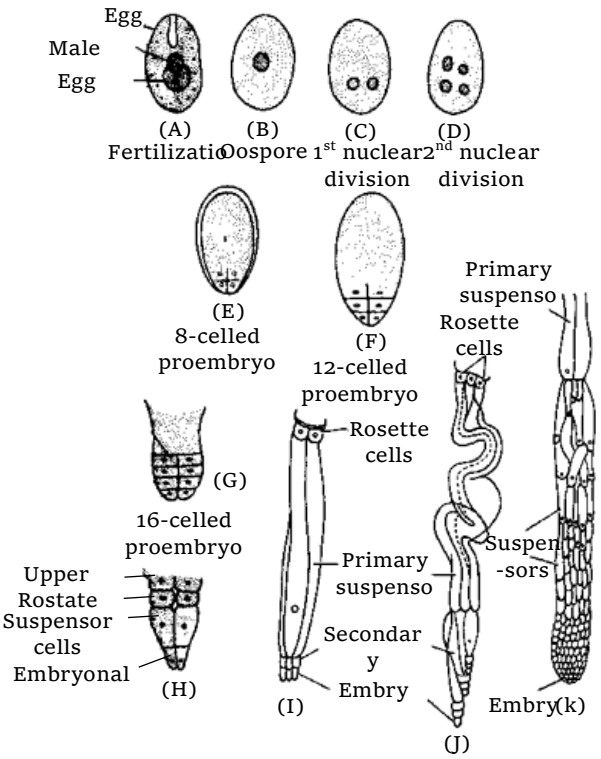


Fig : *Pinus* : Embryogeny

As there is no cell wall on the micropylar end, the cells of open tier provide nutrition to the remain tiers of the proembryo. The cells of this tier do not divide. The cells of rosette tier divide in various planes. They simply conduct the food obtained by the cells of open tier. The cells of suspensor tier elongate pushing the embryonal cells into the 'endosperm'. The four suspensor cells due to considerable elongation may become coiled. These cells may divide transversely to form secondary suspensor or **embryonal tubes**. By another transverse division, two whorls of embryonal tubes, designated as first and second series of embryonal tubes, are formed. All the four cells of embryonal tier separate from one another and develop into four independent embryos. The formation of more than one embryos from one oospore is called cleavage polyembryony. Another type of polyembryony found in *Pinus* is simple polyembryony *i.e.* when more than one embroys are developed as a result of fertilization of different archegonia. Thus in *Pinus* although both types of polyembryony are found but at maturity seed contains only one embryo as food is not sufficient for survival of many embryos. The embryo soon gets differentiated into radicle, plumule, hypocotyl and cotyledons. The number of cotyledons is always more than two (Schizocotyly).

(viii) **Seed formation :** Seed of *Pinus* is winged. The wing develops from the upper surface of ovuliferous scale. Seed has thin withered outer coat, which is pieled off, a stony coat, papery coat, cap like perisperm and food laden endosperm which encloses a central embryo. Embryo possesses 9–14 cotyledons (*P.roxburghii*). A seed represents three generations – parents sporophyte (tesla, tegmen and perisperm, if present), new sporophyte (embryo) and female gametophyte or endosperm.

(ix) **Seed germination :** The seeds may remain dormant for several years. The germination of seed occurs when the environmental conditions are favourable. The radicle protrudes out through the

micropyle and enters the soil forming the primary root. The plumule comes out and along with cotyledons it is pushed in air due to elongation of hypocotyl. The germination is, therefore, epigeal. The plumule forms a few **juvenile leaves** or prophylls. The juvenile leaves are spirally arranged on the branch of unlimited growth. Long shoots arise in their axis. Later on, they dry up as scales. The rate of growth of *Pinus* is quite slow.

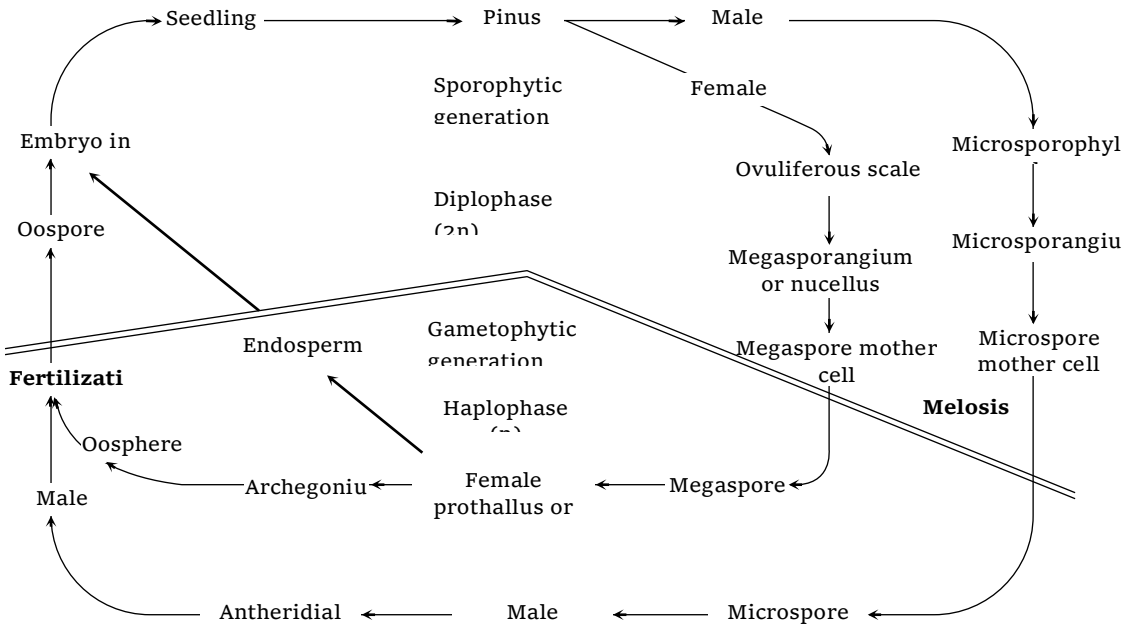


Fig : Graphical representation of life cycle of

(4) **Economic importance :**

(i) Seeds of some species are edible *e.g., P. gerardiana* (chilgoza), *P. edulis*.

(ii) Fossilized resin (amber) is obtained from *P. succinifera* and is of great commercial value.

(iii) Some species of *Pinus* are cheap source of cellulose.

(iv) Some species are used for manufacture of paper.

(v) Wood gas, wood tar and wood alcohol are obtained from *Pinus*.

(vi) Wood of *Pinus* is used for making furniture, electric poles, doors, windows, match sticks *e.g.*, *P. longifolia* (chir) and *P. excelsa* (kail)

4.26 Cycas

Systematic position

Kingdom	–	Plantae
Sub kingdom	–	Embryophyta
Phylum	–	Tracheophyta
Class	–	Gymnospermae

Order – Cycadales

Family – Cycadaceae

Genus – *Cycas*

(1) **Habitat :** *Cycas* is an evergreen palm-like plant. It is the only genus of family Cycadaceae represented in India. *Cycas* has approximately 20 species found in Australia, New Zealand, Japan, China, India, Burma (Myanmar) and Pacific Islands.

In India, four *Cycas* species are common in Orissa, Bengal, Assam, Tamilnadu, Karnataka and Andaman.

(i) ***Cycas revoluta* :** It is a native of China and Japan and is locally called **Tesso**. In our country, it is called 'Sagopalm'. Due to its primitive characters, it is also called living fossil. It is upto 10 ft tall.

(ii) ***Cycas circinalis* :** Plants are about 12 to 15 ft tall and distributed upto 3500 ft. In Hindi, it is called as Janglimadan mast-ka-phul.

(iii) ***Cycas rumphii* :** Plants are about 12 ft tall. It is also cultivated in Indian gardens. In Tamil, it is called **Kama**, Paiyindu.

(iv) ***Cycas beddomei.***

(2) **Structure**

(i) **External structure :** Fully grown plants attain a height of 2– 5 *m* although C. media attains a height of 20*m*. The main plant body is differentiated into root, stems and leaves.

(a) **Roots :** Roots arise from lower part of stem and are of two types :

- **Normal roots :** These form a primary tap root system. These roots are not green, positively geotropic with no root hairs.
- **Coralloid roots :** From the lateral branches of the normal roots are formed dichotomously branched, apogeotropic, bluish green coralloid roots. *Anabaena cycadacearum*, *Nostoc* and bacteria are found in their cortex and sometimes enter in these roots also. It is an example of symbiosis. It helps in fixation and absorption of nitrogen.

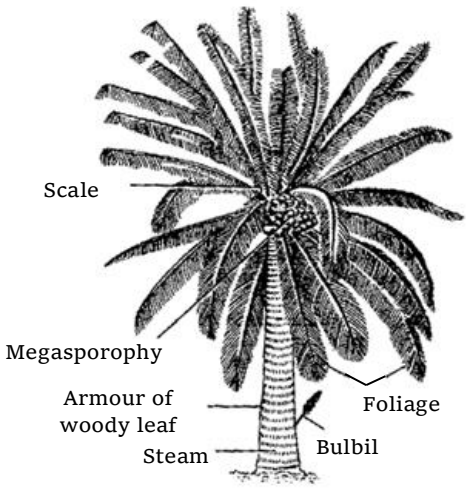


Fig : External morphology of Cycas

(b) **Stem :** Stem is thick, cylindrical, columnar, small, aerial and unbranched. It is covered with persistant leaf bases and scale leaves, which are found in alternate whorls. There is a crown of foliage leaves at the apex of the plant.

(c) **Leaves :** *Cycas* has two types of leaves (dimorphism).

- **Scale leaves :** These are reduced form of foliage leaves without lamella and are arranged in a compact spiral and alternate manner around the apex and no reproductive structures. These are protective in nature. A single scale leaf is a brown, dry, woody, triangular structure, covered with brown hairs or ramenta.
- **Foliage leaves :** These are green unpinnately compound present on the apex of the plant forming a crown. These leaves are upto 3 metres in *C. circinalis*. Leaves are leathery and thick, some leaflets at the base of the rachis are reduced to spines. These are mainly photosynthetic in nature.

Leaves in *Cycas* show xerophytic characters.

(ii) **Internal structure**

(a) **Root**

- **Normal root :** The structures of normal root resembles dicotyledonous root. T.S. of normal root reveals the following structures

Epiblema : This is the outermost layer with unicelled root hairs.

Cortex : Just below the epiblema is multilayered parenchymatous cortex. Some tannin cells are present in the cortex.

Endodermis : Below the cortex is present endodermis which is made up of barrel-shaped cells and below it is a layer of pericycle.

Vascular tissues : It consists of xylem and phloem which are radially arranged, *i.e.*, on different radii.

Pith : It is generally absent.

Secondary growth : It is like dicotledonous plants.

- **Coralloid root :** Structure of stele is similar to normal roots but cortex is divided into three zones :

Outer cortex : Having several layers of parenchymatous cells.

Middle cortex (Algal zone) : Filled with blue green algae, *Anabaena* and *Nostoc*.

Inner cortex : Having several layers of parenchymatous cells. Roots are diarch, triarch and sometimes polyarch.

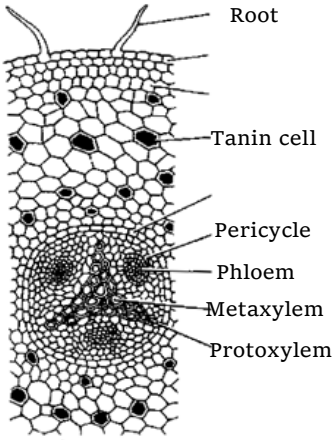


Fig : T.S. normal root of *Cycas*

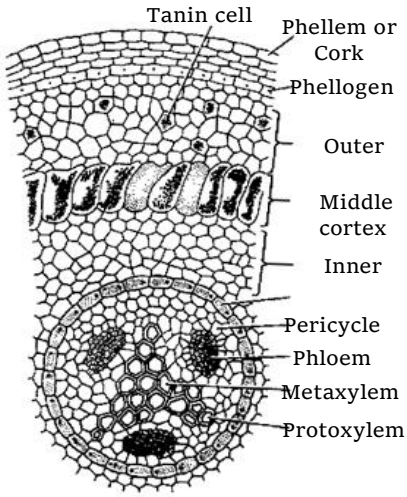


Fig : T.S. coralloid root of *Cycas*

(b) **Stem :** It resembles a dicotyledonous stem having the following tissues :

Epidermis : It is the outermost incomplete layer ruptured due to persistent leaf bases. It is made up of compactly arranged thick-walled cells.

Cortex : Cortex is large, thin-walled, parenchymatous, having a number of mucilage canals. Starch grains are found in the cortex.

Endodermis and pericycle : These layers are not very clear.

Stele : Vascular cylinder is very small having numerous small closely arranged vascular bundles, which are conjoint, collateral and open. Xylem is endarch and consists of tracheids, which have spiral thickening in protoxylem and scalariform thickenings in metaxylem. Phloem is devoid of companion cells. Albuminous cells are found in phloem.

Leaf traces : There are several leaf traces present in the cortex. Four vascular bundles enter the base of leaf, two of these are direct and other two arise from the stele of opposite side and after making semicircle, they enter the leaf. These indirect leaf traces are known as girdling leaf traces of leaf girdles.

Pith : It is large, parenchymatous and is having a number of mucilage canals. Starch grains are also found in pith.

- **Secondary growth :** The secondary growth in initiated by the formation of a cambium ring due to the development of interfascicular cambial strips and their subsequent joining with the intrafascicular cambia. This ring cuts secondary xylem on the inner side and secondary phloem on the outer side in additions to secondary medullary rays on both sides. This cambium ring now ceases to function another cambium now arises pericycle or inner layers of cortex. The new cambium functions in the normal way like the old one. Thus, concentric rings of secondary xylem and secondary phloem are formed. Such a wood is called as polyxylic *i.e.*, comprising more than one xylem cylinders. Due to the presence of alternating rings of thin walled tissue (phloem) the wood of xylem remains loose and hence it is described as manoxylic. The growth in the extrastelar region takes place by the formation of a phellogen (cork cambium) which cuts off phellum (cork) on the outer side and phelloderm (secondary

cortex) on the inner side. The three layers jointly constitute the periderm. The secondary growth pattern of *Cycas* resembles some dicots showing abnormal secondary growth. Secondary wood is devoid of vessels.

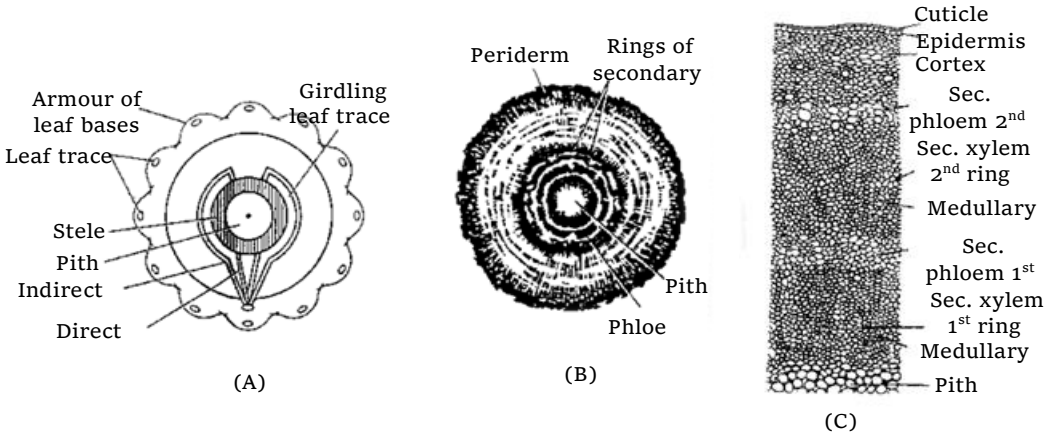


Fig : *Cycas*, T.S. of stem (A) Outline diagram of a young stem (B) Old stem showing polyxylic condition (C) A portion of stem showing two growth rings

The secondary xylem is made up of tracheids showing **multiseriate bordered pits**. Gregus (1958) however, reported the presence of vessels in *C. revoluta*. Bars of sanio have been observed by Sifton, 1915 in the tracheids of *C. revoluta*. The secondary phloem comprises sieve cells and fibers. de Bary, 1884, Miller, 1919 reported the presence of sieve tubes in the secondary phloem but this needs confirmation.

(c) **Leaf**

- **Rachis :** In cross section of the rachis is almost circular with two depressions on upper lateral sides where the leaflets are attached.

Epidermis : The outermost layer is epidermis with thick cuticle having stomata.

Hypodermis : Epidermis is followed by a well developed hypodermis, differentiated into outer chlorenchymatous and inner sclerenchymatous regions.

Ground tissue : Below the hypodermis is well developed parenchymatous ground tissue with mucilage canals. The vascular bundles are arranged forming in inverted omega (Ω). Each vascular bundle is surrounded by a sclerenchymatous sheath and is conjoint, collateral and open. In most parts of the rachis, xylem is **mesarch**, *i.e.*, centripetal xylem towards periphery and two patches of centrifugal xylem one on each side of protoxylem of centripetal xylem outside the centrifugal xylem is cambium and then phloem towards periphery.

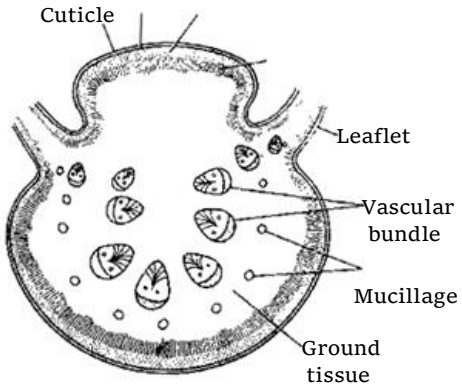


Fig : T.S. rachis of *Cycas*

- **Leaflet**

Epidermis : Epidermis is single layered with thick cuticle. The upper epidermis is complete whereas the lower epidermis is interrupted by several stomata present only in the region of blade (hypostomatic). Upper and lower epidermis are covered by layer of thick cuticle.

Hypodermis : Just below the upper epidermis, there are several layers of sclerenchymatous hypodermis while above the lower epidermis it is present only in the midrib portion.

Mesophyll : Mesophyll is differentiated into **palisade parenchyma** on upper side and **spongy parenchyma** on lower side. Palisade tissue is made up of vertically elongated cells without intercellular spaces. Both tissues contain chloroplasts.

Vascular bundle : In the midrib there is a large vascular bundle. The vascular bundle is collateral and closed. The xylem is mesarch, *i.e.* diploxylic condition with centripetal and centrifugal xylem.

Transfusion tissue : On each side of the midrib in between the palisade and spongy tissues is present transfusion tissue made up of horizontally arranged tracheids which supply water and mineral to mesophyll tissue upto margins.

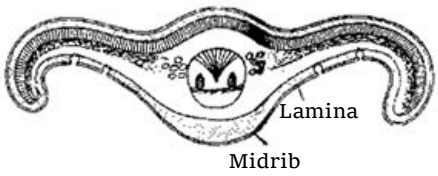


Fig : T.S. leaflet of *Cycas*

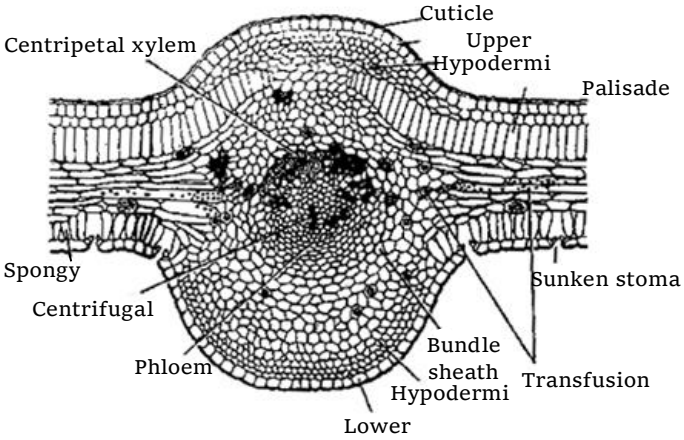


Fig : T.S. leaflet of *Cycas* (a portion

(3) **Reproduction :** *Cycas* plants are dioecious and reproduce by following methods :

(i) **Vegetative propagation :** It occurs by means of bulbils (resting adventitious buds) which are produced on the stem in the axil of scale leaves. They break up from the parent plant and germinate to give rise to new plant.

(ii) **Sexual reproduction :** Plant of *Cycas* is sporophyte (2*n*) and dioecious. The sexual reproduction is of oogamous type, *i.e.*, takes place by the fusion of distinct male and female gametes. The male and female gametes are formed by the germination of micro and megaspores which are born on microsporophylls and megasporophylls. the microsporophylls are grouped together to form a compact conical structure called male cone, whereas the megasporophylls are not aggregated to form a cone, they are produced at the apex of the stem in succession with the leaves.

Male cone : The male cones are borne every year singly at the apex of the male plant. The growth of the male plant is, therefore, checked. Later on, a lateral bud develops which pushes the male cone to one side and occupies a terminal position. The process is repeated during the formation of subsequent male cones. As such, the growth pattern of male plant is sympodial.

The male cone is a shortly stalked, oval or elliptical structure measuring about 40 – 60 *cms* in length. It may sometimes attain a length of 75 *cms*. in *C. circinalis*. Each cone consists of a central axis bearing numerous microsporophylls arranged in spiral manner.

(a) **Microsporophylls :** They are wedge - shaped structures with a slightly broad base. They are soft and fleshy in the younger stages. At maturity, they are hard and woody. They measure about 3 – 4 *cms*. in length and 1.2 – 2.3 *cms*. in breadth. They bear sori of sporangia on the abaxial (lower) surface. The terminal sterile portion of the sporophyll is called **apophysis**. In the apophyseal region the sporophyll gradually tapers and points upward.

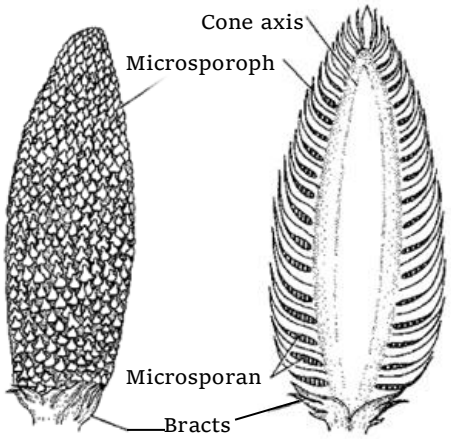


Fig : *Cycas* : (A) External view of male cone (B) L.S. of male cone

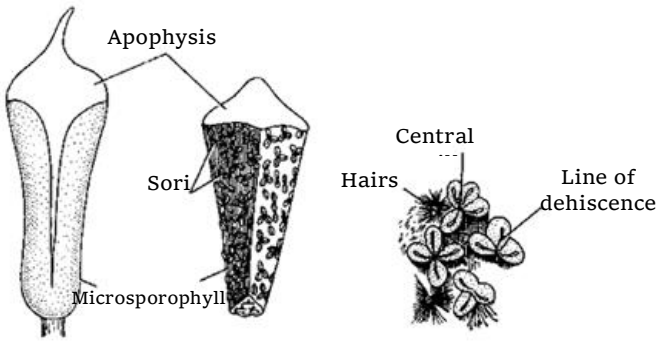


Fig : *Cycas* : (a) Dorsal view of microsporophyll (b) Ventral view of microsporophyll (c)

- **Microsporangium :** The microsporangia are borne in sori on the abaxial surface of the sporophyll. Each sorus contains 2 – 6 microsporangia. The number of microsporangia may be upto 700 in *C.circinalis*, 1000 in *C. revoluta* and 1150 *C.media*. In between the sporangia are present uni or bicelled epidermal hair. The microsporangia are short-stalked, oval or elliplical structures. The development of the sporangium is of eusporangiate type. Each sporangium consists of a 5 – 6 layered wall. The outer most wall layer is called as exothecium whereas the innermost layer is the **tapetum**. The tapetum encloses the sporogenous tissue. The sporogenous cells divide and re-divide to form the microspore mother cells or pollen mother cells (PMC). The PMC undergo meiosis to form tetrahedral tetrads of spores. The cells of exothecium develop a thickening along their radial and inner tangential walls. The cells of tapetum and inner wall layers degenerate at maturity to provide nutrition to the developing pollen grains. The wall of a mature sporangium, thus comprises exothecium only.

(b) **Megasporophyll :** The megasporophylls are spirally borne in acropetal order on the female plant. Since they are loosely arranged, there is no female cone formation. Each megasporophyll is regarded as a **modified foliage leaf** and is about 5 – 10 inches long. In the female plant therefore, the apical meristem remains unaffected. Hence, the growth pattern in the female plant is monopodial.

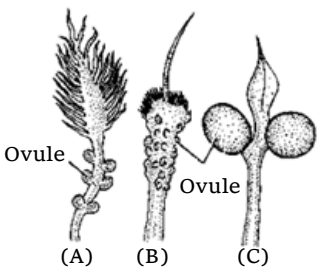


Fig : (A)-(C) Megasporophylls of different species of *Cycas*

The megasporophylls is are flat, dorsiventral structures distinguishable into a proximal stalk or rachis part and a distal lamina. The margin of lamina is serrate or dentate in *C. circinalis, C. beddomei and C.*

rumphii. In the upper part of the rachis are present 1 – 6 pairs of ovules, laterally. This number is variable in different species *e.g.*, 1 – 6 pairs in *C. revoluta, C. circinalis* and only one pair in *C. normanbyana*.

- **Megasporangium (Ovule) :** The ovules of *Cycas* are **largest** in nature, can be seen by naked eyes. In *C. circinalis,* the ovules are largest in size, *i.e.*, about 6 *cm* in length and 4 *cm* in diameter.

The ovules are orthotropous and unitegmic. The main body of the ovule is **nucellus**, covered by a single thick integument except at the top where a small opening is left called **micropyle**.

The integument is distinguishable into three layers, an outer fleshy layer (sarcotesta), middle stony layer (sclerotesta) and inner fleshy layer (sarcotesta). The outer and inner fleshy layers are vascularised as also the nucellus by separate bundles. The apex of the nucellus develops a beak-like process, the nucellar beak, which projects into the micropyle.

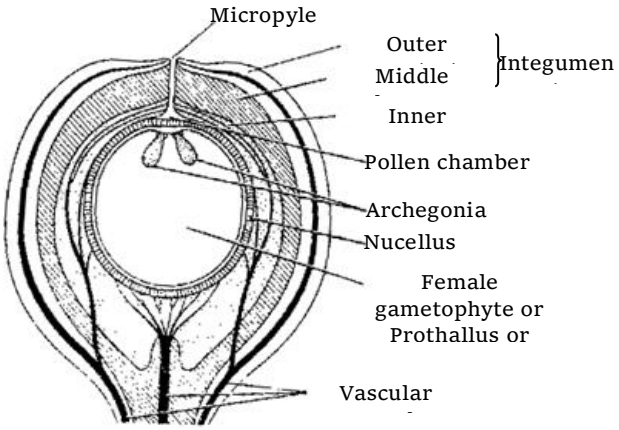


Fig : L.S. megasporangium (ovule) of

Somewhere in the deep layers of nucellus a megaspore mother cell in differentiated. It has a prominent nucleus and dense cytoplasm. It undergoes meiosis to form a linear tetrad of megaspores. Of these, three micropyler megaspores degenerate and the lowest functions. The functional megaspore has a thick papillate outer wall called exospore and a thin, fibriller inner wall, the endospore.

(c) **The gametophyte :** As a result of sporogenesis, the micro and megaspores are formed. They are the first gametophytic cells. The microspores give rise to the male gametophyte whereas the megaspores form the female gametophyte. The gametophytes reproduce sexually.

- **Male gametophyte :** The unicelled microspore undergoes two divisions of microgametogenesis and as a result three cells are formed. These three cells are serially designated as tube cell, generative cell and prothallial cell. At this stage the pollen grain is double layered. The outer wall exine is much thicker than intine. The microsporangium dehisces by a longitudinal slit and pollen grains are dispersed at **3-celled stage**.
- **Female gametophyte :** The nucleus of the functional megaspore divides freely to form a free-nuclear gametophyte. A vacuole appears in the centre. Wall formation now begins from periphery and gradually proceeds towards the centre. As a result, cellular female prothallus or megagametophyte or **endosperm** is formed. The 'endosperm' in *Cycas* is a haploid gametophytic tissue formed before fertilization. This is nutritive in function. Simultaneously, a tiny space develops on the upperside of the ovule between nuclellus and the female gametophyte due to degeneration of certain nucellar cells. This is called as archegonial chamber.

Archegonium : The archegonia are formed from the gametophytic cells lining the archegonial chamber. The number of archegonia formed in a gametophyte is variable *e.g.*, 2 – 8 in *C. revoluta*, 3 – 6 in *C.rumphii* and 3 – 8 in *C. circinalis*. An archegonium consists of a two celled neck but there is no

neck canal cell. There is no venter either. The egg and the ventral canal nucleus remain surrounded by the cells of prothallus. *Cycas* produces largest egg in the plant kingdom measuring 0.5 mm. in diameter.

(d) **Pollination :** The pollination is anemophilous. The pollen grains of *Cycas* are light in weight and easily blown away by wind at 3-celled stage (prothallial cell, generative cell, tube cell). At the time of pollination, a large pollination drop comes out of micropylar end of ovule by disorganisation of nucellar beak. The pollen grains are entangled on this drop and as it dries, the pollens are drawn into the pollination chamber.

(e) **Post pollination changes in the male gametophyte :** After a definite period of rest, the pollen grain germinates. The generative cell divides into a lower stalk cell and upper body cell. Body cell enlarges and forms several **blepharoplasts**, which later forms cilia.

The tube cell elongates, pierces the exine and forms a pollen tube. The pollen tube is slightly swollen and branched at tip. The pollen tube acts as haustorium absorbing food from nucellus. Body cell divides into two daughter cells and each daughter cell metamorphoses into one antherozoid or sperm or male gamete.

The male gametes of *Cycas* are largest (300μ) in nature, visible to naked eye and are oval in form, broad (top-shaped) and naked at posterior end and spirally coiled in the anterior half with thousands of small cilia. The sperms pass into pollen tube and reach the tip of the tube.

(f) **Fertilization :** After reaching the archegonial chamber, the tip of the pollen tube ruptures releasing the two male gametes. Besides, the tube also discharges a fluid having high concentration. When an antherozoid touches the neck cells, it is sucked in violently. By the time the ventral canal nucleus has already degenerated. As a result of syngamy, the zygote is formed. The fertilization in *Cycas* is, therefore, siphonogamous (by pollen tube) accompanied by **zooidogamy** (by flagellate gametes). Thus the fertilization brings to an end of the gametophytic generation and the zygote is the initial stage of sporophytic generation.

(g) **Embryogeny :** The zygote, which is the first sporophytic cell, undergoes free-nuclear divisions. A vacuole develops in the centre pushing the nuclei to the peripheral position. In the upper region there are only a few nuclei but the lower region contains numerous nuclei. This is followed by wall formation that begins from periphery and proceeds to centre (centripetal). The cellular proembryo so formed soon gets differentiated into three regions –

Upper : Haustorial region, **Middle :** Suspensor region and **Lower :** Embryonal region.

Proembryo forms almost all part of embryo. Suspensor cell elongates and pushes the proembryo down into the food laden tissue of the gametophyte. Suspensor continue to elongate till they form a exceedingly long, tortuous and often spirally coiled structure. Proembryo forms, plumule and two cotyledons. Tip of suspensor forms radicle. As there are several archegonia, several developing embryos may be found in one young seed (polyembryony) but only one remains at maturity and others perish (potential true polyembryony).

(h) **Seed formation :** The mature seed of *Cycas* is an orange-red or reddish-brown structure. The seed is covered by a thick testa. It is sweet in taste and emits pleasant odour. These two characteristics are responsible for the their zoochorus, (ornithochorous) dispersal. Major parts of nucellus and inner sarcotesta are used up by the developing embryo reducing them to thin, papery layers.

The seed of *Cycas* comprises tissues of three generations namely parent sporophytic (seed coat and nucellus), gametophytic (endosperm) and second sporophytic (embryo). The embryo is distinguishable into a haustorial tip, a long suspensor, radicle, hypocotyl, plumule and two cotyledons.

(i) **Seed germination :** There is hypogeal germination of *Cycas* seed. In germination, the radicle forms a tap root. The cotyledons remain in the endosperm under the surface of soil. The plumule grows up and forms some scale leaves and later foliage leaves. *Cycas* seed represents 3 generations :

Old sporophytic generation (represented by seed coat and nucellus), Female gametophytic generation (represented by endosperm), and Future sporophytic generation (represented by embryo).

Life history of *Cycas* is diplohaplontic. It shows heteromorphic or heterologous type of alternation of generations.

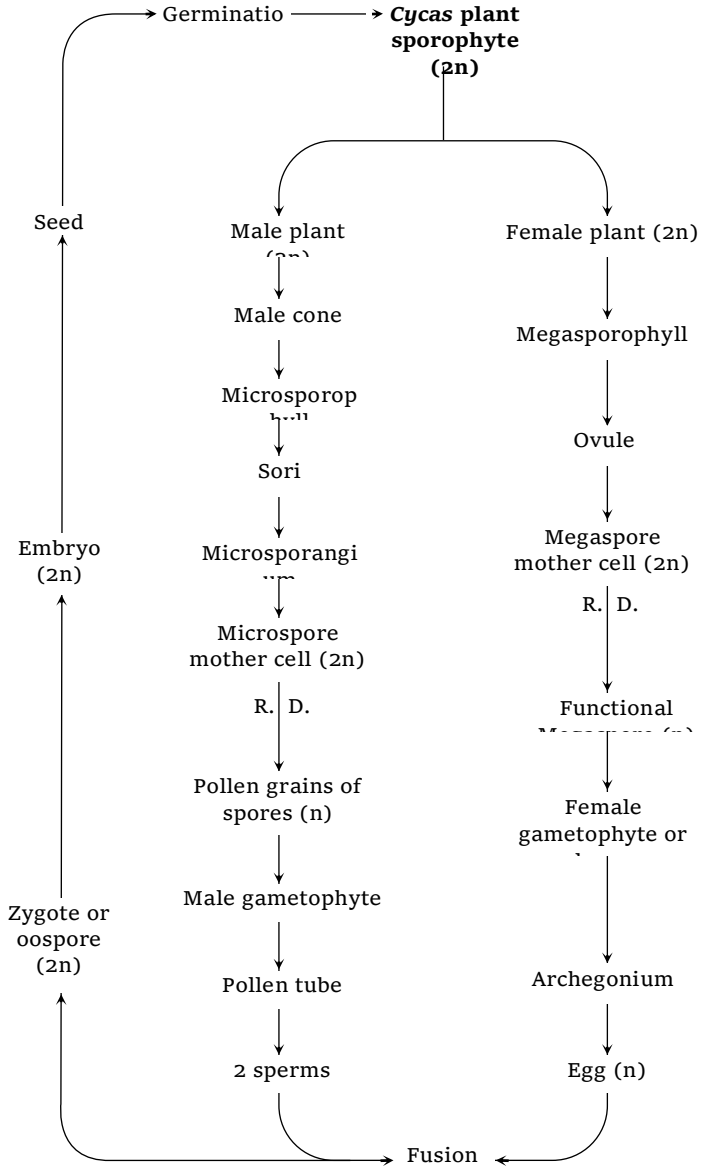


Fig : Graphical representation of life cycle of

(4) **Economic importance**

(i) A starch called sago is obtained from the pith of *Cycas*, that is why *Cycas* is called **sago palm**. In Japan starch extracted from stem of *C. revoluta* is used for preparing saboodana.

(ii) Seed of some *Cycads* are used as fodder for animals.

(iii) Leaves are used for making mats and baskets.

(iv) *Cycas* is an ornamental plants.

(v) Boiled young leaves are eaten as vegetables.

(vi) Extract of young *Cycas* leaves are used in the treatment of many skin diseases. The decoction of seeds is used as purgative. Tincture prepared from its seeds is used by Indians in headache, nausea, bad throat, etc.

ASSIGNMENT

GENERAL CLASSIFICATION

Basic Level

1. The science of naming the plant is known as
(a) Classification (b) Identification (c) Nomenclature (d) Taxonomy

2. The branch of Botany concerned with the classification, nomenclature and identification of plants is
(a) Systematic Botany (b) Ecology (c) Morphology (d) Physiology

3. Linnaeus is credited for introduction of
(a) Binomial system of nomenclature (b) The principle of independent assortment
(c) The concept of inheritance of acquired characters
(d) The law of limiting factors

4. The basic unit of classification is
(a) Genus (b) Species (c) Family (d) Order

5. Who proposed the Binomial Nomenclature System
(a) Whittaker (b) Mendel (c) Carl Linnaeus (d) Tippo

6. Five kingdom classification was proposed by
(a) Birbal Sahni (b) Whittaker (c) Aristotle (d) Oswald Tippo

7. Linnaeus system of plant classification is
(a) Artificial (b) Natural (c) Phylogenetic (d) None of these

8. The complete name of a plant in binomial nomenclature has
(a) Three parts (words) (b) Two parts (words) (c) Five parts (words) (d) One part (words)

9. Identify the correct sequence of taxa in Linnaean hierarchy
(a) Species**,** genus**,** family**,** order**,** class (b) Class, family, species, genus, order
(c) Phylum, class, family, species, order (d) Species, genus, phylum, family, class

10. Which of the following taxonomical ranks contain organisms least similar to one another
(a) Class (b) Genus (c) Family (d) Species

11. Which is a taxon
(a) General (b) Family (c) Class (d) All the above

12. Evolutionary classification is called
(a) Artificial system (b) Natural system (c) Phylogenetic system (d) None of these

13. Hierarchical classification means
(a) To divide division into classes (b)To divide classes into orders
(c) To divide orders into families (d)To rank things one above the other

14. Which of the following statements regarding nomenclature is correct
(a) Generic name always begins with capital letter whereas specific names does not
(b) Scientific name should be printed in italics
(c) Scientific names when typed or handwritten should be underlined
(d) All statements are correct

15. Who amongst the following is regarded as the "*Father of Taxonomy*"
(a) Takhtajan (b) Linnaeus (c) Bentham and Hooker (d)Theophrastus

16. Binomial nomenclature means writing the name of plant in two words, which designate
(a) Genus and species (b) Species and variety (c) Order and family (d) Family and genus

17. Who did propose natural classifications of plants
(a) Carolus Linnaeus (b) John Hutchinson (c) Bentham and Hooker (d)Oswald Tippo

18. In Botanical nomenclature of plants
(a) Genus is written after the species
(b) Both in genus and species the first letter is a capital letter
(c) Genus and species may be same name (d) Both genus and species are printed in italics

19. Who proposed phylogenetic classification of plants
(a) Linnaeus (b) Hutchinson (c) Bantham and Hooker (d)Mehta

20. Binomial nomenclature means
(a) Indication of the name by its order and family
(b) Indication of the name by its family and genus
(c) Indication of the name by its genus and species
(d)Indication of the name by its species and variety

21. Lowest rank in the classification is of
(a) Genera (b) Species (c) Sub-species (d) Variety

22. In five kingdom classification which kingdom incorporates prokaryotes
(a) Protista (b) Monera (c) Myxophyceae (d) Myxomycophyta

23. In the five kingdom classification which kingdom occupies intermediate position from phylogenetic point of view
(a) Monera (b) Protista (c) Plantae (d) None of these

24. Which of the two kingdom have equal rank in the five kingdom classification
(a) Monera and Protista (b)Protista and plantae
(c) Protista and animalia (d)Plantae and animalia

25. Which kingdom incorporates phytoplanktons and zooplanktons
(a) Protista (b) Fungi (c) Animalia (d) Plantae

26. Which kingdom incorporates photoautotrophs, chemoautotrophs and heterotrophs
(a) Monera (b) Protista (c) Plantae (d) Both (b) and (c)

27. Biochemical resemblance is generally used for the identification of which group of individuals
(a) Fungi (b) Monera (c) Protista (d) Plantae

28. ICBN stands for

(a) International Council for Botanical Nature

(b) International Code of Botanical Nomenclature

(c) Indian Code of Botanical Nomenclature (d) None of these

29. In whittaker's 'Five Kingdom Classification', eukaryotes where assigned to

(a) Only two of the five kingdoms (b)Only three of the five kingdoms

(c) Only four of the five kingdoms (d)All the five kingdoms

30. A system of classification in which a large number of traits are considered is

(a) Artifical system (b) Synthetic system (c) Natural system (d) Phylogenetic system

31. For declaration of new species, what characters should be used

(a) Floral characters of new species (b)Anatomical characters of new species

(c) Physiological characters of new species (d) Characters of endosperm

32. In which of the following taxonomy, is equal weightage given to each of thousands of characters that a taxon exhibits

(a) Classical taxonomy (b) Chemotaxonomy (c) Numerical taxonomy (d) Alpha taxonomy

33. If a botanist has to nomenclate a similar species, he will use

(a) Syntype (b) Neotype (c) Mesotype (d) Isotype

34. In the five kingdom system of classification, which single kingdom out of the following can include blue-green algae, nitrogen fixing bacteria and methanogenic archaebacteria

(a) Monera (b) Fungi (c) Plantae (d) Protista

35. In plants Latin names are suggested because

(a) Latin is a simple language

(b) In whole world there would be only one name for one plant

(c) It is easy to write

(d) Most of the names in other languages are not correct

36. Which names are regarded legitimate

(a) Which were first proposed (b)Which are very popular

(c) Which have their holotypes (d)All of these

37. Complex multicellular condition is present in

(a) Protista, plantae and fungi (b)Protista, plantae and animalia

(c) Monera, protista and animalia (d)Plantae**,** fungi and animalia

38. What criteria one has to follow for naming a plant technically at present

(a) Name should not be too long (b)Name should not be difficult to pronounce

(c) Name should be latinized (d)All of these

39. About how many species, scientific names have been provided

(a) 10 million (b) 5 million (c) 2.8 million (d) 1**.**7 million

40. Most of the unicellular organisms are kept under

(a) Monera and protista (b) Monera and plantae (c) Protista and plantae (d) Protista and fungi

41. Division of plant kingdom providing dominant terrestrial flora of the present day is

(a) Pteridophyta (b) Spermatophyta (c) Thallophyta (d) Bryophyta

42. Group embryophyta includes

(a) Bryophyta (b) Pteridophyta (c) Spermatophyta (d) All of these

43. Most primitive members of the plant kingdom are

(a) Thallophytes (b) Bryophytes (c) Pteridophytes (d) Gymnosperms

44. No. of plants species reported in India are

(a) 45**,** 000 (b) 40, 000 (c) 90, 000 (d) 50, 000

45. In Bentham and Hooker's system of classification, 5 orders and 27 families occur in

(a) Thalamiflorae (b) Disciflorae (c) Calyciflorae (d) Heteromerae

46. Which ones are false

(*a*) Series heteromerae has 6 orders and 14 families

(*b*) Natural system of classification does not attempt to bring out phylogenetic relationships

(*c*) Darwin published "Origin of species" in 1856 (*d*) Bicarpellatae has 4 orders and 24 families

(a) *a* and *d* (b) *a, b* and *c* (c) *a* and *c* (d) *b* and *d*

47. Tracheophyta consists of

(a) Bryophytes only (b) Pteridophytes only

(c) Gymnosperms and angiosperms

(d) Pteridophytes**,** gymnosperms and angiosperms

48. An artificial classification is one which

(a) Is based on several characters (b) Shows phylogenetic tendency

(c) Is based on some characters (d) None of these

49. The use of term phylum started from the time of

(a) Couvier (b) Linnaeus (c) Theophrastus (d) Eichler

50. Who made the statement that "taxonomy without phylogeny is like bones without flesh"

(a) John Hutchinson (b) Benthan and Hooker (c) Oswald Tippo (d) Takhtajan

Advance Level

51. A group of plants with similar traits of any rank is

(a) Species (b) Genus (c) Order (d) Taxon

52. A person who studies about the origin, evolution and variations in plants and also about the classification of plants, is called as

(a) Classical taxonomist (b)Herbal taxonomist

(c) α–taxonomist (d)β–taxonomist

53. Select the correct statement

(a) Epigynous condition is advance over hypogynous

(b)Heterospory is more evolved than homospory

(c) Adventitious roots are more advanced than tap root

(d) All the above statements are true

54. In five kingdom system, the main basis of classification is

(a) Nutrition (b) Nucleus structure

(c) Cell wall structure (d) Asexual reproduction

55. In a hierarchical system of plant classification, which one of the following taxonomic ranks generally ends in 'ceae'

(a) Family (b) Genus (c) Order (d) Class

56. In five kingdom classification land plants are classified under

(a) Bryophyta, pteridophyta and spermatophytes (b) Bryophyta and trachaeophyta

(c) Embryophyta and spermatophyta (d) Bryophyta and archaegoniatae

57. Hutchinson's system of classification was revised in

(a) 1995 (b) 1959 (c) 1954 (d) 1946

58. The publication in which binomial nomenclature was presented by *Linnaeus* was

(a) Genera plantarum (b) Species plantarum

(c) Naming of plants (d) Taxonomy of plants

59. Rules regarding the binomial nomenclature are framed by

(a) The scientists of America (b)Director of Royal Botanical Gardens, Kew

(c) In International Congresses (d) Individually by different countries

60. Carolus Linnaeus's system is an artificial system because

(a) It is based on evolutionary trends

(b) It is based on a number of characters

(c) It is based on a few character based on superficial similarities and dissimilarities based on morphology

(d) It is phylogenetic

61. Binomial nomenclature system of Linnaeus means that every organism has

(a) One name given by two scientist

(b) Two names one Latin and other of a person

(c) Two names one scientific and other popular

(d) One scientific name with generic and other with specific epithet

62. When generic name is repeated in specific name of a plant it is called

(a) Synonyms (b) Antonyms (c) Tautonyms (d) None of these

63. Which is the most useful but generally not used criteria for the identification of the species

(a) Interbreeding (b) Morphology (c) Genetic material (d) None of these

MONERA

Basic Level

64. Which of the following plants is found in large number in soil

(a) Fungi (b) Algae (c) Bacteria (d) Blue-green algae

65. Archaebacteria are included in

(a) Monera (b) Protista (c) Animalia (d) Fungi

66. The partially diploid cell called a merozygote is formed in

(a) *Mucor* (b) *E. coli* (c) Yeast (d) *Spirogyra*

67. All life on earth derive its energy directly or indirectly from sun except

(a) Mushroom and moulds (b)Chemosynthetic bacteria

(c) Symbiotic bacteria (d)Pathogenic bacteria

68. Microbes and animals show similarities at

(a) Histological level (b) Cellular level (c) Morphological level (d) Biochemical level

69. An organism lacking chlorophyll but able to carry on photosynthesis of organic matter has been found among which one of the following

(a) Bacteria (b) Fungi (c) Viruses (d) Bacteriophages

70. Which of the following represents obligate anaerobes

(a) *Spirogyra* (b) *Pisum sativum* (c) Onion (d) Methane bacteria

71. Phycoerythrin and phycocyanin pigment is present in

(a) Eubacteria (b) Cyanobacteria (c) Archaebacteria (d) Actinomycetes

72. Members of which group normally reproduce by asexual methods

(a) Eubacteria (b) Cyanobacteria (c) Archaebacteria (d) All of these

73. Cell membrane of which form is composed of branched chain of lipids

(a) Eubacteria (b) Actinomycetes (c) Archaebacteria (d) Cyanobacteria

74. Which one of the following is also called halophils

(a) Eubacteria (b) Actinomycetes (c) Archaebacteria (d) Cyanobacteria

75. Which one belongs to monera

(a) *Amoeba* (b) *Escherichia* (c) *Gelidium* (d) *Spirogyra*

76. Currently bacteria are included in

(a) Thallophyta (b) Mycota (c) Monera (d) Protista

77. Cyanophyceae or blue green algae possess

(a) Definite nucleus but no plastid (b)Definite plastid but no definite nucleus

(c) Definite nucleus and plastid (d) Neither definite nucleus nor definite plastid

78. Bacteria and other monerans do not possess

(a) Ribosomes (b) Mitochondria (c) Plasma membrane (d) Nucleoid

79. Nuclear material without nuclear envelope occurs in

(a) Mycoplasma and green algae (b)Bacteria and green algae

(c) Bacteria and cyanobacteria (d)Cyanobacteria and red algae

Advance Level

80. Monerans comprise

(a) Bacteria (b) Nitrogen fixing organisms

(c) Cyanophyceae (d) All of these

81. Monerans devoid of cell wall are

(a) Bacteria (b) Cyanobacteria (c) Mycoplasma (d) Actinomycetes

82. The organism which are included in the kingdom Monera are

(a) Unicellular (b) Without a definite nucleus

(c) Uninucleate (d) Coenocyte

83. Monerans bearing conidia for reproduction belongs to

(a) Eubacteria (b) Archaebacteria (c) Actinomycetes (d) Mycoplasma

84. Which one of the following does not belong to kingdom monera

(a) Eubacteria (b) Archaebacteria (c) Actinomycetes (d) Myxomycetes

PROTISTA

Basic Level

85. Which group of organisms are devoid of cell wall in their vegetative stage but develop a wall in reproductive phase

(a) Fungi (b) Blue green algae (c) Slime mould (d) Archaebacteria

86. Which organism behaves like plants in the presence of light and absence of organic food, but in reverse conditions behave like animals

(a) Archaebacteria (b) *Euglena* (c) *Nostoc* (d) *Paramecium*

87. Which one of the following organisms possesses characteristics of plant and an animal

(a) *Euglena* (b) Bacteria (c) Mycoplasma (d) *Paramoecium*

88. The scientist who coined the term '*protista*' to include both plant and animal like unicellular organism was

(a) Robert Koch (b) E.F. Haeckel (c) L. Pasteur (d) Joseph Lister

89. Protista includes

(a) Protozoa, algae and fungi (b) Algae, bryophyta, bacteria and fungi

(c) Fungi, slime moulds and vascular plants (d) Protozoa, bacteria, algae and bryophyta

90. Slime moulds belong to kingdom

(a) Monera (b) Protista (c) Plantae (d) Animalia

91. Which protist reproduces both by binary fission and conjugation

(a) Amoeba (b) Paramecium (c) Euglena (d) Monocystis

92. Total parasites belongs to protozoan group
(a) Sporozoa (b) Ciliata (c) Sarcodina (d) Zooflagellata

93. Protozoan protists respire through
(a) Pseudopodia (b) Contractile vacuole (c) Mitochondria (d) General surface

94. Which one is not a protozoan protist
(a) *Plasmodium vivax* (b)*Paramecium caudatum*
(c)*Enterobius vermiclaris* (d)*Trypanosoma gambiense*

95. Protozoan protists are differentiated on the basis of
(a) Nuclei (b) Size
(c) Shape (d) Locomotory structures

96. Endoparasitic protistan protozoans belong to
(a) Sporozoa (b) Ciliata (c) Sarcodina (d) Mastigophora

97. Protozoan found commensal in human colon is
(a) *Entamoeba coli* (b) *P. vivax* (c) *A. aegypti* (d) All of these

98. Primary grouping of protozoan protists is based on
(a) Locomotor organelles (b)Size and shape
(c) Mode of feeding (d)Mode of reproduction

99. Protozoans are able to live efficiently due to their
(a) Motility (b) Rapid reproduction
(c) Ability to manufacture food (d) Specialized organelles

100. Protista contains
(a) Euglena, dinoflagellates and yeast (b) Amoeba, paramecium, hydra
(c) Euglena, paramecium, mushroom (d) Amoeba**,** paramecium and dinoflagellates

101. Gametic meiosis occurs in protists which are
(a) Diploid (b) Haploid (c) Tetraploid (d) Mesokaryotic

102. Protistan protozoan having nuclear dimorphism is
(a) *Amoeba proteus* (b) *Paramecium caudatum*
(c)*Plasmodium vivax* (d) *Trypanosoma gombiense*

103. Protista includes
(a) Unicellular prokaryotes (b) Unicellular eukaryotes
(c) Bacteriophages (d) Blue green algae

104. Which do not belong to protista
(a) Euglenoids (b) Zooflagellates (c) Methanogens (d) Ciliates

105. Percentage plankton constituted by protistans is
(a) 95**%** (b) 85% (c) 80% (d) 70%

106. The life style present in protists is
(a) Plant (b) Fungal (c) Animal (d) All of these

107. Protistans are connecting link between

(a) Plants and animals (b)Fungi and plants

(c) Monerans and kingdoms of multicellular organisms (d)Fungi and animals

108. A symbiotic protist is

(a) Plasmodium (b) Lophomonas (c) Fuligo (d) Trypanosoma

109. In protista, phagotrophic nutrition is found in

(a) Protozoan protists (b) Some dinoflagellates (c) A few euglenoids (d) All of these

110. Which is a marine protist

(a) Amoeba proteus (b) Pelomyxa (c) Noctiluca (d) Paramecium

111. Protista having noncontractile pusule are

(a) Sporozoans (b) Ciliates (c) Dinoflagellates (d) Navicula

112. The protistans in which cell size decreases with each division are

(a) Dinoflagellates (b) Diatoms (c) Slime moulds (d) Radiolarians

113. A protistans which is commonly called animal is

(a) Navicula (b) Noctiluca (c) Vorticella (d) Euglena

114. Golden brown protists are

(a) Bacilariophyceae (b) Dinophyceae

(c) Both bacillariophyceae and dinophyceae (d) Euglenophyceae

115. Protists having transverse and longitudinal groove in their theca are

(a) Forminiferans (b) Radiolarians (c) Diatoms (d) Dianoflagellates

116. Photosynthetic protists having trichocysts are

(a) Dinophyceae (b) Ciliates (c) Bacillariophyceae (d) Euglenophyceae

117. A primitive filament is formed in protist

(a) Gonyaulax (b) Gymnopodium (c) Melanosira (d) Pinnularia

118. Decomposer protists are

(a) Sarcodines (b) Dinoflagellates (c) Slime moulds (d) Diatoms

119. Which is ciliate protist

(a) Euglena (b) Vorticella (c) Pelomyxa (d) Metopus

120. Multinucleate protozoans is

(a) Amoeba (b) Pelomyxa (c) Giardia (d) Arcella

121. Maximum speed of a protist is

(a) 20 μm/*sec.* (b) 2**.**0 *mm/sec***.** (c) 200 μm/*sec.* (d) 2 *cm/sec.*

122. In protists the locomotory organelles are

(a) Flagella (b) Flagella**,** cilia and pseudopodia

(c) Flagella and cilia (d) Flagella, cilia pseudopodia and wrigglers

123. Kingdom protists does not includes

(a) Calcarea and demosporangiae (b)Diatoms and dinoflagellates

(c) Slime moulds and ciliates (d)Flagellates and sarcodines

Advance Level

124. Some protists possess structures for regulation of their water content. They are

(a) Nuclei (b) Contractile vacuole (c) Chromatophores (d) Membranes

125. Protistian genome has

(a) Membrane bound nucleoproteins embedded in cytoplasm

(b) Free nucleic acid aggregates

(c) Gene containing nucleoproteins condensed together in loose mass

(d) Nucleoprotein in direct contact with cell substance

126. Protist obtain food as

(a) Photosynthesisers**,** symbionts and holotrophs (b) Photosynthesisers

(c) Chemosynthesisers (d) Holotrophs

127. Percentage of global photosynthesis performed by photosynthetic protists is

(a) 30% (b) 50% (c) 65% (d) 80**%**

128. Whirling whips are protists which possess two flagella that beat

(a) Slightly towards one side so as to cause rotation of the organism while moving forward

(b) Forward, backward and sideways depending upon the requirement

(c) At right angles to each other due to being present in different grooves

(d) Along with numerous cilia

FUNGI (GENERAL)

Basic Level

129. Which type of tissue is found in the fungi

(a) Parenchyma (b) Chlorenchyma (c) Plectenchyma (d) Collenchyma

130. Who among the following is given the honour of "*Father of Mycology*"

(a) Stanley (b) Bawden (c) De Bary (d) Micheli

131. Reserve food material of fungi is

(a) Starch (b) Protein

(c) Glycogen (d) Glycogen and oil bodies

132. Which season is best for the growth of the fungus

(a) Rainy (b) Summer (c) Winter (d) All of these

133. Fungi inhabiting wood are known as

(a) Epibiotic (b) Epixylic (c) Epigean (d) Eucarpic

134. All fungi can be called as

(a) Heterotrophs (b) Autotrophs (c) Saprophytes (d) Parasites

135. Who gave the parasitic nature of fungus in plants
(a) Pasteur (b) Anton de Bary (c) Robert Koch (d) J. F. Kuhn

136. When fungi feed on dead organic matter, they are known as
(a) Dimorphic (b) Parasites (c) Saprophytes (d) None of these

137. Which one of the following is a parasitic fungus
(a) *Rhizopus* (b) *Peziza* (c) *Mucor* (d) *Peronospora*

138. Which one of the following fungus shows heterothallism
(a) *Erisyphe* (b) *Peziza* (c) *Rhizopus* (d) *Peronospora*

139. Collumella is found in
(a) *Mucor/Rhizopus* (b) *Spirogyra* (c) Moss (d) Both (a) and (c)

140. Which one is a single celled fungus
(a) *Penicillium* (b) *Aspergillus* (c) Yeast (d) All of these

141. Which one of the following is a member of the group fungi imperfecti
(a) *Fusarium* (b) *Alternaria* (c) *Colletotricum* (d) All of these

142. Fungi can be stained by
(a) Safranine (b) Iodine (c) Lactophenol (d) Cotton blue

143. Fungus without any mycelium, is
(a) *Albugo* (b) *Agaricus* (c) *Puccinia* (d) *Saccharomyces*

144. The cell wall of fungi is made up of
(a) Chitin (b) Cellulose (c) Pectin (d) Suberin

145. Which of the following secretes toxins during storage conditions of crop plants
(a) *Fusarium* (b) *Pencillium* (c) *Aspergillus* (d) *Colletotrichum*

146. In manufacture of bread, it becomes porous due to release of CO_2 by the action of
(a) Virus (b) Yeast (c) Bacteria (d) Protozoans

147. Fungal filament system, known as mycelium and pseudomycelium is formed in
(a) Yeast (b) *Rhizophora* (c) *Aspergillus* (d) *Synchytrium*

148. Common bread mold is
(a) *Rhizopus oryzae* (b) *Rhizobium species* (c) *Rhizopus nedosus* (d) *Rhizopus stolonifer*

149. The hyphae of *Aspergillus* are
(a) Aseptate and multinucleate (b) Septate and multinucleate
(c) Aseptate and uninucleate (d) Septate and uninucleate

150. The immobility and spreadout nature of which group leads us to call them plants
(a) Moulds (b) Mushrooms (c) Lichens (d) All of these

151. Which of the following produces spores, but lacks vasculature
(a) Pteridophytes (b) Gymnosperms (c) Fungi (d) Dicots

152. Which one of the following group of fungi is sometimes known as "fungal waste basket"
(a) Phycomycetes (b) Ascomycetes (c) Basidiomycetes (d) Deuteromycetes

153. Which of the following fungi are edible
(a) *Agaricus campestris* (b)*Morchella esculenta* (c)*Podaxon prodaxis* (d)All of these

154. Branched, aseptate, coenocytic mycelium present in
(a) *Aspergillus* (b) *Albugo* (c) *Penicillium* (d) *Erysiphae*

155. The edible part of mushroom is
(a) Basidiopcarp (b) Tertiary mycelium (c) Primary mycelium (d) Secondary mycelium

156. Common bread mold is
(a) Yeast (b) *Mucor* (c) Bacteria (d) Virus

157. Common form of food stored in a fungal cell is
(a) Glycogen (b) Starch (c) Glucose (d) Sucrose

158. A group of fungi with septate mycelium in which sexual reproduction is either unknown or lacking are classified under
(a) Phycomycetes (b) Deuteromycetes (c) Ascomycetes (d) Basidiomycetes

159. Thread like filaments of fungi are known as
(a) Conidia (b) Mycorrhiza (c) Sporangium (d) Hyphae

160. Which is used for preparing alcohol
(a) *Penicillium* (b) *Lactobacillus* (c) *Saccharomyces* (d) *Acetobacter*

161. Asci are formed in
(a) *Ascobolus* (b) *Saccharomyces* (c) *Penicillium* (d) All of these

162. Puff ball is a
(a) Fungus (b) Alga (c) Moss (d) Pine cone

163. Genus *Penicillium* belong to the class
(a) Basidiomycetes (b) Ascomycetes (c) Phycomycetes (d) Deuteromycetes

164. Ray fungi are
(a) Ascomycetes (b) Basidiomycetes (c) Actinomycetes (d) Both (b) and (c)

165. Which of the following divisions of fungi includes 'Club fungi'
(a) Zygomycota (b) Ascomycota (c) Deuteromycota (d) Basidiomycota

166. In mushroom, fungal tissue which formed central part of a gill is
(a) Strema (b) Trama (c) Sub-hyminium (d) Hyminium

167. No need of water for fertilization in
(a) *Ulothrix* (b) *Albugo* (c) Bryophyta (d) Pteridophyta

168. Fungal hyphae are found on the surface of roots because
(a) Fungal hyphae behave at root hairs for absorption of water
(b) Xylem accept water from roots
(c) Both (a) and (b) (d) None of these

169. Coenocytic mycelium is
(a) Uninucleate (b) Multinucleate (c) Binucleate (d) Anucleate

170. Plasmogamy is fusion of
(a) Two haploid cells including their nuclei (b) Two haploid cells without nuclear fusion
(c) Sperm and egg (d) Sperm and two polar nuclei

171. Which takes part in symbiosis of lichen

(a) Alga – Fungus (b) Alga – Alga

(c) Fungus – Fungus (d) Fungus – Gymnosperms

172. Chitin present in fungal wall has a formula

(a) $(C_{22}H_{54}N_4O_{21})_n$ (b) $(C_{21}H_{54}N_4O_{22})_n$ (c) $(C_{22}H_{54}N_4O_{13})_n$ (d) $(C_{22}H_{24}N_4O_{21})_n$

173. A dikaryotic cell has

(a) Two haploid nuclei (b) Diploid zygotes

(c) Two similar nuclei (d) Two dissimilar haploid nuclei

174. Algae fungi are placed in

(a) Ascomycetes (b) Basidiomycetes (c) Phycomycetes (d) Deuteromycetes

175. The fungus that may cause disease in human beings is

(a) *Puccinia* (b) *Aspergillus* (c) *Cystopus* (d) *Rhizopus*

176. A fungus which requires only one single host for completion of its life cycle is called

(a) Heteroecious (b) Autoecious (c) Heterothallism (d) Heterosporous

177. A fungus contains cells with two nuclei from different genomes. The nuclei do not fuse but divide independently and simultaneously as new cells are formed. It belongs to

(a) Phycomycetes (b) Zygomycetes (c) Deuteromycetes (d) Basidiomycetes

178. Organisms which are indicator of SO_2 pollution of air

(a) Mosses (b) Lichens (c) Mushrooms (d) Puffballs

179. Fungi imperfecti (Deuteromycetes) lack

(a) Spores (b) Sexual reproduction (c) Asexual reproduction (d)Hyphae

180. All heterotrophs requires an environment which can provide

(a) Nitrates in solution (b) Organic compounds (c) Ammonium salts (d) Vitamin A

181. 'Witches Broom' of legumes is due to

(a) Mycoplasma (b) Bacterium (c) Fungus (d) Virus

182. fungus used in genetic experiments is

(a) Rhizopus (b) Mucor (c) Neurospora (d) Claviceps

183. Fungi causing hair loss are

(a) Keratophilous (b) Pyrophilous (c) Coprophilous (d) None of these

184. Which one is not related to perfect stage of fungus

(a) Zygospores (b) Meiospores (c) Ascospores (d) Mitospores

185. Which of the following is famous mycologist of India

(a) P. Maheshwari (b) M.O.P. Iyengar (c) A.K. Sharma (d) Sadasivan

186. A widely but periodically occurring plant disease is

(a) Endemic (b) Epidemic (c) Sporadic (d) Epiphytotic

187. A coprophilous fungus is

(a) *Trichoderma* (b) *Pilobolus* (c) *Fusarium* (d) *Humicola*

188. Fungi differ from other kingdoms in being
(a) Unicellular consumer (b)Unicellular decomposers
(c) Multicellular consumer (d)Multicellular decomposer

189. Fungal hyphae are able to penetrate the host with the help of
(a) Mechanical pressure (b)Softening by enzymes (c)Both (a) and (b) (d) Suckers and hooks

190. Associatiation of fungus with roots of tracheophytes is
(a) Amensalism (b) Commensalism (c) Helotism (d) Mycorrhiza

191. What is true
(a) Toadstool is an edible fungus (b)Rust fungi are homoecious
(c) Parathecium is fruiting body (d)In mushroom gills produce basidia

192. Zygospores are formed in
(a) *Puccinia* (b) *Penicillum* (c) *Alternaria* (d) *Mucor / Rhizopus*

193. 'Torula condition' occurs in
(a) *Rhizopus* (b) *Ulothrix* (c) *Spirogyra* (d) *Riccia*

194. A combined solution of copper sulphate and calcium hydroxide which is used as a fungicide is
(a) Fehling solution (b) Folins mixture (c) Carminative mixture (d)Bordeaux mixture

195. The zygote of following fungi is multinucleate
(a) Mucor (b) Yeaet (c) Rhizopus (d) Puccinia

196. According to their modes of nutrition the fungi are classified into
(a) One category (b) Two category (c) Four categories (d) Six categories

197. Parasexuality was first discovered in
(a) Bacteria (b) Virus (c) Fungi (d) None of these

198. Fungal spores produced asexually at the tips of hyphae are called
(a) Sporangiophores (b) Anthospores (c) Conidia (d) Meiospores

199. Columella is a specialized structure found in the sporangium of
(a) *Ulothrix* (b) *Rhizopus* (c) *Spirogyra* (d) None of these

200. Coenogametes are formed in
(a) *Rhizopus* (b) *Saccharomyces* (c) *Albugo* (d) *Alternaria*

201. LSD is obtained from
(a) *Clavatia* (b) *Claviceps* (c) *Amantia* (d) *Trichoderma*

202. A plant example in which reproductive structures lack a layer of sterile vegetative cells surrounding the egg
(a) *Funaria* (b) *Riccia* (c) *Yeast* (d) *Cycas*

203. The disease which occur at irregular intervals and locations are known as
(a) Epiphytotic diseases (b)Endemic diseases (c) Sporadic disease (d) Epidemic diseases

204. Cleistothecium is present in
(a) Only in *Aspergillus* (b) All ascomycetes
(c) *Penicillium* and *Aspergillus* (d) Hemi-ascomycetes

205. Septum in eumycota fungi, bearing a complex pore is designated as a
(a) Coenocyte (b) Septate hypha
(c) Dolipore septum (d) Secondary simple pore

206. Smut of maize is caused by
(a) *Ustilago hordie* (b) *U. nuda* (c) *U. avanae* (d) *U. maydis*

207. *Helminthosporium oryzae* was causative of the disaster
(a) Irish famine in 1845 (b) Collapse of French industry in 1870
(c) Displacement of planters in Ceylon in 1867 (d) Bengal famine in 1943

208. In 1943 the causal organism and host of Bengal famine was
(a) Wheat rust by *Puccinia* (b)Blast of rice by *Pyricularia oryzae*
(c) Blast of rice by *X. oryzae* (d)Brown leaf spot of rice by *H. oryzae*

209. The disease of potato responsible for famous famine of Europe was caused by or late blight of potato is caused by
(a)*Colletotrichum falcatum* (b) *Phytophthora infestans*
(c) *Potato mosiac virus* (d) *Alternaria solani*

210. Ergot is caused by
(a) *Cleviceps* (b) *Penicillium* (c) *Aspergillus* (d) *Rhizobium*

211. Which of the following fungal disease spreads by seed and flowers
(a) Corn stunt (b) Covered smut
(c) Potato root (d) Loose smut of wheat

212. Which of the following is not a fungal disease
(a) White rust of crucifers (b)Black rust of wheat (c)Red rust of tea (d) Red rot of sugarcane

213. Botanical name of species which cause white rust of cruciferae
(a) *Peronospora parasitica* (b)*Puccinia graminis* (c) *Pythium debaryanum* (d) *Albugo candida*

214. Powdery mildews of crops are caused by
(a) Bacteria (b) Ascomycetes (c) Phycomycetes (d) Basidiomycets

215. Wart disease caused by *Synchytrium endobioticum* is found in
(a) Cabbage (b) Potato (c) Pea (d) Groundnut

216. Which of the following is not correctly matched
(a) Root knot disease – *Meloidogyne javanica* (b) Smut of bajra – *Tolysporium penicillariae*
(c) Covered smut of barley **–** *Ustilage nuda*
(d) Late blight of potato – *Phytophthora infestans*

217. In puccinia, infection from barberry leaf to wheat plant is caused by
(a) Pycnospores (b) Aecidiospores (c) Uredospores (d) Teleutospores

218. Aflatoxicosis of poultry is caused by
(a) *A.flavus* (b) *A.fumigatus* (c) *Candida albicans* (d) *Rhizopus*

219. Warm and humid condition is most favourable for the growth of
(a) *Mucor* (b) Moss (c) *Selaginella* (d) *Pinus*

220. Fungi growing on rotten wood are called
(a) Bracket fungi (b) Coral fungi (c) Puffballs (d) Toadstools

221. The disease produced by fungus *Ustilago* are known as smuts because

(a) They parasitise cereals (b)The affected host becomes completely black

(c) Their mycelium is black (d)They produced sooty mass of spores

Advance Level

222. If the thallus of an organism *e.g.* a fungus is entirely converted into one or more reproductive structure, it is called as

(a)Eucarpic (b) Holocarpic (c) Holozoic (d) Homothallic

223. A type of life cycle in which plasmogamy, karyogamy, haplodization take place but not at specific place in life cycle of an organism is called as

(a) Parasexuality (b) Heterozygosity (c) Homozygosity (d) Asexuality

224. In all members of *Ascomycetes*, the number of ascospores and their arrangement in an ascus are as follows

(a) Eight ascospores in a linear order (b) Four ascospores in a linear order

(c) Either eight or four ascospores, but always in a linear order

(d) Either eight or four ascospores in a linear order or unordered

225. Phytotoxins are secreted by plants in response to fungal reaction. These compounds are generally

(a) Proteins (b) Glycoproteins (c) Phenolic compounds (d)Lipids

226. We can demarcate a facultative parasite as one which

(a) Inevitably requires living host (b)Only requires dead organic matter to live

(c) Is actually a parasite but can also become saprophyte

(d) Is actually a saprophyte but can also become a parasite

227. Match the different types of spores listed under column I with the names of the organisms given under column II. Choose the answer which gives correct combination of the alphabets of the two columns

Column I		Column II
Spores		Organisms
(A)Ascospores	p	Diatoms
(B)Endospores	q	*Agaricus*
(C)Auxospores	r	Bacteria
(D)Basidiospores	s	Yeast
	t	Nephrolepis

(a) A = s, B = r, C = p, D = q (b)A = s, B = p, C = r, D = q

(c) A = s, B = p, C = t, d = q (d)A = s, B = t, C = p, D = q

228. Which one secretes pheromones for the function

(a)*Rhizopus* for formation of zygospore (b) All fungi for sexual reproduction

(c) Yeast for mating (d) Plants for growth and development

ALGAE (GENERAL)

Basic Level

229. Phycology is the study of
(a) Algae (b) Fungi (c) Bacteria (d) All of these

230. All cells of sex organs are formed gametes in
(a) Algae (b) Bryophyta (c) Pteridophyta (d) Gymnosperm

231. The element present in thyroxin is obtained from
(a) *Laminaria* (b) *Polysiphonia* (c) *Porphyra* (d) *Gelidium*

232. Incepient nucleus is found in
(a) Myxophyceae (b) Phaeophyceae (c) Rhodophyceae (d) Chlorophyceae

233. Zygotic meiosis takes place in
(a) *Selaginella* (b) *Spirogyra* (c) *Pinus* (d) *Brassica*

234. Alga rich in protein is
(a) *Chlorella* (b) *Spirogyra* (c) *Oscillatoria* (d) *Ulothrix*

235. Single filament of *Nostoc* without mucilage sheath is known as
(a) Mycelium (b) Colony (c) Trichome (d) Hyphae

236. Cyanobacteria is also referred to a
(a) Mycetozoa (b) Myxomycetes (c) Myxophyceae (d) Schizomycetes

237. Which of the following alga shows heterotrichous habit
(a) *Oedogonium* (b) *Chlamydomonas* (c) *Ulothrix* (d) *Stigeoclonium*

238. Which of the following is a Prokaryote
(a) *Chlorella* (b) *Chlamydomonas* (c) *Protomyces* (d) *Oscillatoria*

239. Smallest plant which contain green pigment such as higher green plant is
(a) Schizomycetes (b) Rhodophyceae (c) Chlorophyceae (d) Phaeophyceae

240. Most important alga in research centres is
(a) Mycoplasma (b) *Spirogyra* (c) *Chlorella* (d) Blue-green algae

241. Thallophyta includes
(a) Fungi and bryophyta (b)Algae and bryophyta
(c)Algae, fungi and bryophyta (d) Algae and fungi

242. Planktons are organisms which
(a) Float on water surface (b)Are free swimmers
(c) Are deep sea forms (d) Are burrowing forms

243. The algae which help in the fixation of nitrogen belongs to
(a) Chlorophyceae (b) Phaeophyceae (c) Rhodophyceae (d) Cyanophyceae

244. In the chlorophyta, the reserve food of protein surrounded by starch, form a compact body termed
(a) Paramylum (b) Pyrenoid (c) Volutin (d) Eye spot

245. Pyrenoids are made up of
(a) Core of starch surrounded by sheath of protein
(b) Core of protein surrounded by fatty sheath
(c) Proteinaceous centre and starchy sheath
(d) Core of nucleic acid surrounded by protein sheath

246. In blue-green algae process of photosynthesis takes place in
(a) Lamellae (b) Chromoplast (c) Chromatophore (d) Chloroplast

247. Blue-green algae belong to
(a) Myxomycetes (b) The eukaryota
(c) The prokaryota (d) Neither the eukaryota nor the prokaryota

248. Rhodophyceae is red coloured due to
(a) Xanthopnyll (b) Carotenoids (c) $\gamma-$ phycoerythrin (d) $\gamma-$ phycocyanin

249. Which one is a parasitic algae
(a) *Vaucheria* (b) *Polysiphonia* (c) *Cephaieuros* (d) *Batrachospermum*

250. Agar is commercially obtained from
(a) Blue-green algae (b) Brown algae (c) Green algae (d) Red algae

251. Which one of the following is not a accessory pigment
(a) Chlorophyll '*a*' (b) Chlorophyll '*e*' (c) Phycocyanin (d) Xanthophyll

252. Cyanophyceae has got
(a) Definite nucleus and plastid (b) No definite nucleus but plastid
(c) Neither definite nucleus nor plastid (d) Definite nucleus but no plastid

253. Who is regarded as the "*Father of Indian Phycology*"
(a) Prof**.** M**.**O**.**P**.** Iyengar (b)Prof. J.N. Mishra (c) Prof. R.R. Mishra (d) Prof. R.N. Singh

254. Sexual reproduction and mobile cells are absent in
(a) Chlorophyceae (b) Myxophyceae (c) Rhodophyceae (d) Phaeophyceae

255. Botanical name of *sea palm* is
(a) *Polysiphonia* (b) *Postelsia* (c) *Ectocarpus* (d) *Macrocystic*

256. Laminaria (kelp) and Fucus (rock weed) are the examples of
(a) Green algae (b) Brown algae (c) Red algae (d) Golden brown algae

257. *Agar-Agar* is obtained from
(a) *Gigartina* (b) *Gelidium* (c) *Gracellaria* (d) All of these

258. Iodine is obtained from the members of
(a) Green algae (b) Brown algae (c) Red algae (d) Blue–green algae

259. Example of coenocytic algae is
(a) *Vaucheria* (b) *Chara* (c) *Nostoc* (d) *Polysiphonia*

260. The characteristic spores of diatoms are called
(a) Auxospores (b) Basidiospores (c) Ascospores (d) Zoospores

261. During rainy seasons, the ground becomes slippery due to dense growth of
(a) Lichens (b) Bacteria (c) Green algae (d) Cyanobacteria

262. Sexual reproduction is absent in
(a) *Ulothrix* (b) *Volvax* (c) *Spirogyra* (d) *Nostoc*

263. Last stage of gametophytic generation is
(a) Gametes (b) Zygote (c) Spore mother cells (d) Spores

264. Algae are in the same major group of plants as are the
(a) Mosses (b) Liverworts (c) Fungi (d) Ferns

265. Hormogonia are the vegetatively reproducing structures of
(a) *Ulothrix* (b) *Spirogyra* (c) *Oscillatoria* (d) *Chlamydomonas*

266. Atmospheric nitrogen-fixation is carried on by
(a) *Funaria* (b) *Anabaena* (c) *Chlamydomonas* (d) Fern gametophyte

267. Meiotic division in zygote takes place in
(a) Thallophyta (b) Angiosperms (c) Gymnosperms (d) Pteridophyta

268. Red eye spot containing haematochrome is meant for
(a) Photosynthesis (b) Respiration (c) Photoreception (d) Movements

269. Red oceanic tides are due to
(a) Red algae (b)Dinophyceae
(c) Diatoms
(d) Blue-green algae (*Trichodesmium erythrium*)

270. Sporophytic generation is represented by zygote only in
(a) *Funaria* (b) *Chlamydomonas* (c) *Pinus* (d) *Selaginella*

271. In biotechnological studies, the alga that is exploited as a rich source of protein is
(a) *Spirogyra* (b) *Spirulina* (c) *Chlamydomonas* (d) *Scytonema*

272. More than one pyrenoid are present in
(a) *Ulothrix* (b) *Spirogyra* (c) *Oedogonium* (d) All of these

273. Heterocysts are found in
(a) Chlorophyceae (b) Cyanobacteria (c) Phaeophyceae (d) Actinomyces

274. Storage product in rhodophyceae is
(a) Starch and oil (b) Cellulose (c) Floridean starch (d) Glycogen

275. Blue-green algae are included in
(a) Eukaryotes (b) Rhodophyceae (c) Prokaryotes (d) Chlorophyceae

276. Which of the following pigments is present in all algae
(a) Chlorophyll-*a* (b) Chlorophyll-*b* (c) Chlorophyll-*c* (d) Chlorophyll-*d*

277. Sexual reproduction in algae results in the formation of
(a) Oospore (b) Zoospore (c) Zygote (d) Zygospore

278. Along the sea-coast which of the following is least likely to be found
(a) Brown algae (b) Red algae (c) Mosses (d) All of these

279. Phytoplankton consists of

(a) Non-vascular hydrophytes (b)Aquatic algae and photosynthetic bacteria

(c) Micro-organisms functioning as decomposers (d) Plant consuming animals and their remains

280. The non-motile, greatly thickened asexual spores are called

(a) Hypnospores (b) Aplanospores (c) Macrozoospores (d) Microzoospores

281. The simplest green plants are

(a) Yeast (b) Bacteria (c) Algae (d) Lactobacillus

282. Make correct pair

A. Cyanophyceae	a. Green colour
B. Chlorophyceae	b. Blue green colour
C. Phaeophyceae	c. Red colour
D. Rhodophyceae	d. Brown colour

(a) *Aa*, *Bb*, *Cc*, *Dd* (b) *Ab*, *Bc*, *Cd*, *Da* (c) ***Ab*, *Ba*, *Cd*, *Dc*** (d) *Ad*, *Bd*, *Ca*, *Db*

283. Which one of the following statements concerning the algae is wrong

(a) Most algae are photosynthetic(b)Algae can be classified according to their pigments

(c) All algae are filamentous

(d)*Spirogyra* does not produce zoospores

284. Diatomaceous earth is formed due to remains of which parts of diatoms

(a) Cell wall (b) Chloroplast (c) Cytoplasm (d) Skeleton masses

285. Chlamydomonas are not occurs in

(a) Fresh water (b) Pond and lake (c) River (d) Ocean

286. Palmella stage is met within

(a) *Chlamydomonas* (b) *Spirogyra* and *Gnetum*

(c)*Ulothrix* and *Sphagnum* (d) *Oedogonium* and *Riccia*

287. All algae have

(a) Phycobilins and carotene (b) Chlorophyll '*a*' and chlorophyll '*b*'

(c) Chlorophyll '*b*' and carotene (d) Chlorophyll '*a*' and carotene

288. Physiological anisogamous sexual reproduction is found in

(a) *Mucor* (b) *Selaginella* (c) *Pinus* (d) *Spirogyra*

289. Hormogonia of cyanobacteria are

(a) Spore producing organs (b)Products of syngamy

(c) Fragmented trichomes (d)Cells adjacent to heterocyst

290. The classification of algae is based on

(a) Type of pigment (b) Nature of cell wall material

(c) Nature of reserve food (d) All of these

291. Pyrenoids are the centre of formation of

(a) Enzymes (b) Proteins (c) Fats (d) Starch

292. Floridean starch is found in

(a) Chlorophyceae (b) Rhodophyceae (c) Myxophyceae (d) Cyanophages

293. Product of photosynthesis in blue-green algae generally is
(a) Glucoside (b) Cyanophycean starch (c) Glycerophosphate (d) Globulin

294. Life cycle is haplontic in
(a) *Spirogyra/Ulothrix* (b) *Funaria* (c) *Selaginella* (d) *Cycas*

295. A thick walled spore meant for perennation is known as
(a) Zoospore (b) Aplanospore (c) Hypnospore (d) Akinete

296. The blue-green algae are so called as they have in addition to green pigment chlorophyll, a blue pigment known as **[KCET 1994]**
(a) Phycocyanin (b) Chromoplasm (c) Cyanophycin (d) Phycoerythrin

297. Which of the following does not contain chlorophyll
(a) Fungi (b) Algae (c) Bryophyta (d) Pteridophyta

298. Brown algae is characterised by the presence of **[CBSE PMT 1997]**
(a) Phycocyanin (b) Phycoerythrin (c) Fucoxanthin (d) Haematochrome

299. Of the following group which secrete and deposit calcium carbonate and appear like corals
(a) Red algae (b) Brown algae (c) Blue green algae (d) All of these

300. Coenobium means
(a) A hollow spherical colony (b) A group of filaments (c) Palmelloid form

301. Rolling alga is
(a) *Volvox* (b) *Chlamydomonas* (c) *Chlorella* (d) *Spirogyra*

302. Plant body is a photosynthetic filament in
(a) *Riccia* (b) *Chlamydomonas* (c) *Spirogyra* (d) *Pteris*

303. The pigments that are common to all algae are
(a) Phycocynin and phycoerythrin (b)Chlorophyll *a*
(c) Phycoerythrin and chlorophyll *a* (d)Chlorophyll *a* and phycocyanin

304. Which of the following is obtained from algae
(a) Wax (b) Butter (c) Chocolate (d) Carrageenin

305. In which of the following algal classes the starch and oil are present
(a) Chlorophyceae (b) Phaeophyceae (c) Rhodophyceae (d) Xanthophyceae

306. Stomata are not found in
(a) Algae (b) Mosses (c) Ferns (d) Liverworts

307. Which one of the following algae can be used as bacteriological filter
(a) *Batrachospermum* (b) *Gelidium* (c) *Oscillatoria* (d) *Cymbella*

308. Which was first photosynthetic organism
(a) Green algae (b) Red algae (c) Cyanobacteria (d) Brown algae

309. Pigment mainly responsible for photosynthesis in red algae is
(a) Phycoerythrin (b) Chlorophyll *a* (c) Carotene (d) Xanthophyll

310. Which one produces carrageenin
(a) Brown algae (b) Red algae (c) Green algae (d) Blue green algae

311. Cell wall of *Chlamydomonas* possesses
(a) Cellulose (b) Glycoproteins (c) Hemicellulose (d) Proteins only

312. Eye spot is found in the plant body of
(a) *Ulothrix* (b) *Ulva* (c) *Chlamydomonas* (d) *Spirogyra*

313. Phycoerythrin is found in
(a) *Fucus* (b) *Sargassum* (c) *Oedogonium* (d) *Polysiphonia*

314. The common mode of sexual reproduction in *Chlamydomonas* is
(a) Isogamous (b) Anisogamous (c) Oogamous (d) Hologamous

315. A red alga devoid of red colour is
(a) *Chondrus* (b) *Batrachospermum* (c) *Gelidium* (d) *Porphyra*

316. A chlorophyll found in phaeophyceae but absent in rhodophyceae is
(a) Chlorophyll *c* (b) Chlorophyll *d* (c) Chlorophyll *b* (d) Chlorophyll *a*

317. Trumpet hyphae of certain Brown Algae are similar to
(a) Tracheae (b) Tracheids (c) Sieve tubes (d) Companion cells

318. *Gracilaria* yields agar, carrageenin and related
(a) Fats (b) Alkaloids (c) Phycocolloids (d) Proteins

319. Algae growing on animal bodies and shells are called
(a) Epizoic (b) Epiphytic (c) Sea Lettuce (d) Parasitie

320. Storage product of most algae is
(a) Fat (b) Starch (c) Glycogen (d) Cellulose

321. Kelps are
(a) Fresh water algae (b) Marine algae (c) Terrestrial plants (d) Amphibious plants

322. Parasitic alga is /Tea and Coffee leaves are infected by
(a) *Cephaleuros* (b) *Sargassum* (c) *Oedogonium* (d) *Ulothrix*

323. The alga found in still fresh water is
(a) *Sargassum* (b) *Laminaria* (c) *Polysiphonia* (d) *Spirogyra*

324. Grouping of algae is based on
(a) Food reserve (b) Colony formation (c) Shape (d) Pigments

325. Which one has oil and occasionally starch as reserve food
(a) Chlorophyceae (b) Phaeophyceae (c) Rhodophyceae (d) Xanthophyceae

326. Algae are included in
(a) Tracheophytes (b) Embryophytes (c) Cormophytes (d) Thallophytes

327. In chlorophyceae, sexual reproduction occurs by
(a) Isogamy and anisogamy (b) Isogamy**,** anisogamy and oogamy
(c) Oogamy only (d) Anisogamy and oogamy

328. Which one of the following can not fix nitrogen
(a) *Nostoc* (b) *Azotobacter* (c) *Spirogyra* (d) *Anabaena*

329. During reproduction, *Chlamydomonas*

(a) Loses its flagella and becomes nonmotile (b) Loses its flagella and comes to rest

(c) Retains flagella and starts swimming (d) Retain flagella and starts dividing

330. An alga which can be possibly used in space flight (Space Alga) is

(a) *Nostoc* (b) *Chlorella* (c) *Ulothrix* (d) *Spirogyra*

331. Carrageenin, a jelly-like substance, is obtained from a marine alga called

(a) Irish Moss/*Chondrus* (b)Kelp (c) *Sargassum* (d) *Fucus*

332. Female sex organ of rhodophyceae is called

(a) Trichogyne (b) Ascogonium (c) Carpogonium (d) Oogonium

333. Sexual reproduction involving fusion of two cells in *Chlamydomonas* is

(a) Isogamy (b) Homogamy (c) Somatogamy (d) Hologamy

334. Calcium deposition and larvicidal properties are found in

(a) Diatoms (b) *Oscillatoria* (c) *Chara* (d) *Caulerpa*

335. '*Pond silk*' is the common name of

(a) *Ulothrix* (b) *Spirogyra* (c) *Vaucheria* (d) *Oedogonium*

Advance Level

336. Blue-green algae which live endophytically in protozoans are called

(a) Cyanophages (b) Bacteriophages (c) Cynallae (d) Plasmids

337. Which among the following do you consider as the best evidence to show that two species of algae are closely related

(a) They both respire and release CO_2 (b) They both are found in the same habitat

(c) They both reproduce asexually (d) They both have same type of pigments

338. Thermal algae are forms which grow and survive

(a) In tropical regions where the temperature range is high

(b) In hot water springs where the temperature remains around $70°C$

(c) On the huge rocks exposed to bright sunlight

(d) In deserts where the temperature in summer remains around $70°C$

339. When green algae are illuminated, motile aerobic bacteria usually accumulate near them. This is because, bacteria

(a) Have attraction for light (b)Have attraction for green light

(c) Have attraction for oxygen (d)Have attraction for CO_2

340. Algae are important, we should study algae because

(a) They are good organisms to experiment with

(b) They can be grown in large tank cultures

(c) They may form important constituent of human food (diet) in future

(d) They produce oxygen and organic acids

341. Algae are chlorophyllous organisms characterized by having
(a) Gametes but no specialized sex organs (b) Unicellular sex organs
(c) Multicellular sex organs in which every cell forms a gamete
(d) Any one of the above

342. Good production of rice can be had for number of years without adding nitrogenous manures because
(a) Roots of rice plants have nitrogen fixing bacteria
(b) Of the presence of nitrogen fixing algae in the rice field
(c) Rice plants require very less amount of nitrogen (d)Rice plants do not require nitrogen

343. If phytoplanktons are destroyed in the sea, then
(a) No effect will be seen (b)Primary consumers will grow luxuriently
(c) It will effect the food chain (d)Algae will get more space to grow

344. Algae are useful as they
(a) Are used in study of photosynthesis (b)Purify air
(c) Cause alcoholic fermentation (d)Occur in larger number

345. Marine algae flourished well during which period
(a) Triassic (b) Devonian (c) Permian (d) Ordovician

BRYOPHYTES (GENERAL)

Basic Level

346. Who amongst the following is regarded as the "*Father of Indian Bryology*"
(a) Prof. K.C. Mehta (b) Prof. D.D. Pant (c) Prof. S.R. Kashyap (d) Prof. P.N. Mehra

347. The largest bryophyte is
(a) *Funaria* (Moss) (b) *Marchantia* (c) *Megaceros* (d) *Dowsonia*

348. Protonema is found in the life cycle of
(a) *Spirogyra* (b) *Rhizopus* (c) *Funaria* (d) *Escherichia*

349. The evidence for aquatic origin of bryophytes is
(a) Ciliated sperms (b) Green colour
(c) Protonema thread (d) Some are still aquatic

350. Bryophytes can be separated from algae, because they
(a) Are thalloid forms (b) Have no conducting tissue
(c) Possess archegonia (d) Contain chloroplast

351. Which place in India is called "The Golden Mine of Liverworts"
(a) Eastern Himalayas (b) Western Himalayas (c) Western Ghats (d) Eastern Ghats

352. The term bryophyta was given by
(a) Darwin (b) Braun (c) Aristotle (d) Galen

353. Which one is true moss
(a) Bog Moss (b) Reindeer Moss (c) Club Moss (d) Irish Moss

354. One of the following is of considerable economic importance
(a) *Riccia* (b) *Funaria* (c) *Marchantia* (d) *Sphagnum*

355. Saprophytic bryophyte is
(a) *Buxbaumia aphylla* (b) *Ricciocarpus natan*s (c) *Riccia fluitans* (d) *Radula* species

356. The centrally located sterile region of moss capsule is termed
(a) Protonema (b) Columella (c) Elaters (d) Hardrome

357. Spores are liberated from the sporogonium only by the decay of gametophyte in
(a) *Funaria* (b) *Riccia* (c) *Marchantia* (d) *Anthoceros*

358. Sporophyte dependent upon gametophyte is found in
(a) Algae (b) Fungi (c) Bryophytes (d) Pteridophytes

359. Bryophytes can be distinguished from algae in being
(a) Thalloid (b) With archegonia having sterile outer jacket
(c) Devoid of conducting tissue (d) In possession of chloroplast in their cells

360. Which of the following is true about bryophytes
(a) They posses archegonia (b)They contain chloroplast
(c) They are thalloid (d) All of these

361. Elaters are present in sporogonium of
(a) *Riccia* (b) *Marchantia* (c) *Selaginella* (d) *Sphagnum*

362. Two type of cells hyaline and green or with various shades are characteristic of bryophytes in
(a) *Funaria hygrometrica* (b)*Polytrichum commune*
(c) *Sphagnum pappiolossum* (d) *Porella pelatyphylla*

363. Venter is the part of
(a) Sporogonium (b) Sporangium (c) Antheridium (d) Archegonium

364. Bryophytes differ from pteridophytes in
(a) Swimming antherezoids (b) An independent gametophyte
(c) Archegonia (d) Lack of vascular tissue

365. Gametophytic generation is dominant in
(a) Pteridophyta (b) Bryophyta (c) Angiosperms (d) Gymnosperms

366. Life cycle of which of the following posses spores and embryo but there is a lack of flower and vascular system
(a) Bryophyta (b) Pteridophyta (c) Angiosperm (d) Lichens

367. Bryophytes are of
(a) Great economic value (b)No value at all
(c) Great ecological importance (d) A lot of aesthetic value

368. A female gametangium of bryophyte differs from that of fungus in possessing
(a) Large neck (b) A venter
(c) Jacket layer with sterile cells (d) A single egg cell

369. Calyptra is a structure
(a) Formed by the venter of the archegonia (b) Formed at the base of the antheridia
(c) Formed in the centre of the capsule (d) Formed at the base of the leaves

370. What type of spore cells are in bryophytes
(a) Diploid in nature (b) Haploid in nature (c) Triploid in nature (d) Tetraploid in nature

371. Multicellular branched rhizoids and leafy gametophytes are the characteristics of
(a) All bryophytes (b) Gymnosperms (c) Some bryophytes (d) Pteridophytes

372. Spore dispersal by sensor mechanism takes place in
(a) *Funaria* (b) *Selaginella* (c) Fern (d) *Pinus*

373. Dichotomous branching is found in
(a) Fern (b) *Funaria* (c) Liverworts (d) *Marchantia*

374. Well developed archegonium with neck consisting of 4 – 6 rows of neck cells characterises
(a) Gymnosperms and flowering plants (b) Bryophytes and pteridophytes
(c) Gymnosperms only (d) Pteridophytes and gymnosperms

375. Leafy gametophytes is formed from protonema in
(a) *Marchantia* (b) *Riccia* (c) *Funaria* (d) *Anthoceros*

376. In bryophytes/*Funaria* the sperms are
(a) Quadriflagellate (b) Biflagellate and bent
(c) Biflagellate and spirally coiled (d) Nonflagellate

377. Main plant body of bryophytes is
(a) Autoecious (b) Sporophytic (c) Gametophytic (d) Heteroecious

378. Bryophytes commonly reproduce by
(a) Tubers (b) Adventitious branches
(c) Gradual death and decay of thallus (d) Bulbils

379. Bryophytes have
(a) Archegonia (b)Dominant gametophytic and parasitic sporophytic phases
(c) Thalloid plant body (d)All of these

380. Multicellular jacketed female sex organ of bryophytes is
(a) Archegonium (b) Carpogonium (c) Ascogonium (d) Trichogyne

381. In bryophytes, the posterior part of archegonium grows to protect the embryo. It is
(a) Paraphysis (b) Calyptra (c) Apophysis (d) Hypophysis

382. Female sex organs of bryophytes are called
(a) Oogonia (b) Ascogonia (c) Archaegonia (d) Antheridia

Advance Level

383. What is incorrect for bryophytes

(a) Vascular tissue lacking (b)Independent sporophyte absent

(c) Gametophyte reduced and dependent (d) Asexual reproduction by zoospores absent

384. Bryophytes comprise

(a) Sporophyte is of longer duration

(b) Dominant phase of sporophyte which is parasitic

(c) Dominant phase of gametophyte which produces spores

(d) Small sporophyte phase and generally parasitic on gametophyte

385. Archesporium is

(a) A diploid tissue responsible for the formation of sporogenous tissue

(b) A part of archegonia

(c) A haploid tissue responsible for the formation of gametophytic cells

(d) None of these

386. Among the following which is not characteristic feature of bryophyta

(a) Motile sperms (b) Presence of archegonium

(c) Water essential for fertilization (d) Photosynthetically independent sporophyte

387. Bryophytes are dependent on water because

(a) Archegonium has to remain filled with water for fertilization

(b) Water is essential for fertilization for their homosporous nature

(c) Water is essential for their vegetative propagation

(d) The sperms can easily reach upto egg in the archegonium

388. Common between bryophytes and pteridophytes is

(a) Absence of sporophyte (b) Gametophyte dependent on sporophyte

(c) Sporophyte dependent on gametophyte (d) Multicellular sex organs with sterile jacket

389. Bryophytes are amphibians because

(a) They require a layer of water for carrying out sexual reproduction

(b) They occur in damp places

(c) They are mostly aquatic

(d) All of these

390. What is unique about bryophytes

(a) The do not have roots (b)Bryophytes produce spores

(c) They lack vascular tissues (d)Sporophyte remains attached to gametophyte

391. Which one is a 'mixohydric' moss

(a) *Funaria* (b) *Sphagnum* (c) *Polytrichum* (d) None of these

392. The greatest degree of sterilization in sporogenous tissue among bryophytes in found in

(a) *Riccia* (b) *Marchantia* (c) *Funaria* (d) *Anthoceros*

PTERIODOPHYTES (GENERAL)

Basic Level

393. A fern differs from a moss in having
(a) An independent gametophyte (b)An independent sporophyte
(c) Swimming antherozoid (d)Archegonia

394. In which of the following plants is the diploid generally dominant
(a) Algae (b) Fungi (c) Mosses (d) Ferns

395. Most primitive living vascular plants are
(a) Brown algae (b) *Sphagnum* (c) Ferns (d) Cycads

396. Fern prothallus is
(a) Homothallic (b) Heterothallic (c) Heterotrophic (d) Heteromorphic

397. The aquatic fern which is an excellent biofertilizer is
(a) *Azolla* (b) *Salvinia* (c) *Marsilia* (d) *Pteridium*

398. Pteridophytes are also called
(a) Phanerogames (b) Cryptogames
(c) Vascular cryptogames (d)Amphibian of plant kingdom

399. Meristeles are found in
(a) *Cycas* stem (b) *Pinus* needle (c) Fern leaf (d) Fern rhizome

400. New leaf of ferns is called
(a) Sporophyll (b) Frond (c) Leaf petiole (d) Leaf node

401. The following is an example of saprophytes
(a) Mushroom (b) Lichen (c) Unicellular algae (d) Ferns

402. Distinct alternation of generation is found in
(a) *Rhizopus* (b) Bacteria (c) Viruses (d) *Pteris* (Fern)

403. Sporangia and spore bearing leaf in fern is called as
(a) Ramentum (b) Sorus (c) Indusium (d) Sporophyll/Frond

404. In fern, young leaves are protected by
(a) Rhizome (b) Indusium (c) Sori (d) Ramenta

405. The walking fern is so named because
(a) Its spores are able to walk
(b)It is dispersed through the agency of walking animals
(c) It propagates vegetatively by its leaf tips (d) It known how to walk by itself

406. Which one of the following belongs to vascular cryptogams
(a) Bryophyta (b) Pteridophyta (c) Gymnosperms (d) Angiosperms

407. Heterospory is found in
(a) *Selaginella* (b) *Isoetes* (c) *Marselia* (d) All of these

408. The prothallus of fern is
(a) Heart-shaped (b) Dorsiventral (c) Green (d) All of these

409. Antherozoids of fern are
(a) Spherical (b) Coiled (c) Multiflagellate (d) All of these

410. Fern prothallus is developed from
(a) Spore (b) Oospore (c) Elater (d) Antherozoid

411. Heterospory and seed habit are often exhibited by a plant possessing
(a) Bract (b) Spathe (c) Petiole (d) Ligule

412. The spores of fern plant germinate to form
(a) A new fern plant (b) A prothallus (c) An embryo (d) A zygospore

413. Which of the following is not a pteridophyte
(a) *Ginkgo* (b) *Selaginella* (c) *Polypodium* (d) *Azolla*

414. The gametophytic generation in pteridophytes is commonly called
(a) Thallus (b) Plant body (c) Prothallus (d) Protonema

415. In some of the pteridophytes and gymnosperms the sporophyll aggregate at the apices of the main stem or its branches to form definite compact structures. The compact structures are called
(a) Sporangiophore (b) Sorus (c) Sporangium (d) Strobilus or cone

416. The condition where a pteriodophyte produces two kinds of spores and sporangia is termed as
(a) Homospory (b) Homothallism (c) Heterospory (d) Apospory

417. Pteridophytes are characterized by
(a) Presence of vascular system (b) Absence of flowers
(c) Absence of fruits (d) All of these

418. The prothallus represents
(a) Gametophyte of fern (b) Sporophyte of angiosperm
(c) Sporophyte of gymnosperm (d) Sporophyte of fern

419. Jacket of the antheridia is composed of two ring cells in
(a) Moss (b) Fern (c) *Selaginella* (d) *Pinus*

420. Trabeculae endodermis is found in
(a) Axis and capsule of moss plant (b) Stem of *Selaginella*
(c) Stem of *Cycas* (d) Stem of *Pinus*

421. Heteromorphic alternation of generations is found in
(a) *Spirogyra* (b) *Mucor* (c) *Selaginella* (d) *Pinus*

422. Spore of fern represents
(a) Sporophytic stage (b) Gametophytic stage
(c) Sporophytic and gametophytic stage (d) Apomictic stage

423. In fern plant the ejection of spores with force is achieved by the
(a) Sporangiophore (b) Annulus (c) Stomium (d) Indusium

424. Prothallus of fern has
(a) Antheridia and archegonia on lower surface (b) Antheridia and archegonia on upper surface
(c) Antheridia on upper surface and archegonia on lower surface
(d) Antheridia on lower surface and archegonia on upper surface

425. Which one is absent in fern rhizome
(a) Vessels (b) Sieve cells (c) Phloem parenchyma (d)Tracheids

426. Fern gametophyte is
(a) Multicellular**,** cordate prothallus (b)Liver-shaped thallus
(c) Unicellular, colourless (d)Filamentous, multicellular and green

427. Fern prothallus is developed from
(a) Elaters (b) Spore mother cells (c) Spore (d) Zygote

428. Number of flagella in male gametes of fern is
(a) Zero (b) One (c) Two (d) Infinite

429. The sperm of fern is
(a) Biciliate and coiled (b) Multiciliate and sickle-shaped
(c) Multiciliate and coiled (d) Biciliate and sickle-shaped

430. A plant having vascular supply, producing spores but lacking seed is a
(a) Byophyte (b) Pteridophyte (c) Gymnosperm (d) Angiosperm

431. What happens to the spore of ferns
(a) It germinates to become a prothallus
(b) It germinates to become another spore forming fern plant
(c) It joins with another spore to form a seedling (d) It encysts and is devoured by snail

432. A feature common to gametophytes and sporophytes of mosses and ferns is
(a) Independent existance (b)Autotrophic nutrition
(c) Unbranched habit (d)Branched habit

433. In ferns, antherozoids are
(a) Coiled and multiflagellate (b)Coiled and biflagellate
(c) Sickle shaped and biflagellate (d)Sickle shaped and multiflagellate

434. Multiflagellate male gametes (sperms) are found in
(a) *Chlamydomonas* (b) *Funaria* (c) *Dryopteris* (d) *Riccia*

435. Azolla is used as a biofertilizer because it
(a) Multiplies very fast to produce massive biomass
(b)Has association of nitrogen-fixing Rhizobium
(c) Has association of nitrogenfixing cyanobacteria
(d) Has association of mycorrhiza

436. Heterospory is production of
(a) Sexual and asexual spores (b)Large and small spores
(c) Haploid and diploid spores (d)Diploid and tetraploid spores

437. Which of the following is not involved in the fertilization of fern
(a) Pollen tube (b) Water (c) Archegonia (d) Flagellated sperms

438. Which of the following is aquatic and free floating fern
(a) *Azolla* (b) *Salvinia* (c) *Pteris* (d) Both (a) and (b)

439. In the archegonium of a fern

(a) There are 4 neck canal cells (b) There are 3 neck canal cells

(c) There is one neck canal with one nucleus (d) There is one neck canal with two nucleus

440. The major role in the dehiscence of a fern sporangium is played by its

(a) Annulus (b) Indusium (c) Tapetum (d) Sorus

441. If the number of chromosomes, in the foot of fern embryo is 8 what should be the number in its spores

(a) 4 (b) 8 (c) 16 (d) 23

442. A collection of sporangia attached to placenta and covered over by indusium is known as

(a) Sporophyll (b) Sorus (c) Cone (d) Ramenta

443. Seed habit originated firstly in some

(a) Pteridophytes (b) Pines (c) Monocots (d) Dicots

444. The cells of fern prothallus contains nucleus with

(a) 4 *n* chromosomes (b) 3 *n* chromosomes (c) 2 *n* chromosomes (d) *n* chromosomes

445. Dominant generation in pteridophytes is

(a) Haploid (b) Gametophytic (c) Diploid (d) Triploid

446. In which of the following plant diploid stage generally dominates

(a) Algae (b) Ferns (c) Mosses (d) Fungi

447. Fern's prothallus normally is

(a) Haploid (b) Diploid (c) Triploid (d) Tetraploid

448. Ferns are characterised by

(a) Heterospory (b) Seed bearing (c) Homospory (d)Tracheids and vessels

449. The number of spores in the sporangium of fern is

(a) 16 (b) 32 (c) 64 (d) 128

450. Microsporangia and megasporangia are found in same strobilus in

(a) Fern (b) *Selaginella* (c) *Pinus* (d) Moss

451. In which of the following groups would you place a plant which produces spores and embryos but lacks seeds and vascular tissue

(a) Fungi (b) Bryophytes (c) Pteridophytes (d) Gymnosperms

452. Meiosis in pteridophytes takes place at the time of

(a) Spore formation (b)Sexual organ formation

(c) Germination of spores (d)Gamete formation

453. In which of the following, multiciliated antherozoids are present

(a) *Riccia* and *Funaria* (b) *Pteris* and *Cycas*

(c) *Riccia* and *Cycas* (d) *Marchantia* and *Riccia*

454. In fern, spores are formed in

(a) Sporangium (b) Oogonium (c) Archegonium (d) Stomium

455. Apogamous cells are

(a) Haploid (b) Diploid (c) Polyploid (d) Triploid

456. Which of the following venation is characteristic of fern
(a) Parallel (b) Reticulate (c) Dichotomous (d) Open furcate

457. Fern plant is a
(a) Haploid gametophyte (b)Diploid gametophyte
(c) Diploid sporophyte (d)Haploid sporophyte

458. Rhizophores are formed in
(a) Bryophytes (b) *Selaginella* (c) *Pteridium* (d) Gymnosperms

459. Pteridophytes differ from bryophytes and thallophytes in having
(a) Vascular tissues (b) Motile antherozoids (c) Archegonia (d)Alternation of generations

460. Plant body of pteridophytes is
(a) Sporophyte (b) Gametophyte (c) Prothallus (d) All of these

461. A pteridophyte having pyrenoid in its chloroplasts is
(a) *Pteridium* (b) *Selaginella* (c) *Equisetum* (d) *Marsilea*

462. Rudimentary seed habit occurs in
(a) *Lycopodium* (b) *Selaginella* (c) *Psilotum* (d) *Equisetum*

463. Possible advantage of antheridia occurring on the under surface for fern prothallus is
(a) Protection from wind (b) Protection from direct rays
(c) Easy diffusion of nutrients from prothallus (d) Accumulation of capillary water

464. Fern rhizome is
(a) Rhizophore (b) Root (c) Rhizoid (d) Stem

465. *Azolla/Marsilea* is a
(a) Liverwort (b) Moss (c) Tree fern (d) Water fern

466. Sperm of Fern enters an archegonium due to
(a) Chemotaxy (b) Phototaxy (c) Thermotaxy (d) Cyclosis

467. Mature archegonium of Fern attracts antherozoids chemotactically by means of
(a) Soluble proteins (b) Sugars (c) Malic acid (d) Citric acid

468. According to available fossil records which of the following were the first land vascular plant
(a) Psilophytales (b) Lycopods (c) Horse-tail (d) *Cycas*

469. Which of the following is not heterosporous
(a) *Dryopteris* (b) *Selaginella* (c) *Marsilea* (d) *Pinus*

470. Two distinct generations in a single life history are common in
(a) *Bacillus* (b) *Mango* (c) *Pteris* (*Dryopteris*) (d) *Spirogyra*

471. Polystelic stem is seen in
(a) *Cycas* (b) *Riccia* (c) *Selaginella* (d) *Funaria*

472. Which of the following is known as 'resurrection plant'
(a) *Selaginella* (b) *Welwitschia* (c) *Refflesia* (d) *Chlorella*

473. The shape of sporangium in fern is
(a) Biconvex (b) Circular (c) Biconcave (d) Plano-convex

474. In which of the following secondary growth takes place

(a) *Riccia* (b) *Funaria* (c) *Selaginella* (d) None of these

475. Fern stele is

(a) Dictyostele (b) Siphonostele (c) Protostele (d) None of these

476. Which one of the following is commonly called a "*Maiden hair fern*"

(a) *Pteridium* (b) *Adiantum* (c) *Dryopteris* (d) *Pteris*

477. In ferns, xylem is

(a) Exarch (b) Mesarch (c) Endarch (d) Polyarch

478. Which of the following is a fossil pteridophyte

(a) *Lycopodium* (b) *Lygodium* (c) *Psilotum* (d) *Rhynia*

479. In pteridophytes the reduction division occurs, when

(a) Spores are formed (b)Gametes are formed

(c) Prothallus is formed (d)Sex organs are formed

480. Heterosporous pteridophytes always produce

(a) Monoecious gametophytes (b)Dioecious gametophytes

(c) Homothallic gametophytes (d)None of these

481. The ferns in which the entire sporangium develops from a single superficial cell of the sporophyll are known as

(a) Leptosporangiate (b) Eusporangiate

(c) Unisporangiate (d) Mesosporangiate

482. One character is common in between *Funaria* and *Dryopteris*. The character is

(a) Monoecious gametophyte (b) Dioecious gametophyte

(c) Heterosporous sporophyte (d) Stele is protostele

483. Which of the following are associated with production of gametes in prothallus

(a) Antheridia and oogonia (b)Antheridia and archegonia

(c) Anthers and archegonia (d) Anthers and ascogonium

484. When the sperms of *Funaria* and *Pteris* are put together near the archegonia of *Pteris*, only the sperms of Pteris readily enter the archegonia and reach the egg. The reason being that

(a) Sperms of *Funaria* are killed when mixed with sperms of *Pteris*

(b) Archegonia of *Pteris* secrete a substance with repels sperms of *Funaria*

(c) Archegonia of *Pteris* secrete a chemical substance which attracts sperms of *Pteris* chemotactically

(d) Sperms of *Funaria* are less motile

485. In fern, sporangia are borne on the

(a) Margin of leaf (b) Abaxial side of leaf

(c) Adaxial side of leaf (d) Only on the tip of leaf

486. Significance of heterospory is

(a) Establishment of sex differentiation with the formation of the spores

(b) Development of spores starts in the sporangia

(c) It is responsible for the development of seed habit

(d) All of these

487. Sporangia of eusporangiate ferns

(a) Possess a single layer of wall cells (b) Produce very few spores

(c) Originate from a group of initial cells

(d) Dehiscence at the region of a well defined stomium

488. Sometime prothallus of fern give rise to a fern plant. It is an example of

(a) Apospory (b) Parthenogenesis (c) Parthenocarpy (d) Apogamy

489. Leaf gap in the vascular cylinder in ferns is

(a) Air space (b) Parenchymatous zone

(c) Collenchymatous zone (d) Area exclusively of phloem

490. A mature ligule, having a prominent basal portion, is called

(a) Trichocyst (b) Heterocyst (c) Rhizophore (d) Glossopodium

491. An advantage which made seed bearing plants so greatly surpass the ferns in colonizing the land, is the evolution of the

(a) Ability to photosynthesize (b) Fibrous root system

(c) Woody stem (d) Non-swimming sperms

GYMNOSPERM (GENERAL)

Basic Level

492. In gymnosperms pollination is exclusively by

(a) Animals (b) Wind (c) Water (d) Insects

493. Plant of pine is

(a) Annual herb (b) Biannual herb (c) Evergreen tree (d) Deciduous tree

494. Cycus revoluta is popularly known as

(a) Date palm (b) Sago palm (c) Sea palm (d) Royal palm

495. Gymnosperms are characterised by

(a) Naked seeds (b) Seeds enclosed in fruits

(c) Winged seeds (d) Multiple sperms

496. Fruitless flowering plants are called

(a) Sterile plants (b) Angiosperms (c) Primitive (d) Gymnosperms

497. Gymnosperms are called naked seeded plants

(a) Because their seeds are not surrounded by ovary wall (b) Integument surrounding their seeds is thin

(c) Seeds are produced inside the fruits (d) None of the above

498. Which of the following features can be used to distinguish gymnosperms with angiosperms

(a) Presence of naked ovules in gymnosperms (b) Presence of pollen chamber in gymnosperms

(c) Presence of stomata in angiosperms (d) None of the above

499. Annual rings are well seen in

(a) *Selaginella* stem (b) *Cycas* wood (c) *Pinus* wood (d) All the above

500. Winged seeds are found in

(a) *Cycas* (b) *Pinus* (c) *Papaver* species (d) None of these

501. Pine wood consists of almost entirely

(a) Tracheids (b) Vessels

(c) Equal number of tracheids and vessels (d) More vessels and less tracheids

502. The winged pollen grains are the characteristic feature of

(a) *Cycas* (b) *Ephedra* (c) *Gnetum* (d) *Pinus*

503. What is the similarity between gymnosperms and angiosperms

(a) Phloem of both have companian cells

(b) Endosperm is formed before fertilization in both

(c) Origin of ovule and seed is similar in both (d) Both have leaves**,** stem and roots

504. Circinate venation is found in

(a) *Cycas* (b) Fern (c) Both (a) and (b) (d) None of these

505. In gymnosperm the endosperm is

(a) Haploid (b) Diploid (c) Triploid (d) None of the above

506. In which class of gymnosperms, fossils are present

(a) Cycadophyta (b) Coniferophyta (c) Gnetopsida (d) Both (a) and (b)

507. The arrangement of megaspores in a tetrad in a gymnosperm is

(a) Decussate (b) Tetrahedral (c) Linear (d) Isobilateral

508. Fruits are not found in gymnosperms plants because

(a) They are seedless plants (b)They are not pollinated

(c) They have no ovary (d)Process of fertilization does not take place in them

509. A. Heterospory

B. Seed formation

C. Fertilization process

What is appropriate for gymnosperms

(a) *AB* true *C* false (b) *BC* true *A* false (c) *ABC* all true (d) *ABC* all false

510. In gymnosperms, pollen drop is the

(a) Red drop (b) Pollens droped by wind (c)Secretion of nucleus (d)Water drops

511. "Monkey's puzzle" is a common name for

(a) *Araucaria embricata* (b)*Cycas revoluta* (c) *Pinus longifolia* (d) *Gnetum genon*

512. Angiosperms and gymnosperms resemble in having

(a) Vessels in wood (b) Mode of fertilization

(c) Siphonogamy (d) Nature of endosperm

513. Non-motile male gametes are formed in

(a) *Funaria* (b) *Selaginella* (c) Fern (d) *Pinus*

514. Naked seeds are found in

(a) *Selaginella* (b) *Pinus* (c) *Riccia* (d) *Brassica*

515. Bordered pits are very common in

(a) Monocotyledons (b) Gymnosperms (c) Dicotyledons (d) Pteridophytes

516. The giant tree among the pines belongs to

(a) *Cedrus* (b) *Pinus* (c) *Dalbergia* (d) *Sequoia*

517. Ectotrophic mycorrhiza is present on

(a) The axis of moss (b) Prothallus of fern

(c) Roots of *Pinus* (d) Rhizophores of *Selaginella*

518. Transfusion tissue, a modified vascular tissue is present in the leaves of

(a) *Pinus* (b) *Dryopteris* (c) *Lycopodium* (d) *Dalbergia*

519. Algal zone is characteristic of

(a) Normal root of *Cycas* (b)Root of *Pinus*

(c) Coralloid roots of *Cycas* (d) Stem of *Cycas*

520. Red wood tree is
(a) *Cedrus* (b) *Pinus* (c) *Dalbergia* (d) *Sequoia*

521. Canada balsam is an oleoresin obtained form
(a) *Abies balsamea* (b) *Impatiens balsamia* (c) *Pinus* species (d) *Helianthus annus*

522. Resin canals are commonly found in
(a) Mosses (b) *Selaginella* (c) *Cycas* (d) *Pinus*

523. Primary development of male and female gametophytes takes place in the sporangia itself in
(a) *Selaginella* (b) Fern (c) *Pinus* (d) Both (a) and (c)

524. Needle like foliage leaves are found in
(a) Mosses (b) *Selaginella* (c) Fern (d) *Pinus*

525. Monoecious condition is found in
(a) *Cycas* (b) *Selaginella* (c) *Pinus* (d) *Pteridium*

526. Resin and turpentine are obtained from
(a) *Cycas* (b) *Pinus* (c) *Abies* (d) *Cedrus*

527. Diploxylic or polyxylic vascular bundles are found in
(a) *Pinus* (b) *Dryopteris* (c) *Cycas* (d) *Funaria*

528. Which is the smallest gymnosperm among the following
(a) *Cycas* (b) *Pinus* (c) *Zamia* (d) *Gnetum*

529. Coralloid roots of cycas has
(a) *Anabaena* (b) Mycorrhiza (c) *Rhizobium* (d) *Azotobacter*

530. In which plant largest sperms are found
(a) *Cycas* (b) *Pinus* (c) Mango (d) Sunflower

531. Which one is living fossil
(a) *Pinus* (b) *Cycas* (c) *Selaginella* (d) *Metasequoia*

532. Gymnosperm seeds are naked due to lack of
(a) Pericarp (b) Perianth (c) Nucellus (d) Integuments

533. Vascular bundless of *Cycas* / *Pinus* stem are
(a) Conjoint, collateral and closed (b) Conjoint**,** collateral and open
(c) Conjoint, bicollateral and open (d) Conjoint, bicollateral and closed

534. Sulphur shower is due to
(a) Acid rain (b) Excess SO_2 and SO_3 in atmosphere
(c) Exposed sulphur rocks (d)Pollen of pinus/ cedrus

535. Gymnosperms differ from pteridophytes (gymnosperms are characterised by)
(a) Naked ovule (b) Circinate ptyxis (c) Leaf arrangement (d) Gametophyte

536. Tallest gymnosperm called father of the forest is
(a) *Pinus* (b) *Ephedra*
(c) *Sequoiadendron giganteum* (d) *Ginkgo biloba*

537. 'Bars of sanio' are present in the tracheids of
(a) *Cycas* (b) *Pinus* (c) Both (a) and (b) (d) None of these

538. Most gymnosperms are

(a) Xerophytic (b) Hydrophytic (c) Halophytic (d) Epiphytic

Advance Level

539. Most of the gymnosperms have

(a) Only antheridia (b) Both antheridia and archegonia

(c) Archegonia but no antheridia (d) Both absent

540. Resin duct of a gymnospermous stem is an example of

(a) Big vacuole (b) Lysigenous cavity (c) Intercellular space (d) Schizogenous cavity

541. Cataphylls are

(a) Leaves of *selaginella* (b)Scaly leaves of *Pinus*

(c)Needles of *Pinus* (d)Foliar leaves of *Pinus*

542. Gymnosperms do not have

(a) Trees (b) Shrubs (c) Lianas (d) Herbs

543. Gymnosperms do not have

(a) Xylem vessels and sieve tubes (b)Tracheids and sieve tubes

(c) Vessels**,** sieve tubes and companion cells (d) Tracheids and companion cells

544. Identify the unique feature of gymnosperm

(a) Endosperm is formed before fertilization (b) Mesogamous fertilization

(c) Ovule covered by ovarian wall (d) Pollen drop is the pollen dropped by wind

ANGIOSPERM

Basic Level

545. Angiosperm contains

(a) Trachieds (b) Vessels (c) Both (a) and (b) (d) None of these

546. Which of the following is considered as more evolved

(a) Dicot plant (b) Monocot plant (c) Data are incomplete (d) (a) and (b) both

547. An angiosperm is different from a gymnosperm in the absence of

(a) Vascular tissue (b) Ovary (c) Seed (d) Naked ovule

548. What is exclusive for angiosperms

(a) Vessels (b) Secondary growth (c) Double fertilization (d) Autotrophic nature

549. Plant cells possess wall but the same is absent in

(a) Pollen grain (b) Male gamete (c) Female gamete (d) Both (b) and (c)

550. In what way angiosperms are different from gymnosperms

(a) Secondary growth (b) Geographic distribution

(c) Dispersal of seeds (d) Integument of ovules

MISCELLANEOUS PROBLEMS

Basic Level

551. Which groups depend on external source of free water

(a) Algae**,** mosses and ferns (b)Algae, mosses and gymnosperms

(c) Mosses, ferns and gymnosperms (d)Only algae and mosses

552. Which of the following is grouped under phanerogams

(a) Pteridophytes (b) Gymnosperms (c) Angiosperms (d) Both (b) and (c)

553. Holozoic mode of nutrition is found in

(a) Monera and Protista (b)Protozoans and animals

(c)Protista and fungi (d)Only in higher animals

554. First land inhabiting plants are

(a) Angiosperms (b) Gymnosperms (c) Bryophytes (d) Pteridophytes

555. Which one of the following is not a cryptogam

(a) Algae (b) Bryophyta (c) Pteridophyta (d) Gymnosperms

556. Triploid condition is only present in

(a) Bryophytes (b) Pteridophytes (c) Gymnosperms (d) Angiosperms

557. Which one of the following is not a member of thallophyta

(a) *Spirogyra* (b) *Mucor* (c) Moss (d) Both (b) and (c)

558. Archegoniatae include

(a) Algae, fungi and viruses (b)Algae, lichens and bryophytes

(c) Bryophytes**,** pteridophytes and gymnosperms

(d) Pteridophytes, gymnosperms and angiosperms

559. In which of the following groups would you place a plant which produces seeds but lacks flower and fruits

(a) Fungi (b) Bryophytes (c) Pteridophytes (d) Gymnosperms

560. Facultative saprophyte is

(a) A parasite which can live as a saprophyte (b) Always a parasite

(c) Always a saprophyte (d) May acquire parasitic mode of life

561. Heteromorphic alternation of generations occurs is

(a) *Funaria, Spirogyra, Selaginella* (b)*Funaria***,** *Selaginella***,** *Cycas*

(c) *Spirogyra, Rhizopus, Selaginella* (d)*Rhizopus, Funaria, Spirogyra*

562. Which of the following reproduces vegetatively under favourable conditions

(a) Algae (b) Fungi (c) Bryophyta (d) All of these

563. Plant body is thalloid in

(a) Algae (b) *Riccia* (c) Bryophytes (d) All of these

564. Amphibians of plants kingdom are

(a) Multicellular immobile algae (b) Bryophytes

(c) Unicellular mobile algae (d) Pteridophytes of complex internal structure

565. Both photosynthesis and respiration takes place in

(a) Bacteria (b) Fungi (c) Virus (d) Green plants

566. Who among the following was a paleobotanist

(a) P. Maheshwari (b) S.R. Kashyap (c) B. Sahani (d) V.Puri

567. Tap roots are commonly found in

(a) Gymnosperms (b) Angiosperms (c) Dicots (d) Monocots

568. Diatoms are

(a) Fungi (b) Plantae (c) Protista (d) Protozoans

569. Which group dominates land at present

(a) Bryophyta (b) Pteridophyta (c) Gymnosperms (d) Angiosperms

570. During adverse season, therophytes survive by

(a) Bulbs (b) Corms (c) Rhizomes (d) Seeds

571. To which group would you assign a plant which produces seeds, embryo, possesses vasculature but lack fruit

(a) Bryophyta (b) Pteridophyta (c) Gymnosperms (d) Angiosperms

572. Which of the following group produces spores but does not possess vascular tissues

(a) Monocot (b) Dicots (c) Fungi (d) Gymnosperms

573. Vascular bundles are absent in

(a) Gymnosperms (b) Angiosperms (c) Pteridophytes (d) All the above

574. Ancestors of land plants were

(a) Red algae (b) Brown algae (c) Green algae (d) Bryophytes

575. Vessels occur in

(a) Angiosperms (b) Gymnosperms (c) Pteridophytes (d) Viruses

576. Well developed archegonium with neck having 6 and 4 rows of neck cells occurs in

(a) Pteridophytes and gymnosperms (b) Gymnosperms and flowering plants

(c) Gymnosperms only (d) Bryophytes and pteridophytes

577. Maiden Hair tree is

(a) *Araucaria* (b) *Thuja* (c) *Ginkgo* (d) *Pinus*

578. Retort cell occur in

(a) *Funaria* (b) *Polygonium* (c) *Porella* (d) *Sphagnum*

579. In which of the following elater mother cells and spore mother cells belong to same generation

(a) *Marchantia* (b) *Reboulia* (c) *Riccardia* (d) *Dryopteris*

580. Seeds habit originated in certain

(a) Bryophytes (b) Ferns (c) Gymnosperms (d) Angiosperms

581. First seed plants evolved during

(a) Cretaceous (b) Carboniferous (c) Devonian (d) Silurian

582. Aflatoxins are produced by

(a) Bacteria (b) Viruses (c) Fungi (d) Nematodes

583. Which one of the following can only reproduce by using the metabolic machinery of the host cells

(a) Bacteria (b) Virus (c) Fungi (d) Cuscuta

584. If all the bacteria and fungi of the world are destroyed, then

(a) All living things will become immortal and there will be no disease left

(b) We shall be unable to obtain any antibiotics

(c) The soil will gradually become depleted of all nitrogen

(d) The world will become packed with dead bodies and excretions of all kinds of living organisms

585. Turpentine is got from

(a) Angiospermous wood (b)Angiospermous flowers

(c) Gymnospermous wood (d)Ferns

586. Sago comes from

(a) *Calamus ritung* (b) *Metroxylon rumphii* (c) *Areca catechu* (d) *Phoenix dactylifera*

587. Neck canal cell is absent in the archegonium of

(a) *Funaria* (b) *Cycas* (c) *Dryopteris* (d) All pteridophytes

588. Which one is a living fossil

(a) *Pinus* (b) *Gnetum* (c) *Ginkgo* (d) *Riccia*

589. Elaster mechanism of spore dispersal is found in

(a) *Riccia* (b) *Marchantia* (c) *Funaria* (d) Fern

590. Double fertilization is characteristic of

(a) Pteridophytes (b) Gymnosperms (c) Bryophytes (d) Angiosperms

591. Circinate venation occurs in

(a) Algae (b) Moss (c) Fern (d) *Pinus*

592. Lower plants having green pigments similar to those of higher plants are

(a) Rhodophyceae (b) Chlorophyceae (c) Phaeophyceae (d) Schizomycetes

593. Which amongst the following are not seed producers

(a) Fern and *Funaria* (b) *Funaria* and *Ficus*

(c) *Ficus* and *Chlamydomonas* (d) *Punica* and *Pinus*

594. Plants having (spores), xylem and phloem but lacking seeds are

(a) Bryophytes (b) Gymnosperms (c) Pteridophytes (d) Angiosperms

595. Archegonium is absent in

(a) Bryophyta (b) Pteridophyta (c) Thallophyta (d) Gymnosperms

596. Sieve tubes and companion cells are absent in

(a) Angiosperms (b) Pea (c) Mango (d) Pteridophyta

597. Multiciliated antherozoids occur in

(a) *Riccia* and *Funaria* (b) *Pteris* and *Cycas*

(c) *Riccia* and *Pteris* (d) *Marchantia* and *Riccia*

598. Leafy gametophytes occur in

(a) Pteridophytes (b) Gymnosperms (c) Bryophytes (d) Angiosperms

599. Independent alternation of generations is present in

(a) Angiosperms (b) Gymnosperms (c) Pteridophytes (d) Bryophytes

600. Cedar wood oil is extracted from heart wood of
(a) *Cedrus deodara* (b) *Thuja occidentalis* (c) *Juniperus virginiana* (d)*Magnolia* species

601. Ephedrine is got from the plant part of *Ephedra*
(a) Flower (b) Leaves (c) Stems (d) Roots

602. Sago is got from
(a) *Cycas* (b) *Cedrus* (c) *Pinus* (d) *Taxus*

603. A plant producing seeds but lacking flowers is
(a) Gymnosperms (b) Pteridophyte (c) Angiosperm (d) Bryophyte

604. A spermatophyte with ciliated stage is
(a) *Pteridium* (b) *Riccia* (c) Gymnosperm (d) Angiosperm

605. Secondary growth occurs in
(a) *Riccia* (b) *Funaria* (c) *Selaginella* (d) None of these

606. A dicot is
(a) Mango (b) Coconut (c) Sugarcane (d) Banana

607. The plant in which sporophytic phase is represented by zygote only
(a) *Pinus* (b) *Selaginella* (c) *Chlamydomonas* (d) *Funaria*

608. Fossils of early vascular plants have been discovered in the rocks of
(a) Cambrian (b) Silurian
(c) Devonian (d) Jurassic

609. 'Nonmotile' gametes occur in
(a) *Ulothrix* (b) *Spirogyra* (c) *Funaria* (d) *Selaginella*

610. Annulus occurs in
(a) Annual plants (b)Mosses
(c) Both mosses and ferns (d)Gymnosperms

611. Apophysis occurs in
(a) *Marchantia* (b) *Pteridium* (c) Apocyanaceae (d) Mosses

612. Which ones are nonvascular
(a) Bryophytes (b) Pteridophytes (c) Gymnosperms (d) Angiosperms

613. Branched rhizoids and leafy gametophytes are characteristic of
(a) All bryophytes (b)Some bryophytes
(c) Some pteriodophytes (d)All pteridophytes

614. Which one is the earliest land plant
(a) Rhynia (b) Hornea (c) Cooksonia (d) Cordaites

615. Largest ovules, trees and gametes are found in
(a) Monocots (b) Dicots (c) Both (a) and (b) (d) Gymnosperms

616. Cleavage and archegonial polyembroyony is common in
(a) Gymnosperms (b) Pteridophytes (c) Angiosperms (d) Bryophytes

617. Nonflowering plants are
(a) Dicots (b) Monocots (c) Phanerogams (d) Cryptogams

618. Which is wrong

(a) Naked seeds occur in gymnosperms (b) Endospores develop in pteridophyta

(c) Basidiocarp is fructification of fungus (d) Capsule is part of sporophyte in bryophytes

619. Plant group in which every cell of gametangium forms gametes is

(a) Thallophyta (b) Bryophyta (c) Pteridophyta (d) Gymnosperms

620. Which one of the following has not changed for the last several thousand years

(a) *Dryopteris* (b) *Gnetum* (c) *Ginkgo* (d) Palms

621. What is correct

(a) Bryophytes are vascular cryptogams

(b) Pteridophytes are homogenous group of tracheophytes

(c) Cordaitales grow in gymnosperm forests

(d) Gymnosperms are spermatophytes with naked seeds

622. Sporocarp is a reproductive structure of

(a) Some algae (b) Some aquatic ferns having sori

(c) Angiosperms having spores (d) Bryophytes

623. Which is intermediate between conifers and cycads

(a) *Tsuga* (b) *Ephedra* (c) *Ginkgo* (d) *Cupressus*

624. Partially independent sporophyte is found in

(a) *Pteris* (b) *Funaria* (c) *Dryopteris* (d) *Selaginella*

625. Thin walled nonflagellate spores are

(a) Zoospores (b) Aplanospores (c) Hypnospores (d) Zygospores

626. Gemmae are vegetative reproductive structures found in

(a) Angiosperms (b) Bryophytes (c) Algae (d) Gymnoperms

627. Phytoplankton is made of

(a) Decomposer microorganisms

(b) Plants feeding on animals and their remains

(c) Aquatic algae and photosynthetic bacteria (d) Nonvascular hydrophytes

628. The term chromatophore was introduced by

(a) Pfeffer (b) Schmitz (c) Singer and Nicolson (d) Compraheti

629. Prothallus (gametophyte) gives rise to fern plant (Sporophyte) without fertilization. It is

(a) Apospory (b) Apogamy (c) Parthenocarpy (d) Parthenogenesis

630. Formation of gametophyte directly from sporophyte is

(a) Apogamy (b) Apospory (c) Apocarpy (d) Parthenogenesis

631. Life cycle is haplontic in

(a) *Funaria* (b) *Ulothrix* (c) *Selaginella* (d) *Pinus*

632. Red rust of tea is due to

(a) *Rhizopus* (b) *Puccinia* (c) *Cephaleuros* (d) *Phytophthora*

633. Four leaflets occur in

(a) Sesbania (b) *Oxalis* (c) *Marsilea* (d) *Dryopteris*

634. Fusion of mature individuals which directly act as gametes, is called
(a) Isogamy (b) Anisogamy (c) Hologamy (d) Autogamy

635. Meroblastic type of embryo development takes place in
(a) Ferns (b) *Selaginella* (c) *Pinus* (d) All the above

636. Which are the plants of modern age
(a) Pteridophytes (b) Gymnosperms (c) Monocots (d) Dicots

637. The highest plants in the world are
(a) Indian *Ficus* tree (b) Himalayan Pine tree
(c) Australian *Eucalyptus* (d) California *Sequoia*

638. The term 'Magnoliophyta' has been used for
(a) Angiosperms (b) Gymnosperms (c) Dicots (d) Monocots

639. Which is known as the 'fire of the forest'
(a) *Butea monosperma* (b) *Bougainvillea* (c) *Delonix regia* (d) *Bombax ceiba*

640. Which is the most primitive plants
(a) *Cocos nucifera* (b) *Nelumbo nucifera* (c) *Ginkgo biloba* (d) *Pinus sylvestris*

641. Where the 'chipko movement' started
(a) Tehri-Garhwal (U.P.) (b)Darjeeling (W.B.) (c) Mandi (H.P.) (d) Almora (U.P.)

642. The 'Joker of plant kingdom' is
(a) Yeast (b) *Neurospora* (c) Mold (d) Mycoplasma

643. Sperms of both *Funaria* and *Pteris* were released together near the archegonia of *Pteris*. Only its sperms enter the archegonia as
(a) *Pteris* archegonia repel *Funaria* sperms (b) *Funaria* sperms get killed by *Pteris* sperms
(c) *Funaria* sperms are less mobile
(d)*Pteris* archegonia release chemical to attract its sperms

644. The plant group that produces spores and embryo but lacks vascular tissues and seeds is
(a) Pteridophyta (b) Rhodophyta (c) Bryophyta (d) Phaeophyta

645. Which one is the most advanced from evolutionary view point
(a) *Selaginella* (b) *Funaria* (c) *Chlamydomonas* (d) *Pinus*

646. Protonema occurs in the life cycle of
(a) *Riccia* (b) *Funaria* (c) *Dryopteris* (d) *Spirogyra*

647. A medicine for respiratory disorders is obtained from
(a) *Cannabis* (b) *Eucalyptus* (c) *Ephedra* (d) *Saccharum*

648. Chlorenchyma is known to develop from in
(a) Cytoplasm of *Chlorella* (b) Mycelium of a green mould like *Aspergillus*
(c) Spore capsule of a moss (d) Pollen tube of *Pinus*

649. Nutrient medium is made semisolid by adding
(a) Pectin (b) Agar-agar (c) Sodium chloride (d) Water

650. Which is a walking fern which produces new plants when its leaf tips touch soil
(a) Adiantum (b) *Pteridium* (c) *Pteris* (d) *Marsilea*

651. Largest gametophyte is found in
(a) *Funaria* (b) *Selaginella* (c) *Pinus* (d) *Cycas*

652. Largest spermatozoids are those of
(a) *Pinus* (b) *Selaginella* (c) *Dryopteris* (d) *Cycas*

653. Ancestors of land plants possessed
(a) Arboreal habit (b) Heterotrichous habit (c) Thorny habit (d) Prostrate habit

654. Double fertilization is a trait of
(a) Gymnosperms (b) Angiosperms (c) Pteridophyta (d) Bryophyta

655. Botanical snakes are
(a) Algae (b) Fungi (c) Bryophytes (d) Pteridophytes

656. Select the correct statement
(a) Bryophyta are vascular nonflowering plants (b) Algae are nonvascular phanerogams
(c) Gymnosperms are nonvascular seed bearing plants
(d) Angiosperms are vascular seed bearing plants

657. Meiosis occurs in the zygote of
(a) *Funaria* (b) *Chlamydomonas* (c) *Dryopteris* (d) *Puccinia*

658. Gametophytic generation is dominant in
(a) Pteridophytes (b) Gymnosperms (c) Bryophytes (d) Angiosperms

659. Dominant flora, 200 million years ago was that of
(a) Angiosperms (b) Gymnosperms (c) Ferns (d) Lycopods

660. Amongst plants, the largest egg is found in
(a) *Pinus* (b) *Sequoia* (c) *Cycas* (d) *Drypoteris*

661. Pyrenoids are characteristically found in the chloroplast of
(a) Fungi (b) Algae (c) Pteridophytes (d) Angiosperms

MUCOR

Basic Level

662. *Mucor* is a
(a) Parasitic fungus (b) Saprophytic fungus
(c) Facultative saprophytic fungus (d) None of the above

663. Mycelium of *Mucor* is
(a) Septate and uninucleate (b)Septate and binucleate
(c) Coenocytic (d)None of the above

664. *Mucor* is classified under
(a) Chytridiomycetes (b) Zygomycetes (c) Ascomycetes (d) Deuteromycetes

665. According to recent classification system, *Mucor* is classified under
(a) Plant kingdom (b) Animal kingdom
(c) Both plant and animal kingdom (d) A separate kingdom

666. *Mucor* shows
(a) Isogamy (b) Anisogamy (c) Oogamy (d) None of the above

667. Sporangiospores of *Mucor* are
(a) Haploid (b) Diploid (c) Triploid (d) Polyploid

668. Heterothalism in *Mucor* was first reported by
(a) Robert Hooke (b) Blakeslee (c) Louis Pasteur (d) A. Fleming

669. In *Mucor*, asexual reproduction takes place by
(a) Motile zoospores (b) Spores (c) Zoogametes (d) Zygospores

670. Under favourable conditions *Mucor* reproduces
(a) Asexually (b) Sexually (c) Parasexually (d) None of the above

671. Torula condition of *Mucor* produces
(a) Spores (b) Chlamydospores (c) Oidia (d) None of the above

672. After fusion of sexual gametes in *Mucor* or *Rhizopus*, the resultant structure is known as
(a) Oospore (b) Cleistothecium (c) Zygospore (d) Zygote

673. Which of the following induces sexual reproduction in *Mucor*
(a) Indole acetic acid (b) Trisporic acid (c) Gibberellic acid (d) Citric acid

674. Which one of the following life cycles is associated with *Mucor*
(a) Haplontic (b) Diplontic (c) Isomorphic (d) Heteromorphic

675. Zygospore of *Mucor* germinates to form
(a) Mycelium (b) Promycelium (c) Hyphae (d) Germ tube

Advance Level

676. In *Mucor* species usually isogamy takes between
(a) Same strains (b) + and - strains (c) Zygospores (d) Microspores

677. Which of the following types of heterothallism is found in *Mucor*
(a) Morphological heterothallism (b) Physiological 2- allele heterothallism
(c) Physiological bipolar mutiple allele heterothallism
(d) Physiological tetrapolar multiple allele heterothallism

678. In *Mucor* and *Rhizopus* there occurs a phenominon known as heterothallism which means
(a) Fusion of two gametes from two thalli of opposite strains
(b) Fusion of two gametes from thalli of similar stain
(c) Formation of a zygospore partheno-genetically (d)Torula stage

RHIZOPUS

Basic Level

679. In *Rhizopus*, sexual fusion takes place between
(a) Two gametangia (b) Two gametes (c) Two hyphae (d) Two sporangia

680. Motile sperms are absent
(a) Rhizopus (b) *Funaria* (c) Fern (d) *Cycas*

681. Mode of nutrition in *Rhizopus* is
(a) Parasitic (b) Symbiotic (c) Saprophytic (d) Autotrophic

682. *Rhizopus* belongs to
(a) Zygomycetes (b) Basidiomycetes (c) Ascomycetes (d) Deuteromycetes

683. Food stored in *Rhizopus* / *Cystopus* / Fungi as
(a) Protein and steriods (b) Sugar and oil (c) Protein and starch (d) Glycogen and oil

684. In *Rhizopus* if conjugation fails, gametangia behave as zygospore. It is called as
(a) Conidia (b) Gametangia (c) Parthenospore (d) Sporangiospore

685. Fusion of gametangia in *Rhizopus* is
(a) Planogemetic copulation (b)Gametangial contact
(c) Gametangial copulation (d)Spermatogamy

686. The zygospore in *Rhizopus* develops into
(a) Zygospore (b) Progametangium (c) Promycelium (d) Gametangium

687. The following is not brought about by *Rhizopus*
(a) Spoilage of food (b) Deterioration of particles
(c) Soil building (d) Production of antibiotics

688. *Rhizopus* reproduces asexually through
(a) Sporangiospores (b) Aplanospores (c) Chlamydospores (d) Akinetes

689. Mycelium of *Mucor*/ *Rhizopus* is
(a) Aseptate and unicellular (b) Septate and unicellular
(c) Septate and multicellular (d) Coenocytic

690. Ainsworth has placed *Rhizopus* in
(a) Zygomycetes (b) Mastigomycotina (c) Ascomycotina (d) Myxomycotina

691. Fungus *Rhizopus* resembles moss in having
(a) Hyphae (b) Mycelium (c) Spores (d) Archegonia

692. The wall of *Rhizopus* hypha is composed of
(a) Cellulose (b) Chitin (c) Pectin (d) Hemicellulose

693. Yeast like budding of oidia in *Mucor*/ *Rhizopus* is called
(a) Palmella (b) Chantransia (c) Torula (d) Gongrosira

694. Thick walled asexual spores formed by *Rhizopus* are
(a) Aplanospores (b) Akinetes (c) Plasmospores (d) Chlamydospores

695. In *Rhizopus* we find white cottony mycelium which shows black spots during asexual reproduction. These spots are

(a) Zoospores (b) Spores (c) Oospores (d) Sporangia

696. The disease caused by *Rhizopus* in domestic animals

(a) Torulosis (b) Mucomycosis (c) Moniliasis (d) None of these

697. The disease caused by *Rhizopus* sp.

(a) Early blight of potato (b)Damping of seedlings

(c) Soft rot in sweet potato (d)Blast disease in rice

698. The hormone which induces the first reaction of sexual reproduction in *Rhizopus*

(a) Gibberellic acids (b) Trisporic acids (c) Traumatic acids (d) Ascorbic acid

Advance Level

699. In *Rhizopus*, hyphae are

(a) Branched, septate and uninucleate (b) Branched**,** aseptate and multinucleate

(c) Unbranched, aseptate and multinucleate (d) Unbranched, septate and coenocytic

700. The reduction division in the life cycle of *Rhizopus* occurs

(a) At the time of germination of zygospores (b) During the formation of germ sporangium

(c) During asexual reproduction (d) During the formation of gametangium

701. Species of *Rhizopus*

(a) Homothallic (b) Heterothallic

(c) Mostly homothallic rarely heterothallic (d) Mostly heterothallic rarely homothallic

702. The sexual reproduction is initiated in *Rhizopus* by

(a) Telomorphic reaction (b)Zygotropic reaction

(c)Both of these (d)Thigmotropic reaction

YEAST

Basic Level

703. Meiosis occur in yeast in

(a) Ascospores (b) Ascus mother cell (c) Ascus (d) None of the above

704. Alcoholic fermentation is performed by

(a) *Chlorella* (b) *Agaricus* (c) Yeast (d) *Puccinia*

705. Yeast produces an enzyme complex that is responsible for fermentation. The enzyme complex is

(a) Aldolase (b) Dehydrogenase (c) Invertase (d) Zymase

706. Which one is not a mode of reproduction is yeast

(a) Budding (b) Plasmogamy (c) Oogamy (d) Ascospore formation

707. Sometimes, in yeast, the conjugation takes place between a parent cell and a bud. It is called

(a) Isogamy (b) Syngamy (c) Pedogamy (d) Parthenogenesis

708. Life cycle of yeast is
(a) Haplodiplobiontic (b) Haplobiontic (c) Diplobiontic (d) All of these

709. Yeast is divided under the class
(a) Basidiomycetes (b) Deuteromycetes (c) Ascomycetes (d) Zygomycetes

710. Yeast is employed for production of
(a) Curd (b) Cheese (c) Acetic acid (d) Ethyl alcohol

711. Yeast is
(a) Purely aerobic (b) Anaerobic
(c) Rarely anaerobic (d) Both aerobic and anaerobic

712. Yeast is important source of
(a) Proteins (b) Riboflavin (c) Vitamin *C* (d) Sugars

713. In Yeast the sexual reproduction is by conjugation. After fusion the zygotic nucleus divides meiotically and forms haploid spores. The unicellular structure with haploid spores is
(a) Sporangium (b) Gametangium (c) Ascus (d) Zoosporangium

714. Yeast cell divides by
(a) Mitosis only (b) Mitosis and Amitosis
(c) Endomitosis and Amitosis (d) Mitosis and Endomitosis

715. Yeast are economically important because they
(a) Spread plant diseases (b) Spread animal diseases
(c) Are used in tea and tobacco industry (d) Are used in wine and baking industry

716. Yeast is abundantly found in
(a) Moist bread (b) Horse dung
(c) Organic substances rich in fats (d) Organic substances rich in sugar

717. During budding the primary septum separating the parent cell and the bud is made up of
(a) Glycogen (b) Mannan (c) Chitin (d) Cellulose

718. The antibiotic obtained from the yeast is
(a) Ephedrin (b) Saccharin (c) Campestrin (d) Polymixin

Advance Level

719. In yeast during budding which process occurs
(a) Synapsis (b) Unequal division of cytoplasm
(c) Doubling of chromosomes (d) Spindle formation

720. In yeast, cell wall contains
(a) Amylose and glucose (b)Glucose and mannose
(c) Glucose and muramic acid (d) Sucrose and mannose

721. Yeast differs from *Rhizopus* in being
(a) Multicellular and coenocytic (b) Unicellular and uninucleate
(c) Unicellular and coenocytic (d) Filamentous

ALBUGO

Basic Level

722. In *Albugo* the food reserve is mostly
(a) Glycogen (b) Volutin granules (c) Protein granules (d) Fat

723. Mycelium in *Albugo* is
(a) Intracellular (b) Intercellular (c) Surface of host (d) Surface of flower

724. Zoospore of *Albugo* possesses flagella
(a) Two similar and apical (b)Four similar and medium
(c) Four apical (d)Two dissimilar and median

725. Which statement is incorrect for *Albugo*
(a) Biflagellated male gametes (b)Non-flagellated female gametes
(c) Biflagellated zoospores (d)None/All of the above

726. Conidia of *Albugo* are arranged
(a) Irregularly (b) Acropetally (c) Basipetally (d) Intercalary

LICHEN & MYCORRHIZA

Basic Level

727. Mycorrhiza is a
(a) Long thin root (b) Association of root and fungus
(c) Root like underground stem (d) Parasitic root

728. The symbiotic association of fungi and algae is called
(a) Lichen (b) Mycorrhiza (c) Both (a) and (b) (d) Mycoplasma

729. In lichens, sexual reproduction belongs to
(a) Fungal partner only (b) Algal partner only
(c) Fungal and algal partners (both)
(d) Either fungal partner or algal partner (not both)

730. Lichen show symbiotic relationships between
(a) Fungus and roots of higher plants (b) Fungus and alga
(c) Two algae (d) Two fungi

731. Lichens multiply by
(a) Conidia (b) Oidia (c) Ascospores (d) Soredia

732. VAM represents
(a) Saprophytic fungi (b) Symbiotic fungi (c) Saprophytic bacteria (d) Symbiotic bacteria

733. Mycorrhiza represents
(a) Antagonism (b) Endemism (c) Symbiosis (d) Parasitism

734. Which statements is wrong about lichens

(a) Some species are eaten by reindeers (b) Lichens are indicators of pollution

(c) They grow rapidly about 2*cm* per day

(d) They have symbiotic relationship between alga and fungus

735. Fungal partner of a lichen is commonly

(a) Ascomycetes (b) Basidiomycetes (c) Phycomycetes (d) Deuteromycetes

736. Mycorrhizal association occurs in *Pinus*, *Ficus* and

(a) *Utricularia* (b) Legumes (c) *Eucalyptus* (d) *Azardirachta*

737. In endomycorrhiza, the fungus is commonly

(a) Zygomycetes (b) Phycomycete (c) Ascomycete (d) Basidiomycete

738. In ectomycorrhiza, the fungus is generally

(a) Zygomycete (b) Phycomycete (c) Ascomycete (d) Basidiomycete

739. Lichen with branched system but small base is

(a) Fructicose (b) Foliose (c) Crustose (d) Symbiont

740. In mojority of lichens, there is association of

(a) Green algae and ascomycetes (b) Green algae and basidiomycetes

(c) Blue green algae and ascomycetes (d) Blue green algae and basidiomycetes

741. In mycorrhiza, the fungal hyphae

(a) Remain restricted to the root surface (b) Remain restricted up to the root cortex

(c) Pass into the root interior (d) Enter the root apex and reach all parts

742. Lichens grow at a very slow rate (1 *mm per* year). In how many years a lichen matures

(a) 1 – 4 years (b) 4 – 8 years (c) 100 years (d) 20 – 25 years

743. Lichens which seems to be something painted on the rocks is

(a) Crustose (b) Foliose (c) Fructicose (d) Mycobiont

744. Which of the following structure helps in the respiration of lichens

(a) Soredia (b) Cyphella (c) Isidia (d) Cephalodia

745. Which lichen is known as 'old man's beard'

(a) *Orchill* (b) *Usnea* (c) *Cladonia* (d) *Parmelia*

Advance Level

746. Mycorrhiza works as

(a) Modified root (b) A root hair in adverse condition

(c) An organism for vegetative propagation (d) Mechanical tissue for support

747. Lichens indicate so_2 pollution because they

(a) Show association between algae and fungi (b) Grow faster than others

(c) Are sensitive to so_2 (d) Flourish in so_2 rich environment

748. Lichens are ecologically important as they

(a) Purify air (b) Are pioneers of barren rocks

(c) Are symbionts of algae and fungi (d) Are associated with mycorrhizal roots

749. Reindeer moss is
(a) *Sphagnum* (b) *Marchantia*
(c) *Cladonia rangifera* (d) None of these

750. Mycorrhizae are useful for
(a) Providing resistance against stresses (b) Killing pathogens and insects
(c) Enhanced absorption of minerals nutrients and water from soil
(d) Fixing nitrogen

SPIROGYRA

Basic Level

751. Chloroplasts of *Spirogyra* have
(a) Smoth margin (b) Wavy margin
(c) Smooth or wavy margin (d)None of these

752. Most common and advanced type of conjugation in *Spirogyra* is
(a) Scalariform (b) Indirect lateral (c) Direct lateral (d) None of these

753. The chloroplast in *Spirogyra* is
(a) Spiral band shaped (b) Cup shaped (c) Star shaped (d) Girdle shaped

754. Reproduction in *Spirogyra* is
(a) Asexual (b) Conjugation (c) Both (a) and (b) (d) None of these

755. The sexual reproduction in *Spirogyra* is
(a) Oogamous (b) Anisogamous (c) Cleistogamous (d) None of these

756. Which type of sexual reproduction is found in *Spirogyra*
(a) Conjugation (b) Binary fission (c) Fragmentation (d) Spores formation

757. The product of conjugation of *Spirogyra* is called
(a) Zoospore (b) Akinete (c) Chlamydospore (d) Zygospore

758. Scalariform conjugation occurs in
(a) *Ulothrix* (b) *Oedogonium* (c) *Spirogyra* (d) *Chlamydomonas*

759. The zygospore of *Spirogyra* after undergoing a rest germinates into a unicellular structure called
(a) Sporophyte plant (b) Germ cell (c) Germ tube (d) Germ plant

760. On germination each zygospore of *Spirogyra* gives rise to
(a) Four plants (b) Three plants (c) Two plants (d) One plant

761. Sexual reproduction in *Spirogyra* is morphologically characterised by
(a) Oogamy (b) Anisogamy
(c) Isogamy (d) Isogamy and oogamy both

762. Zygospore of *Spirogyra* produces
(a) 2 zoospores (b) 4 zoospores (c) 2 – 4 zoospores (d) None of these

763. A spore of *Spirogyra* sp. after resting period is
(a) Haploid (b) Diploid (c) Aplanospore (d) Zygospore

764. Sexual reproduction in which cells of two different *Spirogyra* filaments conjugate is known as
(a) Lateral conjugation (b) Scalariform conjugation
(c) Parthenocarpy (d) Azygospory

765. *Spirogyra* has a
(a) Haplontic life cycle (b) Diplontic life cycle
(c) Haplobiontic life cycle (d) Diplobiontic life cycle

766. In *Spirogyra*, ladder like structure is formed in
(a) Lateral conjugation (b) Fragmentation
(c) Palmella stage (d) Scalariform conjugation

767. In *Spirogyra* sometimes the gametes behave directly as zygospores without fusion, Such reproductive bodies are called
(a) Azygospores (b) Hypnospores (c) Zygospores (d) Aplanospores

768. Indian species of *Spirogyra* in which prof. Iyengar discovered direct lateral conjugation is
(a) *Spirogyra sahnii* (b) *Spirogyra indica* (c) *Spirogyra jogensis* (d) *Spirogyra karnalae*

769. The zygote containing 4 meiospores in *Spirogyra* is called
(a) Akinete (b) Parthenospore (c) Incipient sporophyte (d) Chlamydospore

770. In *Spirogyra* during the germination of zygospore how many haploid nuclei take part
(a) One (b) Two (c) Three (d) All four

771. Asexual reproduction in *Spirogyra*
(a) Has not been recorded (b) Takes place by formation of zoospores
(c) Takes place by formation of aplanospores (d) Takes place by formation of hypnospores

772. The floating mass of *Spirogyra* in a water pond is supported by bubbles of gases which is
(a) Oxygen (b) Air (c) Methane (d) Carbon dioxide

773. The cell wall of *Spirogyra* is made up of
(a) Cellulose (b) Pectin (c) Lignin (d) Chitin

774. Pyrenoid is found in one of the following part of *Spirogyra*
(a) Cytoplasm (b) Cell wall (c) Chloroplast (d) Nucleus

775. *Spirogyra* differs from moss protonema in having
(a) Pyrenoid (b) Branched filament (c) Discoid chloroplast (d) Rhizoidal branches

776. *Spirogyra* differs from *Mucor* in having
(a) Uninucleate gametangia (b)Multicellular gametes
(c) Anisogamete (d)Sexual reproduction

777. Uniqure character of *Spirogyra* vegetative cell is
(a) Cell wall is definite and thick (b)Cell wall is hygroscopic
(c) Pyrenoid bodies are present (d)Nucleus is having cytoplasmic strands

778. *Spirogyra* is a
(a) Fresh water and free floating alga (b) Marine and free floating alga
(c) Fresh water and locomotory alga (d) None of these

779. Maximum number of chloroplasts recorded in *Spirogyra* is
(a) 6 (b) 12 (c) 20 (d) 16

780. In *Spirogyra* there are
(a) Many pyrenoids (b) One pyrenoid (c) Three pyrenoids (d) No pyrenoid

781. Non flagellate amoeboid gametes of *Spirogyra* are
(a) Zoogametes (b) Aplanogametes (c) Planogametes (d) Zoidiogametes

782. Replicate septum of *Spirogyra* possesses
(a) Ring like outgrowth (b) Peg like protuberance (c) Perforation (d) H – shaped piece

783. Which is not characteristic of *Spirogyra*
(a) Fragmentation (b) Isogamous conjugation (c)Pond scum formation (d)Zoospory

784. *Spirogyra* is called pond silk because
(a) Filaments are made up of silk (b)Filaments are slippery to touch
(c) Both (a) and (b) (d) None of the above

785. If three filaments are involved in lateral conjugation in *Spirogyra*, zygospores will be found in
(a) All the three filaments (b)Only the middle filament
(c) Lateral filaments (d)Either (b) or (c)

786. Zygospore of *Spirogyra* is
(a) Multilayered (b) Three layered (c) Two layered (d) One layered

787. Lateral conjugation of *Spirogyra* occurs in individuals
(a) Free floating (b) Homothallic
(c) Heterothallic (d) Having different characters

788. In life cycle of *Spirogyra*, a brief period of tetranucleate condition occurs in
(a) Vegetative cells (b) Germinating zygospores (c)Gametangium (d) Holdfast

789. No growth of *Spirogyra* can occur in
(a) River (b) Pond (c) Stream (d) Sea

Advance Level

790. *Spirogyra* increases it body length by the division of
(a) The apical cell (b) The basal cell
(c) Every cell of the body (d) Accumulation of food in his body

791. Sexual reproduction in *Spirogyra* can be described as
(a) Morphological anisogamy and physiological isogamy
(b) Morphological as well as physiological isogamy
(c) Morphological as well as physiological anisogamy
(d) Morphological isogamy and physiological anisogamy

792. Sexual reproduction in *Spirogyra* involves fusion of
(a) Two similar motile gametes
(b) Two similar non- motile gametes but physiological dissimilar
(c) One motile and one non- motile gametes (d) Two dissimilar motile gametes

793. When three *Spirogyra* filaments are participating in conjugation. The possibilities are that
(a) The middle one may be female and outer ones are male
(b) The middle one may be male and outer ones are female
(c) Both (a) and (b) (d) None of these

794. Which of the following statement is not true for *Spirogyra* and *Mucor*
(a) Both have zygotic meiotic division (b) Both reproduce asexually by spores
(c) Both produce azygospores when sexual reproduction fails
(d) Both produce azygospores and parthenospores

795. In *Spirogyra*
(a) The filaments showing scalariform conjugation are homothallic
(b) The filaments showing lateral conjugation are homothallic
(c) The filaments showing lateral conjugation are heterothallic
(d) Asexual reproduction occurs by zoospores

796. *Spirogyra* shows the presence of
(a) Sexual reproduction between adjoining cells (b) Presence of distinct antheridia and oogonia
(c) Sexual reproduction between the contents of a single cell
(d) Only asexual reproduction

ULOTHRIX

Basic Level

797. Basal cell of *Ulothrix* is
(a) Extra green (b) Colourless (c) Full of reserve food (d) Without a nucleus

798. Number of flagella present in the gametes of *Ulothrix* is
(a) Four (b) Three (c) One (d) Two

799. Basal cell of *Ulothrix* is
(a) Antheridium (b) Meristematic (c) Holdfast (d) Zoogonidium

800. Presence of basal rhizoidal cell in *Ulothrix* is an example of
(a) Dead cell (b) Vestigial cell
(c) Accessory cell (d) Beginning of division of labour

801. In *Ulothrix*, zygote is

(a) Nonflagellate (b) Uniflagellate (c) Biflagellate (d) Tetraflagellate

802. In *Ulothrix*, sexual reproduction is by

(a) Isogamy (b) Anisogamy (c) Oogamy (d) Conjugation

803. Meiosis in *Ulothrix* takes place during

(a) Zoospore formation (b) Gamete formation

85(c) Zygote germination (d) Zoospore germination

804. Chloroplast of *Ulothrix* is

(a) Reticulate (b) Cuplike (c) Spiral (d) Girdle shaped

805. *Ulothrix* is

(a) Attached unbranched filament (b) Attached branched filament

(c) Colonial alga (d) Free floating

806. Cells of *Ulothrix* are

(a) Round (b) Spherical (c) Cylindrical (d) Rectangular

807. *Ulothrix* occurs in

(a) Running fresh water (b) Stagnant fresh water (c) Running salt water (d) Stagnant salt water

808. Pigments present in *Ulothrix* are

(a) Chl. *a*, Chl *b* and phycocyanin (b) Chl *a*, Chl *c*, phycocyanin and fucoxanthin

(c) Chl**.** *a***,** Chl *b***,** carotenes and xanthophylls (d) Chl *a* and fucoxanthin

809. A cell of *Ulothrix* has chloroplasts

(a) 1 (b) 2 (c) 3 (d) 4

810. The zoospores of *Ulothrix* are liberated by

(a) Degeneration of lateral walls (b)Formation of a pore in lateral wall

(c) Gelatinization of lateral wall (d)Gelatinization of all the cell walls

Advance Level

811. Which is correct statement for *Ulothrix*

(a) Filamentous alga with flagellated reproductive stages

(b) Filamentous alga with nonflagellated reproductive stages

(c) Membranous alga producing zoospores

(d) Nonmotile colonial alga lacking reproductive stages

812. In *Ulothrix*, the cell contains

(a) A chloroplast with many pyrenoids (b) A chloroplast with a few pyrenoids

(c) A few chloroplasts with a few pyrenoids (d) Many chloroplasts with a few pyrenoids

FUNARIA

Basic Level

813. Which is the characteristic of *Funaria*

(a) Scaliform xylem (b) Peristome (c) Both (a) and (b) (d) None of these

814. In *Funaria*, stomata are present on the

(a) Leaf (b)Stem

(c) Upper part of capsule (d) Lower part of capsule

815. Annulus of moss capsule separates

(a) Operculum and columella (b)theca and columella

(c) Theca from operculum (d)Columella from apophysis

816. Primitive types of stomata are found in the

(a) Leaves of moss plants (b)Axis of the moss plant

(c) Apophysis of capsule of moss (d)All the above

817. Paraphysis in moss are

(a) One celled and club shaped (b)Multicelled and club shaped

(c) One celled and bottle shaped (d)Multicelled and bottle shaped

818. The female sex organ in Riccia and *Funaria* is

(a) Archegonium (b) Antherdium (c) Oospore (d) Paraphyses

819. In *Funaria* leaves are arrange on stem

(a) Oppositely (b) Spirally (c) Opposite decussate (d) None of these

820. The capsule of *Funaria* is

(a) Symbiont (b) Semiparasite (c) Total parasite (d) Saprophyte

821. A protective cap or hood like covering on the developing capsule in a moss or liverwort is known as

(a) Spine (b) Calyptra (c) Lodicule (d) Calyptrogen

822. Protonema of *Funaria* is

(a) Thalloid (b) Foliose (c) Filamentous (d) Crustaceous

823. In *Funaria* the leaves which surround the antheridial cluster are called

(a) Perichaetial leaves (b) Foliage leaves (c) Scale leaves (d) Perigonial leaves

824. In *Funaria* the leaves surrounding the archegonia cluster are called as

(a) Perichaetial leaves (b) Perigonial leaves (c) Acicular leaves (d) Foliage leaves

825. The peristomial teeth in *Funaria* are

(a) Hydric (b) Xeric (c) Mesic (d) Hygroscopic

826. Mosses show

(a) Isomorphic alternation of generation (b) Hetermorphic alternation of generation

(c) Haplobiontic life cycle (d) None of these

827. The body of *Funaria* is

(a) Simple rosette thallus

(b) Differentiated into root, central axis and leaves

(c) Differentiated into rhizoids**,** stem and leaves (d) None of these

828. The Sporophytic phase in *Funaria* is well developed and is composed of

(a) Foot**,** seta and capsule (b)Spore sac (c) Capsule only (d) Foot and capsule

829. Which of the following stage of *Funaria* is haploid

(a) Gametophyte (b) Sporophyte (c) Both (a) and (b) (d) None of these

830. In *Funaria*

(a) Outer peristome teeth are hygroscopic than the inner teeth

(b) Both the types of teeth are hygroscopic

(c) Inner teeth are responsible for spores dispersal (d)Outer teeth are diploid and inner haploid

831. Which one of the following is absent in sporophyte of *Funaria*

(a) Foot (b) Seta (c) Elaters (d) Columella

832. In moss capsule, dispersal of spores takes place through

(a) Peristome teeth (b) Annulus (c) Calyptra (d) Operculum

833. In the life cycle of *Funaria* sp. spore is/ are the beginning of the generation/generations

(a) Sporophytic (b) Gametophytic

(c) Both gametophytic and sporophytic (d) Peristome

834. Columella in *Funaria* is

(a) Fertile tissue (b) Nourishing tissue (c) Supporting tissue (d) Protecting tissue

835. Spore mother cells in *Funaria* are

(a) Haploid (b) Tetraploid (c) Diploid (d) Triploid

836. *Funaria* may be differentiated from *Pinus* by the character

(a) No fruits are produced (b) No seeds are produced

(c) Antheridia and archegonia are present (d) Presence of sporophyte

837. The sporophyte of *Funaria* begins development within

(a) Antheridia (b) Capsule (c) Protonema (d)Archegonium

838. Vegetative reproduction in *Funaria* takes place by

(a) Primary protonema (b) Gemmae (c) Secondary protonema (d)All of these

839. In which cell types of *Funaria*, reduction division takes place

(a) Antheridial cells (b) Archegonial cells (c) Zygotic cells (d)Spore mother cells

840. Sex organs in *Funaria* develop

(a) At the axil of leaves (b) At the tip of stems (c) In the protonema (d) Inside the capsule

841. The green upright sterile hair like structure among antheridia of *Funaria* are known as

(a) Apophysis (b) Perigonial teeth (c) Trabeculae (d) Paraphyses

842. Sporogonium of *Funaria* is dependent on gametophyte
(a) Fully (b) For food only
(c) Partially for water and minerals (d) None of these

843. The dominant phase in the life cycle of *Funaria* is
(a) Protonema (b) Leafy gametophyte (c) Spore (d) Sporophyte

844. In *Funaria* the following is not connected with spore dispersal
(a) Seta (b) Peristome (c) Annulus (d) Foot

845. In *Funaria,* calyptra is derived from
(a) Antheridium (b) Columella (c) Capsule (d) Archegonium

846. In moss, reduction division takes place in
(a) Capsule (b) Archegonia
(c) Antheridium (d) At the tip of rhizoids

847. In moss capsule, the number of peristome whirls are
(a) 1 (b) 2 (c) 3 (d) 4

848. The middle sterile portion in the capsule of moss (*Funaria*) is
(a) Spore sac (b) Protonema (c) Collumela (d) Apophysis

849. Rhizoids in *Funaria* arise from
(a) Basal region (b) Ventral region (c) Dorsal region (d) None of these

850. Which one of the following is true moss
(a) Club moss (b) Reindeer moss
(c) Irish moss (d) Bogg moss (Sphagnum)

851. Where are the antheridia and archegonia situated in moss
(a) On the apex of leaves (b)In the axil of leaves
(c)On the apex of stem (d)On the base of stem

852. The moss plants develop from
(a) Diploid spores (b) Protonema (c) Oospores (d) Antherozoids

853. When moss (*Funaria*) spores germinate, they form
(a) Leafy gametophyte (b) Capsule (c) Protonema (d) Rhizoids

854. which is not a part of moss capsule
(a) Peristome (b) Protonema (c) Theca from operculum (d)Annulus

855. The dehiscence of moss capsule takes place by rupture of
(a) Operculum (b) Peristome (c) Annulus (d) Calyptra

856. In moss, medulla has
(a) Endodermis (b) Hadrome (c) Hypodermis (d) Piliferous layer

857. Which is haploid in *Funaria*
(a) Capsule (b) Columella (c) Protonema (d) Seta

858. Moss protonema can be differentiated from filamentous alga in
(a) Long rhizoids (b) Coenocytic nature
(c) Oblique septa (d) Absence of chloroplasts

859. In *Funaria* male and female sex organs occur at the tip of two branches, main axis and large branch. The condition is called
(a) Pleurocarpous (b) Acrocarpous (c) Apocarpous (d) Syncarpous

860. Juvenile state of moss is
(a) Protonema (b) Capsule (c) Prothallus (d) All of these

861. Moss protonema resembles in structure
(a) Multicellular green alga (b) Hypha of Rhizopus
(c) Unicellular structure of Acetabularia (d) None of these

862. The antherozoids of *Funaria* are
(a) Aciliate (b) Biciliate (c) Multiciliate (d) Monociliate

863. Rhizoids of *Funaria* are
(a) Colurless, multicellular with transverse septa (b) Colurless**,** multicellular with oblique septa
(c) Colourless and unicellular (d) Coloured and multicellular

864. Sporophyte of *Funaria* contains columella
(a) Sterile and lateral (b) Fertile and lateral (c) Fertile and middle (d) Sterile and middle

865. Bryophytes grow in moist and shady habitats because
(a) Water absorbing system is absent (b) They are aquatic
(c) They cannot grow on land (d)They require water for their fertilization

866. A part from fixation and water absorption the rhizoids of *Funaria* help in
(a) Perennation (b) Dispersal
(c) Storage (d) Vegetative reproduction

867. *Funaria* differs form marchantia in having
(a) Foot (b) Calyptra (c) Ventral canal cell (d) Protonema

868. Mosses grow in moist places because they
(a) Lack vascular tissue (b)Have gametes which require water for transport
(c) Lack root and stomata (d)Cannot grow on land

869. Peat moss is
(a) Club moss (b) Reindeer moss (c) Irish moss (d) Bog Moss

870. Epidermis of axis/stem of *Funaria* show
(a) Absence of cuticle (b) Absence of stomata
(c) Presence of cuticle but absence of stomata (d) Both (a) and (b)

871. Mosses are indicator of
(a) Air pollution (b) Water pollution (c) Radiation pollution (d) Soil pollution

872. Which of the following is a diploid
(a) Capsule of moss (b) Gametophyte, archegonia and egg of moss
(c) Gametophyte, antheridia and sperm of moss (d) Gametophyte and spore of moss

873. In *Funaria* the archesporium is derived from

(a) Outer layer of endothecium (b) Inner layer of endothecium

(c) Outer layer of amphithecium (d) Inner layer of amphithecium

Advance Level

874. The protonema of moss differs from green alga in having

(a) Buds (b) Colourless rhizoids

(c) Oblique septa and discoid chloroplast (d) All of these

875. *Funaria* is a bryophyte because it

(a) Has no roots and stems (b) Has sporophyte attached to the gametophyte

(c) Is non-vascular (d) All of these

876. Protonema is

(a) Fossil pteridophyte (b) A part of the sporophyte of *Funaria*

(c) The juvenile phase of the moss gametophyte (d) None of these

877. Life cycle of *Funaria* is not completed without water. Choose the correct statement

(a) As *Funaria* is a bryophyte plant (b) As branches will not develop

(c) As fertilization takes place in presence of water only

(d) As plant is delicate and will become dry and die without water

878. *Funaria* gametophyte is

(a) Dioecious and autoecious (b) Monoecious and autoecious

(c) Dioecious and heteroecious (d) Monoecious and heteroecious

879. The peristome of *Funaria* has

(a) 4 teeth in one ring (b) 32 teeth in 2 rings (c) 16 teeth in one rings (d) 16 teeth in 2 rings

880. In archegonium of moss (*Funaria*) plant, the number of neck canal cells is

(a) 2 (b) 3 (c) 5 (d) 6 to 18

881. If a moss protonema is developed from few cells of the moss capsule wall, then most probably it will be

(a) Haploid (b) Diploid (c) Triploid (d) Polyploid

882. The moss plant is a

(a) Sometimes gametophyte and sometimes sporophyte

(b) Predominantly gametophyte with sporophyte attached to it

(c) Gametophyte

(d) Sporophyte

883. *Funaria* is fixed in substratum by

(a) Unicellular simple rhizoids

(b)Multicellular branched oblique septate rhizoids

(c) Branched coenocytic rhizoids (d) Tuberculate rhizoids

RICCIA

Basic Level

884. Thallus of *Riccia* is
(a) Triploid (b) Diploid (c) Haploid (d) Tetraploid

885. Plant body of *Riccia* is
(a) Sporophyte (b) Gametophyte (c) Aquatic (d) Sporophyte

886. In *Riccia*, the archegonium is
(a) Rounded (b) Cup-shaped (c) Star-shaped (d) Flask-shaped

887. *Riccia* gametophyte develops from spore and ends in
(a) Thallus (b) Capsule (c) Zygote (d) Spore

888. Sporophyte of *Riccia* contains
(a) Spores, elaters and nutritive cells (b) Spores and nutritive cells
(c) Elaters and spores (d) Spores only

889. Sex organs are embedded in the thallus in
(a) Moss (b) *Riccia* (c) *Azolla* (d) Fern

890. In *Riccia* / *Marchantia* the rhizoids are
(a) Branched unicellular (b)Branched multicellular
(c) Unbranched multicellular (d) Unbranched unicellular

891. Rhizoids in *Riccia* are
(a) Unicellular smooth-walled (b)Unicellular tuberculate
(c) Both smooth-walled and tuberculate unicellular
(d)Multicellular smooth-walled and tuberculate

892. What is not true for *Riccia*
(a) Simple sporophytic stage
(b) Spores are released by rupture of sporangiam
(c) Sporophyte is total parasite (d) Rhizoids are unicellular

893. The sporophyte of *Riccia* is
(a) Chemoautotrophs (b) Partial parasite
(c) Photosynthetically independent (d) Total parasite

Advance Level

894. In *Riccia* / Bryophytes
(a) Sporophyte is parasitic over gametophyte (b) Gametophyte is parasitic over sporophyte
(c) Sporophyte is independent of gametophyte (d) Sporophyte is semiparasite

895. Spores of *Riccia* are liberated by
(a) Peristome teeth and seta
(b) Shrinkage of annulus and explosion of capsule
(c) Death and decay of thallus and external pressure on calyptra
(d) Xerochasy of elaters

896. An archegonium of *Riccia* has

(a) 4 neck canal cells, 1 venter canal cell and one oosphere

(b) 4 neck canal cells, 2 venter canal cells one oosphere

(c) 4 neck canal cells, one venter canal cell and two oospheres

(d) 6 neck canal cells, 2 venter canal cells and one oosphere

PTERIDIUM , PTERIS AND DRYOTERIS

Basic Level

897. *Pteridium* possesses

(a) Polycyclic dictyostele (b)Actinostele

(c) Siphonostele (d)Amphiphloic siphonostele

898. Placenta in *Dryopteris* is the place of attachment of

(a) Ovules (b) Ramenta (c) Sporangia (d) Archegonia

899. In *Dryopteris*, the sori are borne

(a) Laterally (b) Abaxially (c) Adaxially (d) Marginally

900. In Pteridophytes/ *Dryopteris* meiosis occurs at the time of

(a) Gamete formation (b)Spore formation

(c) Formation of prothallus (d)Formation of sex organs

901. In *Dryopteris*, the antherozoids are

(a) Biflagellate sickle-shaped (b)Multiflagellate sickle shaped

(c) Multiflagellate spirally coiled (d) Biflagellate spirally coiled

902. Which one controls dehiscence of sporangium in *Dryopteris*

(a) Annulus (b) Tapetum (c) Sorus (d) Indusium

903. Presence of ciliated antherozoids in *Dryopteris* indicates

(a) Terrestrial habit (b) Aquatic ancestry (c) Both A and B (d) None of these

904. Neck canal cells in *Dryopteris* are

(a) One with two nuclei (b) Two (c) One with one nucleus (d)Four

905. Brown hair found at the base of *Pteris* leaves are

(a) Modified stipules (b) Modified leaflets (c) Ramenta (d) Spines

906. Kidney- shaped soral covering of *Dryopteris* is

(a) Ramentum (b) Placenta (c) Indusium (d) Sporophyll

907. The site of spore formation in *Dryopteris* is

(a) Sorus (b) Sporophyll (c) Sporophore (d) Sporangium

908. What is not true for *Dryopteris*

(a) Mature archegonia secretes maleic acid

(b) Antherozoids are sickle shaped and multi flagellate

(c) Archegonia has one binucleate neck canal cell

(d) Antheridia develop on ventral surface of prothallus

909. 'Male shield fern' is

(a) *Dryopteris* (b) *Pteris* (c) *Adiantum* (d) None of these

910. Sorus of *Dryopteris* fern is

(a) Simple sorus (b) Gradate sorus (c) Mixed sorus (d) None of these

911. The stele is arranged in the form of 'C' in which portion of fern plant (*Dryopteris*)

(a) Rhizome (b) Young rachis (c) Old rachis (d) Lamina

912. Sporophyte of *Pteris* is

(a) Independent of gametophyte from the very beginning

(b) Dependent upon gametophyte only in the beginning

(c) Dependent on gametophyte fully (d)None of the above

913. Fern *Dryopteris* is

(a) Homosporous (b) Heterosporous (c) Both (a) and (b) (d) None of these

914. The development of *Dryopteris*

(a) Eusporangiate (b) Leptosporangiate (c) Both (a) and (b) (d) None of these

915. Sporophyte of *Pteris*

(a) Supplies water and inorganic salts to the gametophyte

(b) Is independent of gametophyte from the very beginning

(c) Is dependent on gametophyte only in the beginning (d) None of these

916. Spores of *Dryopteris* are

(a) Haploid (b) Diploid (c) Triploid (d) Tetraploid

917. In *Pteris*, the sori are

(a) Continuous and linear (b) Discontinuous and circular

(c) Discontinuous and reniform (d) Discontinuous and vermiform

918. *Pteris* differs from *Funaria* in having

(a) Dependent sporophyte (b)An independent gametophyte

(c) Swimming antherozoids (d)Dominant sporophytic phase

919. The stele in the rachis of *Pteris* is

(a) Collar shaped (b) Horse shoe- shaped (c) Omega shaped (d) H- shaped

920. Young sporophyte of *Pteris* fern draws nourishment from prothallus through

(a) Root (b) Rhizoids (c) Foot (d) Haustoria

921. The stele of *Pteridium* root is

(a) Diarch exarch (b) Diarch endarch (c) Polyarch exarch (d) Polyarch endarch

922. Sorus bearing leaf of *Pteridium* is called

(a) Ramenta (b) Indusium (c) Sporophyll (d) None of these

923. Indusium in *Pteridium* is

(a) Outer true and inner false (b)Only true

(c) Outer false and inner true (d)Only false

Advance Level

924. In *Dryopteris*

(a) Sporophyte is parasitic over gametophyte (b) Sporophyte is independent

(c) Gametophyte is independent (d) Both (b) and (c)

925. What is correct

(a) Protonema of moss and prothallus of *Dryopteris* are sporophytic

(b) Protonema of moss and prothallus of *Dryopteris* are gametophytic

(c) Moss protonema is sporophytic, *Pteris* prothallus is gametophytic but plant body of *Pteris* and *Funaria* are gametophytic

(d) Plant body of moss is gametophytic while that of *Dryopteris* is both gametophytic and sporophytic

SELAGINELLA

Basic Level

926. The main plant body of *Selaginella* sp. is

(a) Gametophyte (b) Sporophyte

(c) Both gametophyte and sporophyte (d) Halophyte

927. *Selaginella* is characterized by the presence of

(a) Homospory (b) Ligule (c) Flowers (d) None of these

928. Which one of the following characters is not shown by *Selaginella*

(a) Circinate venation (b)Precocious germination

(c)Microphyllous leaves (d)Protostele

929. *Selaginella* has the character of evolutionary importance. That character is

(a) Ligule (b) Seed (c) Heterospory (d) Strobilus

930. In *Selaginella*, reduction division occurs

(a) During formation of microspores

(b) During formation of both microspores and megaspores

(c) During formation of sperms (d) Immediately after fertilization

931. Number of megaspore in *Selaginella* rupestris is

(a) One (b) Two (c) Three (d) Four

932. The number of antherozoids produced from an antheridium of *Selaginella* is
(a) 64 (b) 256 and above (c) 25 to 50 (d) 128 to 256

933. In *Selaginella* megaspores are about how many times larger than microspores
(a) Five times (b) Ten times (c) Twenty times (d) Hundred times

934. In which one of the following species of *Selaginella*, the apex continues its vegetative growth beyond the formation of strobilus
(a) *S. helvetica* (b) *S. cuspidiata* (c) *S. rupestris* (d) None of these

935. The number of male prothellial cells in *Selaginella* are
(a) One (b) Two (c) Four (d) Nil

936. Which one of the following is not involved in fertilization of ferns
(a) Water (b) Pollen tube (c) Flagellated sperms (d) Archegonia

937. Which of the following is not common in *Funaria* and *Selaginella*
(a) Roots (b) Archegonium (c) Embryo (d) Motile sperms

938. Rhizophore of *Selaginella* is
(a) Positively geotropic (b) Negatively geotropic (c) Apogeotropic (d) None of these

939. Positively geotropic structure rhizophore of *Selaginella* is
(a) Root (b) Stem
(c) A new organ called sui generis (d) None of these

940. The basal portion of ligule of *Selaginella* is hemispherical and is called
(a) Glossopodium (b) Awn of ligule (c) Bundle sheath (d) Pedicel of ligule

941. Which of the following does not belong to *Selaginella*
(a) Ramenta (b) Trabeculae (c) Rhizophore (d) Ligule

942. In *Selaginella* when sporophyte develops directly from female gametophyte other than oosphere, the condition is called
(a) Apospory (b) Aplanospory (c) Apogamy (d) Cleistogamy

943. One character common for *Selaginella* and fern is
(a) Heterospory (b) Protostele
(c) Development of sporangium (d) Absence of ovule

944. In *Selaginella* male gametes are
(a) Aflagellated (b) Monoflagellated (c) Biflagellated (d) Multiflagellated

945. In *Selaginella*, the megasporophyll is comparable to a structure in angiosperms
(a) Stamen (b) Leaf (c) Carpel (d) Ovule

946. *Selaginella* possesses an outgrowth proximally on the adaxial surface. It is
(a) Ligule (b) Indusium (c) Stipule (d) Petiole

947. Botanical name of Sanjeevani is
(a) *Selaginella chrysocaulos* (b) *Selaginella bryopteris*
(c) *S. chrysorhizos* (d) None of these

948. In *Selaginella* stem, trabeculae represent modified
(a) Phloem cells (b) Endodermal cells (c) Pericycle cells (d) Cortical cells

949. In *Selaginella*
(a) Gametophyte is dominant (b)Sporophyte is dominant
(c) Sporophyte is total parasite (d)Gametophyte is total parasite

950. The first division in zygote of *Selaginella* is
(a) Transverse (b) Longitudinal (c) Oblique (d) Both A and B

951. *Selaginella* multiplies vegetatively through
(a) Tubers (b) Resting buds (c) Fragmentation (d) All of these

952. Which one does not occur in *Selaginella*
(a) Heterospory (b) Heterophylly (c) Homospory (d) Ligulate leaves

953. Which is absent in leaf of *Selaginella*
(a) Xylem (b) Phloem (c) Palisade parenchyma (d)Stomata

Advance Level

954. Which of the following is not correct with reference to *Selaginella*
(a) *Selaginella* is commonly distributed on hills and plains
(b) Some species of *Selaginella* are truly xerophytic
(c) The vascular cylinder is protostelic (d) The endodermis is trabeculated

955. *Selaginella* differs from *Pteris* (fern) in which of the following character
(a) Absence of seed (b) Absence of vessels in xylem
(c) Need water for fertilization (d) Heterosporous condition

956. *Selaginella* has a tendency to form seed, called seed habit, because it follows
(a) Retention of megaspore permanently inside the megasporangium
(b) Heterospory
(c) Both above characters (d) None of these

957. The stem of *Selaginella* is anatomically characterised by the presence of
(a) Siphonostele (b) Amphiphloic siphonostele
(c) Protostele (d) Ectophloic siphonostele

958. Antherozoids of *Selaginella* has
(a) Elongated body with many flagella
(b) An elongated body with two flagella at one end
(c) Top shaped body with many flagella (d) Oval body with two flagella at one end

959. The 13 - celled male gametophyte of *Selaginella* shows
(a) 8 cells of the antheridium +5 prothallial cells (b) 9 cells of the antheridium +4 prothallial cells
(c) 10 cells of the antheridium +3 prothallial cells
(d) 12 cells of the antheridium +1 prothallial cell

960. Trabeculae in *Selaginella* stem represent

(a) Modified pericycle cells (b)Modified endodermal cells

(c) Modified inner cortical cells (d)Modified phloem cells

PINUS

Basic Level

961. The pollination in *Pinus* is

(a) Entomophilous (b) Anemophilous (c) Hydrophilous (d) Malscophilous

962. *Pinus* produces

(a) No seeds (b) Flowers

(c) No vascular tissues (d) Naked seeds in cones

963. *Pinus* is

(a) Deciduous (b) Dioecious (c) Monoecious (d) None of these

964. In *Pinus* only lower part of oospore is concerned with the development of embryo, such development is

(a) Meroblastic (b) Periblastic (c) Mesoblastic (d) None of these

965. *Pinus* seed is originated in

(a) Capsule (b) Microsporophyll (c) Microsporangia (d) Megasporophyll

966. The male cone of *Pinus* is formed of

(a) Anthers (b) Megasporophylls (c) Ligules (d) Microsporophylls

967. In *Pinus* male gametes are produced in the pollen tube by the division of which of the following cells

(a) Body cell (b) Stalk cell (c) Tube cell (d) Prothallial cell

968. In *Pinus*, the approximate time for fertilization after pollination is

(a) Only a few hours (b) Only a few days (c) Only a few weeks (d) About one year

969. Female gametophyte (endosperm) in *Pinus* is formed

(a) Before pollination (b) After pollination (c) After fertilization (d) None of these

970. The foliage leaves or needles in *Pinus* are borne by

(a) Branches of unlimited growth (b) Branches of limited growth

(c) Branches of limited and unlimited growth (d) Female cones

971. Which of the following features are true for *Pinus*

(a) Haploid endosperm (b) Biciliated sperms

(c) Double fertilization (d) Presence of antheridia

972. *Pinus* shows

(a) Heterospory (b) Polyembryony

(c) Homospory (d) One type of branching

973. The microsporophylls of *Pinus* has

(a) Many microsporangia (b)No microsporangia

(c) 2 microsporangia (d)Only one microsporangium

974. Pollination of pollen grains in *Pinus* takes place at
(a) One celled stage (b) Two celled stage (c) Three celled stage (d) Four celled stage

975. In *Pinus*, the spur (dwarf shoot) has
(a) One needle (b) Two needles (c) Three needles (d) All correct

976. The secondary wood of *Pinus* is characterised by
(a) Presence of resin cells (b)Presence of resin ducts
(c) Absence of resin ducts (d)Presence of vessels

977. The winged pollen grain of *Pinus* sp. are produced in
(a) Pollen chamber (b) Anther (c) Tapetum (d) Microsporangium

978. How many prothallial cells are formed in the male gametophytes of *Pinus*
(a) One (b) Two (c) Three (d) Many

979. In *Pinus* seeds there are
(a) Two cotyledons (b) One cotyledon (c) Fleshy cotyledons (d) Many cotyledons

980. Endosperm of *Pinus* is
(a) Male gametophyte (b) Female gametophyte (c) Sporophyte (d) None of these

981. *Pinus* shows
(a) Simple polyembryony (b) Cleavage polyembryony
(c) Both simple and cleavage polyembryony (d) None of these

982. *Pinus* seed shows
(a) Hypogeal germination (b)Epigeal germination (c)Dormancy (d) None of these

983. Female cone of *Pinus* can be compared to which part of the plant
(a) Flower (b) Megasporophyll (c) Inflorescence (d) Microsporophyll

984. Which of the following structures in *Pinus* are haploid
(a) Megaspore, integument, root (b)Endosperm**,** megaspore**,** pollen grain
(c) Pollen grain, leaf, root (d)Megaspore, endosperm, embryo

985. If the haploid number of chromosomes in *Pinus* is 12, the number in its endosperm cells will be
(a) 12 (b) 24 (c) 36 (d) 6

986. The wood of *Pinus* is
(a) Pycnoxylic and homoxylous (b)Pycnoxylic and heteroxylous
(c) Manoxylic and homoxylous (d)Manoxylic and heteroxylous

987. Which one of the following alternatives represents the gametophytic phase in *Pinus*
(a) *Pinus* plant (b) Zygote
(c) Micro and megaspores (d) Male and female cones

988. Time lapse between fertilization and seed formation in *Pinus* is
(a) 6 years (b) 2 years (c) 1 ½ years (d) 1 year

989. The endosperm of *Pinus is*
(a) Haploid (b) Diploid (c) Triploid (d) Polyploid

990. Integument in *Pinus* ovule is
(a) Haploid (b) Diploid (c) Triploid (d) Tetraploid

991. Ovules in *Pinus* are generally

(a) Anatropous with three integuments (b) Anatropous with one integument

(c) Amphitropous with three integuments (d) Orthotropous with two integuments

992. Number of archegonia in *Pinus* ovule is generally

(a) 1 to 4 (b) 2 to 5 (c) 2 to 6 (d) 4 to 8

993. The spur of *Pinus occelsa* is

(a) Unifoliar (b) Bifoliar (c) Trifoliar (d) Pentafoliar

994. In *Pinus* female gametophyte develops only from

(a) Upper most haploid megaspore (b)The lower most haploid megaspore

(c) Penultimate megaspore (d) The 3rd megaspore

995. The seed of *Pinus* represents

(a) One generation (b) Two generations (c) Three generations (d) Four generations

996. What nature does, acicular nature of *Pinus* needle depicts

(a) Mesophytic (b) Xerophytic (c) Hydrophytic (d) Sporophytic

997. Which statement is correct with reference to *Pinus*

(a) It is of much economic value (b)It is cosmopolitan in distribution

(c) If grows in deserts and exhibits xerophytic character

(d) If form deciduous trees in temperate region

998. *Pinus*

(a) Bears flowers (b) Exhibit no vascular tissue

(c) Produces seeds in cones (d) Does not produce seeds in cones

999. Among the following which does not belong to sporophytic generation in *Pinus*

(a) Roots (b) Endosperm (c) Dwarf shoot (d) Long shoot

1000. Popular dry fruit "chilgoza" is produced by

(a) *Pinus sylvestris* (b) *Pinus monophylla* (c) *Pinus gerardiana* (d) *Pinus roxburghii*

1001. In *Pinus* needle vascular bundles are

(a) Bicollateral (b) Collateral and closed (c) Collateral and open (d) Concentric

1002. The male cone of *Pinus* is modified

(a) Long shoot (b) Needle leaves (c) Dwarf shoot (d) None of these

1003. Pollen grain wings of *Pinus* are outgrowths of

(a) Intine (b) Exine (c) Exo-intine (d) Sporangial wall

1004. In *Pinus*, the male gametes are

(a) Nonciliate (b) Multiciliate (c) Biciliate (d) Uniciliate

1005. *Pinus* differs from Mango in having

(a) Tree habit (b)Green leaves

(c) Ovules not enclosed in ovary (d)Wood

1006. Which one is common between *Pinus* and *Dryopteris*

(a) Presence of antheridia and archegonia (b) Presence of pollen tube

(c) Absence of seeds (d) Absence of fruits

1007. Female cone of *Pinus* develops seeds in

(a) One year (b) Two years (c) Three years (d) Four years

1008. Male cone of *Pinus* replaces

(a) Needles (b) Scales (c) Dwarf shoots (d) Long shoots

1009. Dwarf shoot of *Pinus* is

(a) Shed every year (b) Shed after 2 – 3 years (c) Shed after five years (d) Never shed

1010. Which tissue present in leaves of *Pinus* conducts food and water laterally

(a) Transfusion tissue (b) Phloem (c) Xylem (d) Medullary rays

1011. Nucellus of *Pinus*

(a) Is vestiges of endosperm (b) Forms wall of megaspore

(c) Is a membranous layer between the edible part and seed coat

(d) Is the remnant of embryo

1012. Which is commonly known as "Blue pine"

(a) *Pinus strobus* (b) *P. wallichiana* (c) *P. merkussii* (d) *P. syluestris*

1013. Which species of *Pinus* is found at maximum height

(a) *P. excelsa* (b) *P. merkussii* (c) *P. insularis* (d) *P. roxburghii*

1014. Tripoliar spur is found in

(a) *Pinus* gerardiana (b) *P. wallichiana* (c) *P. sylvestris* (d) None of these

1015. Resin canals in cortex and xylem of stem of *Pinus* are

(a) Schizogenous cavities (b)Lysigenous cavities

(c)Schizobysigenous cavities (d) None of these

1016. *Pinus* wood is

(a) Porous (b) Non-porous (c) Slightly porous (d) None of these

1017. Transfusion tissue is present in which organ of *Pinus*

(a) Needle (b) Stem (c) Root (d) None of these

1018. The microsporangia are present on ..... surface of microsporophyll in *Pinus*

(a) Dorsal (b) Ventral (c) Both (a) and (b) (d) None of these

1019. Megasporophyll of *Pinus* is made of

(a) Bract scale (b) Ovuliferous scale (c) Both (a) and (b) (d) None of these

1020. *Pinus* has medullary rays

(a) Homogenous (b) Heterogenous (c) Short (d) Large

1021. Among the following which does not belong to sporophyte generation in *Pinus*

(a) Dwarf shoot (b) Long shoot (c) Roots (d) Endosperm

1022. "Kail" is

(a) *Pinus roxburghii* (b) *P. wallichiana* (c) *P. gerardiana* (d) *P. insularis*

1023. The term "Saccus" is used for

(a) Wings of seeds of *Pinus* (b) Wings of pollen grain of *Pinus*

(c) Prothallial cell of pollen grain of *Pinus* (d) Intine of pollen grains of *Pinus*

1024. The edible part of seed of *Pinus* is

(a) Epispore (b) Endosperm (c) Perisperm (d) Pericarp

1025. Saccus of *Pinus* pollen is a modification of

(a) Intine (b) Exine (c) Tube cell (d) Perine

1026. The mature embryo of *Pinus* consists of

(a) Radicle and plumule (b) 1 + 10 cotyledons

(c) Radicle**,** plumule and many cotyledons (d) 3 cotyledons + endosperm

Advance Level

1027. Seed of *Pinus* shows three generations as

(a) Parent sporophyte**,** gametophyte and future sporophyte

(b) Parent gametophyte, sporophyte and future gametophyte

(c) Parent sporophyte, sporophyte, future gametophyte (d)None of these

1028. In *Pinus* male and female reproductive structures occur

(a) On different branches of the same plant (b) On different plants

(c) On same branch (d) None of these

1029. Which of the following tissue is present in the leaves of *Pinus* and serve to conduct water and food

(a) Xylem (b) Phloem (c) Transfusion tissue (d) Conducting tissue

1030. The wing in *Pinus* seed originates from

(a) Integument (b) Adaxial surface of ovuliferous scale

(c) Bract scale (d) Cone axis

1031. The sclerenchyma of the hypodermis in the *Pinus* needle helps in

(a) Photosynthesis (b) Mechanical support

(c) Checking transpiration (d) Increasing the absorptive surface of the cell

1032. The seed of *Pinus* sp. is

(a) Uneconomic and nonendospermic (b) Abaxial and rounded

(c) Adaxial and endospermic (d) Hypogeal and monocotyledonous

1033. Which of the following is the best explanation for the excurrent (pyramidal) shape of *Pinus* (the branches giving the plant the appearance of a tall cone)

(a) Competition among adjoining trees for sunlight

(b) The effect of auxins on growth of stem tips

(c) Adaptation for wind pollination

(d) Efficiency of water transport from ground to leaves

1034. Of the following, the false character with respect to *Pinus* is

(a) Bract and ovuliferous scales (b)Embryo with two cotyledons

(c) Resin canals in needles (d)Tracheids with bordered pits

1035. In the embryo of *Pinus* rosette cells lie

(a) Above suspensor cells (b)Between suspensor and embryonal cells

(c) Between primary and secondary suspensor cells (d)Between embryonal and apical cells

1036. The gametophytes of *Pinus* are protected from dessication by living in

(a) Moist soil (b)Moist tissue of sporophyte in the cone

(c) Bogs and marshes (d)The rainy season only

1037. With respect to the life cycle of *Pinus*, considering the formation of the female cone at the summer of year zero, fertilization occur in

(a) Late autumn of 2nd year (b)Late spring of 2nd year

(c) The same year *i.e.* zero year but in the next season

(d)The early summer of next year (*i.e.* first year)

CYCAS

Basic Level

1038. *Cycas* occurs commonly in

(a) South America (b) North America (c) South East Asia (d) Europe

1039. Spermatozoid of *Cycas* is

(a) Biflagellate (b) Nonflagellate (c) Uniflagellate (d) Multiflagellate

1040. Which is not a characteristic feature of *Cycas*

(a) Naked ovules (b) Circinate vernation (c) Vessels (d) Girdling leaf traces

1041. *Cycas* has the largest

(a) Ovule (b) Egg (c) Sperm (d) All of these

1042. *Cycas* is

(a) Hermaphrodite (b) Dioecious (c) Monoecious (d) None of these

1043. *Cycas revoluta* is

(a) Date Palm (b) Sea Palm (c) Royal Palm (d) Sago Palm

1044. Wood of *Cycas* is

(a) Monoxylic and manoxylic (b) Manoxylic and polyxylic

(c) Diploxylic (d) Monoxylic

1045. *Cycas* contains

(a) Mucilage ducts (b) Laticiferous vessels (c) Resin ducts (d) Oil ducts

1046. In *Cycas*, pollination is by

(a) Wind (b) Insect (c) Water (d) Both (a) and (b)

1047. In *Cycas*, the ovules are attached to megasporophyll

(a) Laterally (b) Dorsally (c) Ventrally (d) Apically

1048. *Cycas* resembles angiosperms in having
(a) Circinate vernation in leaves (b) Vessels
(c) Motile sperms (d) Ovules

1049. Pollen grain of *Cycas* are shed at stage
(a) One – celled (b) Two – celled (c) Three – celled (d) Four – celled

1050. In *Cycas*, the endosperm is
(a) Sporophytic structure (b)Gametophytic structure
(c)New structure (d)Formed after fertilization

1051. Male gametes of cycads are
(a) Rounded and nonciliate (b) Sickle – shaped biflagellate
(c) Boat – shaped nonciliate (d) Large, top-like, spirally twisted with cilia

1052. Coralloid roots of *Cycas* possess a symbiotic alga
(a) *Aulosira* (b) *Spirogyra* (c) *Ulothrix* (d) *Anabaena*

1053. Coralloid roots help *Cycas* in
(a) Fixation and absorption of nitrogen (b) Absorption of water
(c) Absorption of minerals (d) Respiration

1054. *Cycas* and ferns resemble in possessing
(a) Circinate venation (b) Pollen tube (c) Ovule (d) Seeds

1055. Sago of *Cycas* is given to patients with stomach disorders because it is
(a) Cheap (b) Easily digestible with less starch
(c) Tastier (d) With high nutritive value

1056. Which is incorrect about *Cycas*
(a) Its xylem has vessels (b) It has circinate venation
(c) It does not have well organised female flower (d) Its roots possess some blue–green algae

1057. Vegetative reproduction in *Cycas* occurs by
(a) Scale leaves (b) Sporophylls (c) Bulbils (d) Fragmentation

1058. Megasporophyll of *Cycas* is homologous to
(a) Carpel (b) Stamen (c) Petal (d) Sepal

1059. What is true about foliage of *Cycas*
(a) Palmate and pinnate foliage leaves
(b) Brown scales and pinnate green foliage leaves
(c) Oblong and long leaves (d) Green and scaly leaves

1060. Diploxylic condition occurs in *Cycas* in
(a) Root (b) Stem (c) Coralloid root (d) Leaflet

1061. Microsporangia of *Cycas* occur over microsporophyll
(a) Adaxially (b) Abaxially (c) Laterally (d) Marginally

1062. The microsporophyll of *Cycas* represents a
(a) Male gamete (b) Stamen (c) Pollen grain (d) Pollinium

1063. Fern character in *Cycas* is

(a) Coralloid roots (b) Tap root system (c) Circinate venation (d) Reticulate venation

1064. *Cycas* trunk is covered with

(a) Leaves (b) Leaf bases (c) Scale leaves (d) Both (a) and (b)

1065. Ptyxis in *Cycas* is

(a) Simple (b) Circular (c) Circinate (d) None of these

1066. Inverted 'Omega' shaped arrangement of vascular bundles is found in

(a) *Cycas* leaflet (b) *Cycas* rachis (c) *Cycas* stem (d) *Cycas* root

1067. Transfusion tissue is found in

(a) *Cycas* leaf (b) *Cycas* leaflet (c) *Cycas* petiole (d) *Cycas* root

1068. The number of prothallial cells in male gametophyte of *Cycas* is

(a) 1 (b) 2 (c) 3 (d) 0

1069. *Cycas* ovule is

(a) Orthotropous and unitegmic (b) Orthotropous and bitegmic

(c) Anatropous and unitegmic (d) None of these

1070. How many archegonia develop on one gametophyte of *Cycas*

(a) 1 (b) 2 (c) 1 – 5 (d) 3 – 6

1071. Germination of *Cycas* seed is

(a) Epigeal (b) Hypogeal (c) Both (a) and (b) (d) None of these

1072. The number of neck canal cells in archegonium of *Cycas* is

(a) 2 (b) 4 (c) 6 (d) 0

1073. The number of cotyledons in seed of *Cycas* is

(a) 1 (b) 2 (c) Many (d) All of these

1074. *Cycas* plant is like ..... in appearance

(a) Mango (b) *Acacia* (c) Date palm (d) *Ficus*

1075. Vascular bundles of *Cycas* stem are

(a) Conjoint (b) Collateral and closed

(c) Conjoint**,** collateral and open (d) Conjoint, collateral and closed

1076. Leaves in *Cycas* show

(a) Hydrophobic characters (b) Xerophytic characters

(c) Mesophytic characters (d) Lithophytic characters

1077. Number of ovules present on megasporophyll of *Cycas* is

(a) Only one (b) One pair (c) 1 – 6 pairs (d) Absent

1078. In *Cycas*

(a) Male strobilus and megasporophylls occurs on the same individual

(b) The same cone consists of both micro and megasporophylls

(c) The same sporophyll bears microsporangia and ovules

(d) Male strobilus (cone) and megasporophylls occur on separate individuals

1079. Secondary wood of *Cycas* is devoid of

(a) Tracheids (b) Vessels (c) Protoxylem (d) Metaxylem

1080. Polyembryony seen in *Cycas* is

(a) Potential true polyembryony

(b)Potential true polyembryony and cleavage polyembryony

(c) Adventive polyembryony (d) All of these

1081. The secondary growth in stem of *Cycas* is brought about by

(a) Persistant cambium (b) Short lived cambium

(c) Number of cambia produced in succession (d) Isolated strips of cambium

1082. Which species of *Cycas* is having largest male cones

(a) *Cycas revoluta* (b) *C. rumphii* (c) *C. circinalis* (d) *C. beddomei*

1083. Male and female *Cycas* plants show which type of growth

(a) Monopodial in both (b) Sympodial in both

(c) Monopodial in male and sympodial in female plant

(d) Sympodial in male and monopodial in female plant

Advance Level

1084. A leaf of *Cycas* is supplied with

(a) Two girdle and two direct traces (b) Two girdle and a number of direct traces

(c) Several girdle traces and several direct traces (d) Several girdle traces and direct traces

1085. *Cycas* is living fossil as it has

(a) Ciliated sperms (b) Structure like that of Tree Fern

(c) Restricted occurrence in certain areas (d) Been found in fossil state also

1086. *Cycas* has two cotyledons but is not included under angiosperms because it has

(a) Circinate ptyxis (b) Compound leaves (c) Monocot like stem (d) Naked seeds

1087. Early embryogeny in *Cycas* is characterized by

(a) Absence of suspensor cell (b) Presence of expanded free nuclear division

(c) Reduced free nuclear division (d) Many cotyledons

***

ANSWER

ASSIGNMENT (BASIC AND ADVANCE LEVEL)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
c	a	a	b	c	b	a	b	a	a	d	c	d	d	b	a	c	d	b	c
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
b	b	b	d	a	a	b	b	c	c	a	c	d	a	b	d	d	d	d	a
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
b	d	a	a	c	c	d	c	a	d	d	a	d	b	a	b	b	b	c	c
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
d	c	a	c	a	b	b	b	a	d	b	d	c	c	b	c	d	b	c	d
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
c	b	c	d	c	b	a	b	a	b	b	a	d	c	d	a	a	a	d	d
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
a	b	b	c	a	d	c	b	d	c	c	b	d	c	d	a	c	c	b	b
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
b	b	a	b	a	a	d	c	c	c	d	a	b	a	c	c	d	c	d	c
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
d	d	d	a	c	b	a	d	d	d	c	d	d	b	a	b	a	b	d	c
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
d	a	b	c	d	b	b	a	b	b	a	a	d	c	b	b	d	b	b	b
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
a	c	a	d	d	d	b	d	c	d	d	d	a	d	c	b	c	c	b	a
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220
b	c	c	c	c	d	d	d	b	a	d	c	d	b	b	c	b	a	a	a
221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
d	b	a	c	c	d	a	a	a	a	a	a	b	a	c	c	d	d	c	c
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
d	a	d	b	c	c	a	c	c	d	a	c	a	b	b	b	d	b	a	a

261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280
d	d	a	c	c	b	a	c	d	b	b	d	b	c	c	a	d	c	b	a
281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
c	c	c	a	d	a	d	d	c	d	d	b	b	a	c	a	a	c	a	a
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320
a	c	b	d	d	a	d	c	b	b	b	c	d	a	b	a	c	c	a	b
321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340
b	a	d	d	d	d	b	c	b	b	a	c	d	c	b	c	d	b	c	c
341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
b	b	c	b	d	c	d	c	a	c	b	b	a	d	a	b	b	c	b	d
361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380
b	c	d	d	b	a	c	c	a	b	c	a	c	b	c	b	c	c	d	a
381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
b	c	c	d	a	d	d	d	a	d	a	a	b	d	c	a	a	c	d	b
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420
d	d	d	d	c	b	d	d	c	a	d	b	a	c	d	c	d	a	b	b
421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440
c	b	b	a	a	a	c	d	c	b	a	b	a	c	c	b	a	d	d	a
441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460
a	b	a	d	c	b	a	c	c	b	b	a	b	a	a	d	c	b	a	a
461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480
b	b	d	d	d	a	c	a	a	c	c	a	a	c	a	b	b	d	a	b
481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500
a	a	b	c	a	d	c	d	b	d	d	b	c	b	a	d	a	a	c	b
501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520
a	d	d	c	a	d	c	c	c	c	a	c	d	b	b	d	c	a	c	d
521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540
a	d	d	d	c	b	c	c	a	a	b	a	b	d	a	c	b	a	d	d

541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560
b	d	c	a	c	b	b	c	d	c	a	d	b	c	d	d	c	c	d	a
561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580
b	d	d	b	d	c	c	c	d	d	c	c	c	c	a	d	c	d	a	b
581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600
c	c	b	d	c	b	b	c	b	d	c	b	a	c	c	d	b	c	c	c
601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620
c	a	a	c	d	a	c	b	b	c	d	a	d	a	d	a	d	b	a	c
621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640
d	b	c	b	b	b	c	b	b	b	b	c	c	c	c	c	c	a	a	c
641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660
a	d	d	c	d	b	c	c	a	a	a	d	b	b	d	d	b	c	b	c
661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680
b	b	c	b	d	a	a	b	b	a	c	c	b	a	b	b	b	a	a	a
681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700
c	a	d	c	c	c	d	a	d	a	c	b	c	d	d	b	c	b	b	a
701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720
d	a	c	c	d	c	c	d	c	d	d	b	c	b	d	d	c	a	b	b
721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740
b	a	b	d	a	c	b	a	a	b	d	b	c	c	a	c	a	d	a	c
741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760
b	b	a	b	b	b	c	b	c	c	b	a	a	c	d	a	d	c	c	d
761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780
d	d	a	b	a	d	a	c	c	a	c	a	a	c	a	a	d	a	d	a
781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800
b	a	d	b	d	b	b	b	d	c	d	b	c	b	b	a	b	d	c	d
801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820
d	a	c	d	a	c	a	c	a	b	a	b	b	d	c	c	b	a	b	b

821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840
b	c	d	a	d	b	c	a	a	a	c	a	b	c	c	b	d	d	d	b
841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860
d	c	b	d	d	a	b	c	a	d	c	b	c	b	c	b	c	c	b	a
861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880
a	b	b	d	d	d	d	b	d	d	d	a	b	d	d	c	c	b	b	d
881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900
b	b	b	c	b	d	c	b	b	d	c	b	c	a	c	a	a	c	b	b
901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920
c	a	b	a	c	c	d	b	a	c	b	b	a	b	c	a	a	d	b	c
921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940
a	c	c	d	b	b	b	a	c	b	a	d	d	b	a	b	a	a	c	a
941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960
a	c	d	c	c	a	b	b	b	a	d	c	c	a	d	c	c	b	d	b
961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980
b	d	c	a	d	d	a	d	a	b	a	b	c	d	d	b	d	b	d	b
981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
c	b	c	b	a	a	c	d	a	b	a	b	d	b	c	b	a	c	b	c
1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020
c	a	b	a	c	d	c	c	b	a	c	b	a	a	a	b	a	b	c	b
1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040
d	b	b	b	b	c	a	a	c	b	b	c	c	b	a	b	b	c	d	c
1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060
d	b	d	b	a	a	a	d	c	b	d	d	a	a	b	a	c	a	b	d
1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080
b	b	c	d	c	b	b	a	a	d	b	d	b	c	c	b	c	d	b	a
1081	1082	1083	1084	1085	1086	1087													
c	c	d	b	c	d	b													