Plant Kingdom

* Eukaryotic unicellular photoautotrophic organisms with different nature of cell wall and cell wall materials are transferred to Protista from Plant Kingdom.
* Similarly Prokaryotes such as Bacteria and Blue green algae are transferred to Monera and Fungi to Kingdom Fungi.
* Whittaker's Plant Kingdom has Photoautotrophic, usuallymulticellular, chlorophyllous Eukaryotes with cellulosic cell wall.
* Present day Plant kingdom includes Algae, Bryophytes, Pteridophytes, and the seed bearing Gymnosperms and Angiosperms (Spermatophytes).

Algae

* These are chlorphyllous, thalloid, phtoautotrophic, mostly aquatic organisms. Some of them form lichens along with fungi, some are epizoic on shells and sloth bear (alga *Trichophilouswickerii*). Some are present on moist stones, wood and soil.
* These are rarely unicellular flagellates like *Chlamydomonas*, unicellular non-flagellates like *Chlorella*, colonial flagellates like *Volvox*, coenobial non-flagellates like *Scenedesmus*, unbranched filamentous forms like *Spirogyra* and *Ulothrix*, Branched filamentous like *Cladophora*, heterotrichous like *Fritschiella*, forms with nodal and intermodal demarcation like *Chara* and some of them with massive body as in case of Kelps like *Macrocystis* (largest alga) and *Laminaria*.
* Cell wall has cellulose and other carbohydrates.
* All have chlorophylls, carotenoids and some have even Phycobilins.
* Reserve food material is usually starch.
* Vegetative reproduction takes place mainly by fragmentation.
* Asexual reproduction is mainly by motile flagellate Zoospores.
* Sexual reproduction takes place by gametogamy or syngamy. The fusing gametes are flagellated and morphologically similar as in Chlamydomonas(isogamy) or non-flagellated as in some species of Spirogyra, the flagellated gametes are dissimilar (anisogamy) as in some species of Chlamydomonas. In some the male gamete is very small flagellated (Volvox) or non-flagellated (Red algae) and the female gamete is non-flagellated and very large (Oogamy).
* The sex organs are usually unicellular. If multicellular as in *Chara*, they are not surrounded by jacket. Male sex organ is antheridium and female is Oogonium.
* Vascular tissues are absent.
* Zygote does not develop into embryo.
* Much of the global photosynthesis is carried out by algae. These are the main primary producers of aquatic environment.
* About 70 species of algae like *Prophyra*, *Laminaria* and *Sargassum* are consumed as food.
* Commercial hydrophilic colloids liken Algin (Brown algae), Carrageen (Red algae) are algal products. Agar-Agar is used to grow microbes in laboratories and also used in ice-cream and jelly preparation.
* Iodine is extracted from kelps like *Laminaria*.
* *Chlorella* is used as Single Celled Protein and also as food for astronauts.

* On the basis of pigment distribution, storage food and cell wall composition, these are classified mainly into three main classes such as Chlorophyceae, Phaeophyceae and Rhodophyceae.

Chlorophyceae

* These are commonly called as **Greenalgae** or **Grassgreen algae**.
* The green coloration is due to the presence of Chlorophyll a and Chlorophyll b present in chloroplasts. Chloroplasts may be discoid, reticulate, ribbon like, star like, cup-shaped etc.
* These usually live in fresh water bodies and some in Brakish and Marine waters.
* Each chloroplast has either one more than one starch storing protein bodied called as Pyrenoids. Some algae store food in the form of oil.
* Cell wall has inner cellulose and outer pectic layers.
* Vegetative reproduction takes place by fragmentation.
* Asexual reproduction takes place usually by zoospore formation. In some it is by aplanospore and akinete formation.
* Sexual reproduction is usually isogamous. In some it takes place by Anisogamy and in others by Oogamey (*Volvox*).
  Ex: *Chlamydomonas, Volvox, Spirogyra, Ulothrix, Chara*

Phaeophyceae

* These are most found in Marine habitats and usually large sized and known as Kelps (*Laminaria, Macrocystis*). Some are filamentous as in *Ectocarpus*.
* These are commonly called as Brown algae. These have olive green to various shades of Brown and this coloration is due to a xanthophyll known as Fucoxanthin,
* They have chlorophyll a and c.
* The reserve food is an alocohol called as Mannitol or a complex carbohydrate called Laminarin.
* Cell wall has cellulose covered by gelatinous substance Algin.
* The plant body usually has a holdfast, a short stipe and elaborate photosynthetic frond.
* Vegetative reproduction takes place by fragmentation.
* Asexual reproduction is by Zoospore formation. These are pear shaped and have two unequal lateral flagella. These flagella are tinsel and whiplash type.
* Sexual reproduction is by isogamy, anisogamy and oogamy. Fertilisation talks place either outside or inside the oogonium. The male gametes are smaller and resemble the zoospores with two lateral flagella and pyriform shape.
  Ex: *Ectocarpus, Dictyota, Laminaria, Sargassum, Fucus*

Rhodophyceae

* Members of Rhodophyceae are commonly called as Red algae and mostly live in warmer marine waters.
* They have chlorophyll a and d. The red color is due to R-Phycoerythrin. It also has phycocyanin. Due to the presence of Phycoerythrin they can grow in deep waters where other algae can not grow.
* Thallusis usually multicellular and some even have complex organization.
* The reserve food is Floridean Starch which is similar to Amylopectin and Glycogen.

* Vegetative reproduction takes place by fragmentation and asexual reproduction by non-flagellate spores called as archaeospores, neutral spores and monospores.
* Sexual reproduction takes place by oogamy. The female sex organ is carpogonium with a single egg cell and male sex organ is spermatangium with non-motile male gametes called as spermatia.
* They show post fertilization changes.
  Ex: *Porphyra, Polysiphonia, Gracilaria, Gelidium*

Bryophytes

* These are **atracheate, embryophytic, and archegoniates** growing commonly in moist shady localities.
* These are commonly called as **Amphibians of the Plant Kingdom** because they grow on moist soils and require water for sexual reproduction.
* These are the **First land plants**and replace the lichens on rocks during Plant Succession.
* Main plant body is thalloid or foliose or differentiated gametophyte attached to substratum by rhizoids.
* Plant body has parenchymatous tissue.
* Sex organs are multicellular and jacketed. The male sex organ is called as Antheridium and female as Archegonium. The antheridium forms biflagellate male gametes and the archegonium has only one egg cell.
* Fertilisation is by zooidogamousoogamy and archegonial secretion has sugars which attract male gametes by chemotaxy.
* Zygote develops into multicellular relatively undifferentiated embryo which becomes adult sporophyte and attached to gametophyte as partial or complete parasite.
* Sporophyte has Foot, Seta or Meristematic zone and Capsule. Capsule has spore mother cells which divide meiotically to form spores. All the spores are morphologically similar and hence **Homosporous**.
* They show heteromorphic alternation of generations and life cycle is Haplo-diplontic.
* Bryophytes serve as food for herbivores.
* Sphagnum forms peat which has been used as fuel and packing material for transporting live specimens as it holds more water.
* They form a mat on the soil and reduce the impact of falling rain on soil to prevent soil erosion.
* Rothmaler divided Bryophytes into three classes as Hepaticopsida, Anthocerotopsida and Bryopsida

Class Hepaticopsida

* Members of this class are commonly called as **Liverworts** which grow in moist shady localities.
* The gametophyte is thalloid (Riccia, Marchantia) or has leaf like appendages in two rows on stem like axis (Porella).
* It is dorsiventral, prostrate and has unicellular rhizoids (smooth walled and pegged) and multicellular scales known as Amphigastriaon the ventral side.
* They may show dichotomous branching as in Riccia and Marchantia.
* Vegetative reproduction is by fragmentation or by the formation of multicellular green structures called as Gemmae (*Marchantia*).

- During sexual reproduction, antheridia and archegonia are formed on the same thallus (Riccia) or on different thalli (*Marchantia*).
- Sporophyte us usually complete parasite on gametophyte and has no **columella**. It has foot and capsule or foot, seta and capsule.
- Sterile, unicellular sporogenous cells with spiral wall thickenings known as **Elaters**are formed in the capsule of some liverworts like *Marchantia*. These help in Spore dispersal.

Class Anthocerotopsida

- Members of this class are commonly called as **Hornworts** because the sporophyte emerges out of the gametophyte in the form of a horn.
- The gametophyte is dorsiventral with unicellular rhizoids but without scales.
- Vegetative reproduction is by fragmentation.
- Thallus has blue green algae such as *Nostoc*.
- Antheridia and Archegonia are formed singly or in groups on the dorsal side in special chambers.
- Sporophyte has **foot, intercalary meristematic**zone and **capsule**. It is partially parasitic on gametophyte.
- Capsule has **columella** and **Psuedo-elaters**. Pseudo elaters help in spore dispersal.
  Ex: *Anthoceros, Notothylas*

Class Bryopsida

- These are called as **Mosses** as the green gametophytes grow in groups.
- The gametophyte has two stages in the life cycle. They are prostrate, branched filamentous **Protonema**looking like alga formed from spore and adult erect leafy gametophyte developed from adventitious buds of protonema known as **Gametophore**.
- Rhizoids are multicellular and branched. Scales are absent.
- Gametophore has Stem like structure called as **Cauloid** and leaf like structures called as **Phylloids**.Phylloids are arranged in alternate manner on the stem.
- Vegetative reproduction takes place by fragmentation, gemmae formation and by secondary protonema formed from wounded parts of gametophore.
- Sex organs arise in groups at the apex of stem and its branches and interspersed by multicellular, uniseriate green structures called as Paraphyses.
- Sporophyte is partial parasite on gametophore and differentiated into foot, seta and capsule.
- Capsule has peristomial teeth which help in spore dispersal by showing hygroscopic movements. Capsule has columella interior to spore sac.
  Ex: *Funaria* (Cord moss or Fire moss), *Sphagnum* (Peat or Bogg moss), *Polytrichum* (Haircap moss)

Pteridophyta

- These are tracheatecryoptogams with arechegonia and embryo.
- These are first terrestrial plants
- These are first terrestrial plant having vascular tissues.
- These are present in cool, damp, shady places. Some grow in sandy-soil conditions. These are club mosses (Lycopodium, Selaginella), Horse tails (Equisetum) and Ferns (Dryopteris).

* The dominant stage in the life cycle is Sporophyte. It is demarcated into root, stem and leaves.
* It has adventitious root system. Psilotum lacks roots.
* Sporophyte has xylem and phloem. Xylem has tracheids, xylem parenchyma. Vessels are present in Selaginella, Equisetum. Phloem has sieve cells and companion cells are absent.
* Stele of the stem is Protostele (central core of xylem surrounded by Phloem), Siphonostele (Medullatedprotostele), Solenostele (protostele with scattered leaf gaps), Dictyostele (Dissected siphonostele with overlapping leaf gaps).
* The leaves are small, microphyllous without leaf gaps as in Selaginella and Lycopodium or large macrophyllous as in Ferns like Dryopteris.
* Sporangia are formed singly in the axil of sporophylls which aggregate to form cones as in *Selaginaella* and *Equisetum* or developed on the abaxial surface in groups called sori as in ferns like Dryopteris.
* Sporangium is developed from a single initial (Leptosporangiate development) or from a group of initials (Eusprorangiate development).
* Spores are formed due to meiosis in spore mother cells of sporangia. In majority of them all the spores formed in a species are morphologically similar and described as homosporous (*Lycopodium*, *Dryopteris*). Some produce morphologically two different types of spores described asheterosporous as in *Selaginella* and *Salvinia*.
* Spores germinate and form relatively very small, microscopic, usually photosynthetic, independent gametophytes known as Prothalli. Prothallus is monoecious or dioecious in homosporous species but always dioecious in hetersporous species. Microspores form male gametophyte and megaspores form female gametophyte. These require water for survival and hence Pteridophytes are limited to narrow geographical area.
* Gametophytes have sessile jacketed multicellular sex organs. The male is antheridium and female is arechegonium. Antheridia form biflagellated (Selaginella, Lycopodium) or multiflagellated (Dryopteris) male gametes. Archegonium has jacket at the neck with four rows of jacket cells. Only one egg cell is present in the archegonium.
* Fertilisation is by ZooidogamousOogamy.
* In some pteridophytes the female gametophyte is retained in the megasporangium of sporophyte. Fertilization and embryo development takes place in the sporangium itself. This event is considered as precursor for seed habit.
* Embryo develops into sporophyte.
* In Ferns like *Dryopteris*, the stem is Rhizome, the large leaves are aerial and pinnately compound and called as Fronds. The young leaves are coiled around themselves like watch spring (Circinate vernation) and petioles are covered by brown hair called Ramenta. The leaflets show open dichotomous or furcate venation. Sori of sporophyll are covered by a membranous sheath called as **Indusium**. In *Pteris*, the reflexed margin of leaflet of sporophyll that protects the sorus is called as **FalseIndusium**. The antherozoids are spirally coiled and multiciliated.

Pteridophyta is classified into four classes called as Psilopsida (*Psilotum*), Lycopsida (*Selaginella*, *Lycopodium*), Sphenopsida (*Equisetum*) and Pteropsida (*Dryopteris*, *Pteris*, *Adiantum* etc. commonly called as Ferns).

Gymnosperms

* These are embryophytic, arechegoniate, tracheatephanerogams.
* These are evergreen usually trees, rarely shrubs and very rarely perennial herbs. Sequoia is one of the tallest trees and Ginkgo is living fossil.

* The dominant stage is in the life cycle is sporophyte and divided into root, stem and leaf.
* The root system is usually Taproot system. Roots of some plants are associated with fungal mycelia and form Mycorrhizal roots (Pinus), while in others associated with Cyanobacteria like Nostoc and Anabaena as in Cycas.
* The stem is branched (*Pinus, Cedrus*) or unbranched (*Cycas*).

* Leaves are simple as in Ginkgo and Gnetum or Pinnate compound as in Cycas. They persist for few years. The leaves are well adapted to withstand extreme of temperature, humidity and wind. In conifers like *Pinus*, the needle like leaves with sunken stomata and thick cuticle reduce the surface area to minimize water loss (xerophytic adaptation).
* Anatomically the stem has Eustele with conjoint, collateral and open vascular bundles. Xylem usually lacks vessels and companion cells are absent in phloem. Stem and root shown secondary growth.
* These plants are heterosporous and produce both mega and microspores on the same plant (Monoecious - Pinus) or on different plants (Dioecious – Cycas). Spores are formed in sporangia which in return formed on microsporophylls and megasporophylls. The sporophylls aggregate and form flower like structures called as Cones or Strobili. Strobilus with microsporophylls is Male and with megasporophylls is female.

* The pollen grains or microspores are liberated at more than 2-celled stage from microsporangium and carried to the ovule by wind (Direct and Anemophilous pollination), germinate in pollen chamber of ovule to form a few celled male gametophyte usually without ciliated male gametes.
* Megasporophylls possess Integumentedmegasporangia known as Ovules. These sporophylls form female cones of female strobili.
* Ovules are unitegmic, orthotropous and exposed. Body of the ovule has massive diploid nutritive tissue called as nucellus. One of the cells of nucellus behaves as megaspore mother cell. This cell divides meiotically and forms haploid megaspores. One of the megaspores develops into female gametophyte retained within the ovule and has 2 or more archegonia. Female gametophyte nourishes the zygote to develop into embryo and therefore called as endosperm.
* Male and female gametophytes of Gymnosperms are not independent and parasitic on sporophytes. They are retained in the sporangia.
* Fertilisation is siphonogamousoogamy. Both siphonogamy and zooidogamousoogamy are seen in Cycas.In most of the gymnosperms only siphonogamy is seen.
* Zygote develops into embryo. The ovules transform into seeds. The seeds are exposed because of absence of ovary or fruit. Hence the name gymnosperms to these plants.
* Seeds are endospermic and polyembryonic.
* The life cycle is diplo-haplontic and alternation of generations areheteromophic.

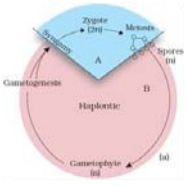
* Multiciliated male gametes, presence of microsporangia as sori on the abaxial surface of microsporophyll, presence of indusial hairs around the sori, leaves with circinate vernation and ramenta are the fern characters shown by *Cycas*.

Gymnosperms are divided into three classes known as Cycadopsida (*Cycas*), Coniferopsida (*Pinus*), and Gnetopsida (*Gnetum*).

Angiosperms

* These are tracheate, non-archegoniate, fruit bearing, spermatophyticembryophytes,
* These grow in wide variety of habitats and occur in differentforms (Herbs, Shrubs and Trees). The smallest plant is almost microscopic *Wolfia* and the tallest is *Eucalyptus* (100 meters tall). It is the dominant vegetation on the soil.
* These are useful to us in many ways like food, fodder, fuel, cloth, medicines and several others.
* The root system is tap root system or adventitious root system.
* Xylem has vessels as the main conducting elements and phloem has companion cells and sieve tubes.
* True flowers having Perianthare present. The flower has stamens or androecium as male sex organ and gynoecium or carpels as female sex organs.
* Anther of the stamen has microsporangia in which microspores or pollen grains are formed from microspore mother cells upon reduction division. The microspores are carried to stigma by various agents during pollination. Pollination is indirect. The male gametophyte is three celled.
* Gynoecium or pistil has carpels which has ovules in the ovary. Ovules are of various types. The most common one is anatropous ovule. It has only one megaspore mother cell which undergoes reduction division and forms four haploid megaspores. One megaspore develops into female gametophyte or embryosac within the ovule which has 8-nuclei and 7-cells. It has an egg apparatus with three cells out of which one is egg cell and the two others are synergids. The central cell has two polar nuclei. At the posterior side there are three antipodals.
* The pollen tube enters the ovule and eventually into its embryosac through synergid and discharges its two male gametes.
* One of the male gametes fuses with the egg cell and forms the zygote and the second one fuses with the two polar nuclei and forms the triploid Primary Endosperm Nucleus. It is called as Double fertilization which is unique to angiosperms.Fertilisation is siphonogamousoogamy.
* Zygote develops into embryo which has either one (Monocots) or two cotyledons (Dictos)and PEN into triploid endosperm which nourishes the embryo and sometimes even the seedling. Ovary develops into fruit.

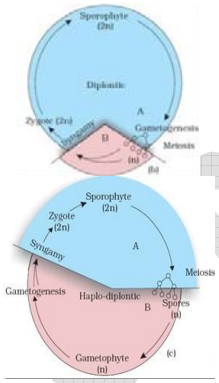
Plant Life cycles and Alternation of Generations



* The haploid gametophytic and diploid sporophytic stages can divide my mitosis. The haploid stage of the plant which produces gametes is called as gametophyte. The diploid stage of the plant that produces haploid spores by meiosis is called as sporophyte.
* In the life cycle of sexually reproducing plant the haploid and diploid stages come alternately and the phenomenon is called as alternation of generations.
* In haplontic life cycle, the diploid stage is limited to only zygote. The zygote undergoes meiosis and forms haploid spores which give rise haploid gametophyte. Gemetophytes are free living but

not the sporophyte. Such life cycle is called as Haplontic life cycle. It is seen in algae like *Volvox*, some species of *Chlamydomonas* and *Spirogyra*.

* Life cycle in which the haploid phase is limited to gametes formed due to reduction division in vegetative cells and the dominant stage is independent diploid sporophyte is called as Diplontic life cycle. Ex: *Fucus*.



* In diplohaplontic life cycle both sporophyte and gametophye are multicellular but the sporophyte dominant and gametophyte is reduced independent or parasitic on sporophyte. Ex: Pteridophytes, Gymnosperms and Angiosperms.
* In Bryophytes the gametophyte is dominant and the multicellular sporophyte is less developed and dependent on gametophyte. Such life cycle is described as Haplo-diplontic life cycle. Algae like Ectocarpus and Laminaria shown this type of life cycle.
* Diplobiontic life cycle is seen in *Polysiphonia*.

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