3 Plant Kingdom

The sago palm is one of the most common plants (Cycas revoluta). Several indigenous cultures across the range of these plants collect and eat the trees' seeds as a food source, and some harvest starch from the stems (called sago).

Topic Notes

- *Classification Systems and Taxonomy*
- *Phanerogamae*

CLASSIFICATION SYSTEMS AND TAXONOMY

1

TOPIC 1

ARTIFICIAL AND NATURAL CLASSIFICATION SYSTEM

Taxonomy (means, "arrangement law") is the science of classifying organisms in order to build universally agreed categorisation systems in which each creature is grouped into increasingly inclusive categories. A hierarchial system refers to the grouping of bigger to smaller, more specialised categories.

Carolus Linnaeus classified plants based on their vegetative characteristics or the androecium structure. Such systems were artificial. Due to the fact that they were based on some morphological features, they differentiated closely related species. Furthermore, the artificial systems provided equal weightage to vegetative and sexual qualities; this is unacceptable because we know that vegetative features are frequently more easily modified by the environment.

In contrast, natural categorisation systems arose, which were based on natural affinities among species and took into account not only surface but also interior aspects such as ultrastructure, anatomy, embryology, and phytochemistry. George Bentham and Joseph Dalton Hooker proposed such a categorisation for flowering plants.

Phylogenetic System of Classification

The phylogenetic system of classification is based on evolutionary relation between various organisms. It was constructed with the help of cues from evolutionary links and ancestry and is used to depict the genetic links between creatures. It is represented by *cladograms*, which are groupings of organisms that include an ancestral species and its descendants.

This suggests that species from the same taxon have a common ancestor. We now use information from a variety of additional sources to assist us in resolving categorisation issues. When there is no supporting fossil evidence, these become much more significant.

Numerical Taxonomy

Numerical taxonomy deals with the numerical grouping of taxonomic entities and is based on their characteristics. It seeks to construct a taxonomy *via* the use of numerical methods such as cluster analysis rather than a review of their characteristics.

Numerical Taxonomy is based on visible features and has bioinformatics programs dedicated to it. All characters are allocated numbers and codes, and the data is subsequently processed. Each character is given equal weightage in this manner, and hundreds of characters can be considered at the same time.

Cytotaxonomy

Cytotaxonomy is a discipline of taxonomy that classifies organisms based on their cellular structures. The chromosomal layout of an organism is most commonly used for this method. It is used to infer the connection between two organisms. The inference of species connections is based on the theory that closely related species have comparable chromosomal configurations called *karyotypes*. The similarities and differences in chromosomes are later used to reconstruct karyotype and species evolution.

Chemotaxonomy

Chemotaxonomy (or chemosystematics), is the taxonomic discipline that categorises and identifies organisms based on differences in their biochemical makeup. Plant selection based on chemotaxonomy is required for effective research of natural products. Taxonomists use chemical ingredients of plants to resolve confusion.

Example 1.1: Case Based:

Taxonomy consists of seven operations— definition, nomenclature, recognition, comparison, and categorisation of taxonomic categories, genetic variation, specimen identification, and taxonomic definition in the ecosystem. The biologist needs a method to supply all of this information in order to obtain complete knowledge of the similarities and differences between various creatures.

Plant taxonomy, often known as classification, is the study of identifying organisms and classifying them into hierarchical groups, with each level assigned a name.

(A) Which of the following is linked to evolutionary descent and ancestry mapping?

(a) Cladograms (b) Dendrograms

(c) Mammograms (d) Phylograms

(B) What were the problems related to Linnaeus' first classification system of plants?

(a) The system was natural, and hence prone to change.

(b) The system was based on morphological structures and provided different weightage to vegetative and sexual characters.

(c) The system differentiated close species and provided equal weightage to vegetative and sexual characters.

(d) There were no problems related to Linnaeus' first classification of plants.

(C) Discuss how numerical taxonomy can be used to overcome the problems caused by traditional taxonomic methods.

(D) What forms the foundation of linnaeus artificial system of classification?

(E) Assertion (A): The chromosomal layout of an organism is most commonly used for chemotaxonomy. It is used to infer the connection between two organisms.

Reason (R): This is based on the theory that all species have comparable chromosomal configurations called karyotypes.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

Ans. (A) *(a) Cladograms*

Explanation: The phylogenetic categorisation system is based on evolutionary descent. It is constructed with the help of cues from evolutionary links and ancestry and is used to depict the genetic ties between creatures. It produces *cladograms*, which are groupings of organisms that contain an ancestor species and its descendants. The rest of the options are unrelated.

(B) *(c) The system differentiated close species and provided equal weightage to vegetative and sexual characters.*

Explanation: Carolus Linnaeus classified plants based on vegetative characteristics or the structure of androecium. Such systems were artificial. Due to the fact that they were based on some morphological features, they differentiated closely related species. Furthermore, the artificial systems provided equal weightage to vegetative and sexual qualities; this is unacceptable because we know that vegetative features are frequently more easily modified by environment.

(C) In biological systematics, numerical taxonomy is a system of classification that deals with the numerical grouping of taxonomic units based on their character states. Rather than relying on subjective evaluation of their properties, it aims to create a taxonomy using numerical procedures like cluster analysis.

(D) The artificial system of classification uses one or two morphological characters for groups of organisms. Linnaeus classified organisms based on the numerical strength of some organs such as androecium number in a flower.

(E) *(d) A is false but R is true.*

Explanation: The chromosomal layout of an organism is most commonly used for cytotaxonomy (not chemotaxonomy). It is used to infer the connection between two organisms.

The inference of species connections is based on the theory that only closely related species have comparable chromosomal configurations called karyotypes.

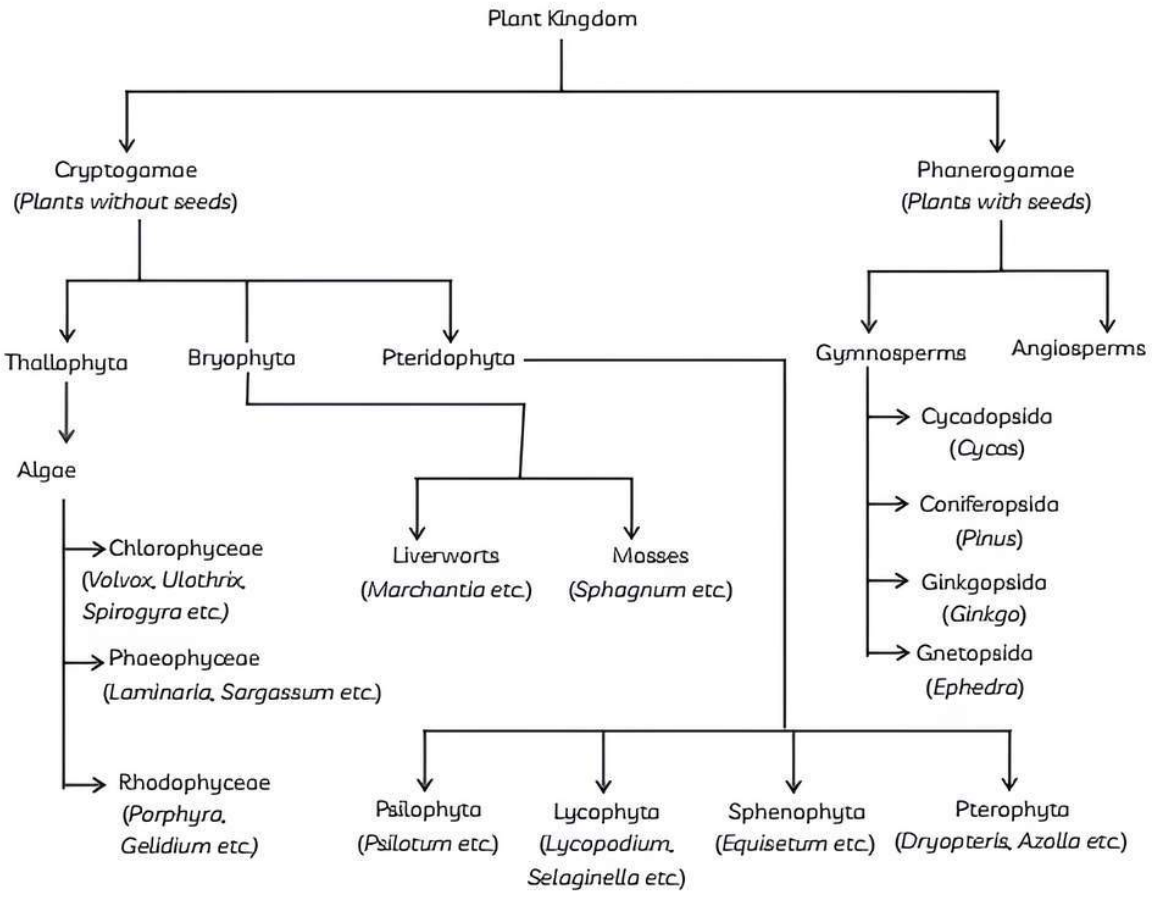
Classification of the Plant Kingdom

The plant kingdom is divided into subgroups. This classification is dependent on a few characteristics, namely:

(1) **Plant body:** The presence of a distinct plant body and parts such as root, stem, and leaves.

(2) **Vascular system:** The presence of a system for transportation in the plant body (a vascular system) such as xylem or phloem.

(3) **Reproductive organs:** Flowers and seeds, and whether the seeds are bare or wrapped in fruit, all contribute to seed production.



TOPIC 2

ALGAE

Division Thallophyta (means — Undifferentiated plants) are the simplest form of plants as they possess undifferentiated or thallus-like structures. The plant body cannot be differentiated into true roots, stems and leaves. Reproductive organs are single-celled non-jacketed structures called gametangia. Asexual reproduction occurs through spores. Currently, it includes only **Algae**.

Algae (sing: Alga-sea weed), are chlorophyll containing thallophytes creatures that are simple, autotrophic, and mostly aquatic. Only a few algae occur in moist terrestrial habitats like tree trunks, wet rocks, moist soil, etc.

Algae

Algae may be found symbiotically in the presence of fungus, such as in lichen.

Algae, like other aquatic plants, are covered by a mucilage. Mucilage protects the algae from epiphyte growth and decaying effect of water.

Algae vary greatly in appearance. Some examples are tabulated as follows:

Appearance of algae	Examples
Microscopic/ Unicellular	*Chlamydomonas, Chlorella, Spirulina*
Colonial	*Volvox*
Filamentous	*Ulothrix, Spirogyra*
Massive plant bodies	*Kelps*

Characteristics of Algae

The plant body is called a thallus, and it can be:

(1) Unicellular

(2) Colonial

(3) Filamentous

Vascular tissues are absent but mechanical tissues are present. Reproduction in algae is primarily vegetative. It may occur by fragmentation.

Asexual reproduction occurs by spore formation (zoospores). Zoospores are flagellated (motile) and on germination give a size to a new plant. Sexual reproduction is also seen, sometimes by fusion of two gametes which can be:

(1) **Isogamous:** Male and female gamete have similar morphology. In *Chlamydomonas*, gametes can be flagellated and similar in size but in *Spirogyra*, gametes are similar and non-motile in nature.

(2) **Anisogamous:** Male and female gametes have different morphology. In some species of *Chlamydomonas*, there is a fusion of two dissimilar gametes is seen.

(3) **Oogamous:** Male and female gametes have different morphology with female gamete significantly larger than male gamete. In *Volvox* and *Fucus*, fusion of one large, non-motile (female) gamete with smaller, motile (male) gamete.

Classification of Algae

Algae are divided in to three types basically:

(1) Chlorophyceae

(2) Phaeophyceae

(3) Rhodophyceae

Chlorophyceae (Green Algae)

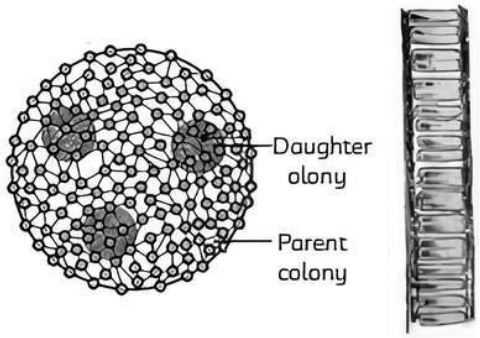
Green algae can occur in all types of habitats. Only 10% of green algae are marine and majority of the species are freshwater.

Photosynthetic pigments are similar to higher plants chlorophyll *a*, chlorophyll *b*, carotenes and xanthophylls. Chloroplasts can be round, flat, filamentous, glass-shaped, spiral, or ribbon-shaped in several species.

Chloroplasts contain storage bodies called pyrenoids which store carbohydrates and protein. Some algae may be capable of storing food in the form of droplets of fat. Green algae frequently have a rigid cell wall made up of an internal lining comprising cellulose and an outer covering of pectose.

Vegetative reproduction is often accomplished by fragmentation. In asexual reproduction, different spores like zoospores, aplanospores, hypnospores, akinetes, autospores, etc. are seen. Flagellated zoospores generated in zoosporangia are used for asexual reproduction. Sexual reproduction differs greatly and it can be isogamous, anisogamous, or oogamous.

Examples: *Volvox*, *Ulothrix*, *Chlamydomonas*, *Spirogyra* and *Chara*.



Volvox *Ulothrix*

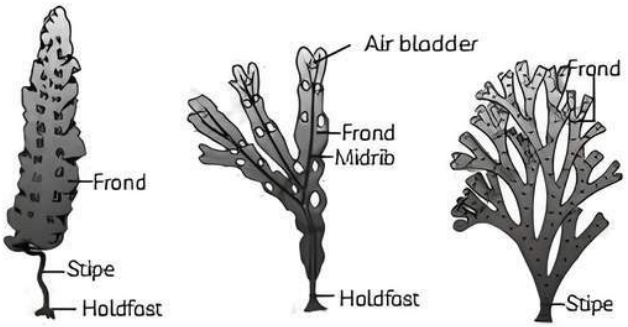
Phaeophyceae (Brown Algae)

Brown Algae comprises about 2000 species.

The body consists of branched, filamentous forms *(Ectocarpus)* heavily branched forms (*Kelps*), and parenchymatous structures in higher forms (*Fucus laminaria*). They contain chlorophyll *a* and *c*, as well as carotenoids and xanthophylls. The quantity of fucoxanthin found in them determines their colour, which ranges from olive green to brown. Food is stored in the form of laminarin or mannitol (complex carbohydrates). The vegetative cells are covered by a cellulosic wall that is normally coated on the exterior by an algin gelatinous covering. The plant body is normally held to the surfaces using a holdfast and consists of Stalk, Stipe, and Frond (leaf-like photosynthetic organ).

Most brown algae reproduce asexually *via* biflagellate, pear-shaped zoospores and have two unequal laterally attached flagella. Isogamous, anisogamous, or oogamous sexual reproduction is also possible. Union of gametes can occur inside or outside the oogonium.

Examples: *Ectocarpus*, *Dictyota*, *Laminaria*, *Sargassum* and *Fucus*.



Laminaria *Fucus* *Dictyota*

Rhodophyceae (Red Algae)

Red algae are defined as eukaryotic algae and have approx 5000 living species. It is the most ancient group of algae.

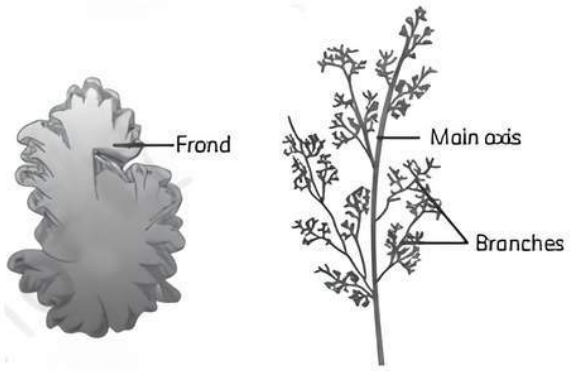
They are marine except for a few freshwater species (*e.g. Batrachospermum*).

They contain pigments like chlorophyll *a*, *d*, and phycoerythrin. Cell wall is made up of cellulose, pectin and mucopolysaccharides called phycocolloids (*e.g.* agar, carrageenin, etc.). Food is stored in the

form of floridean starch, structurally identical to amylopectin and glycogen.

Red algae often proliferate vegetatively by fragmentation. Asexual reproduction takes place variety of spores like neutral, monospores, tetraspores, carpospores and gammae. Sexual reproduction is oogamous. The male sex organ is called spermatangium or antheridium which produces a non-flagellated male gamete. The female sex organ is a flask-shaped structure called carpogonium.

Examples: *Polysiphonia, Porphyra, Gracilaria* and *Gelidium.*



Porphyra *Polysiphonia*

Major Characters of Green, Brown and Red Algae

Algae (Thallophyta)		
Green algae (Chlorophyceae)	**Brown algae (Phaeophyceae)**	**Red algae (Rhodophyceae)**
Sub aerial, fresh water habitats.	Marine habitats.	Marine habitats.
Several unicellular species present.	No unicellular species present.	Few unicellular species present.
Chlorophyll *a* and *b* present.	Chlorophyll *a* and *c* present.	Chlorophyll *a* and *d* present.
Starch is used as reserve food.	Laminarin is used as reserve food.	Floridean starch is used as reserve food.
Cellulosic cell wall present.	Cell wall contains cellulose and algin.	Cell wall contains cellulose and Polysulphate esters.

Algae (Thallophyta)		
Green algae (Chlorophyceae)	**Brown algae (Phaeophyceae)**	**Red algae (Rhodophyceae)**
Xanthophylls present.	Fucoxanthin present.	Phycoerythrin present.
Zoospores present.	Zoospores present.	Zoospores absent.
Examples: *Chlamydomonas, Ulothrix and Spirogyra.*	***Examples:*** *Fucus, Sargassum and Ectocarpus.*	***Examples:*** *Polysiphonia, Gelidium and Porphyra.*

Example 1.2: What is the basis of the classification of algae?

Ans. The pigments, flagellation and reserve food content of the various species of algae and cell wall are used to classify them. Based on these criteria, algae are classified into three categories — red algae, brown algae, and green algae.

Economic Importance of Algae

(1) **As Food:** Some of the species of marine algae are used as food. Examples: *Porphyra, Laminaria, Sargassum* and *Ulva.*

(2) **As Food Supplement:** Green algae like *Chlorella* and blue-green algae like *Spirulina* are rich in proteins. They can be used as food supplements even by space travellers.

(3) **For Photosynthesis:** About 50% of carbon dioxide is fixed by algae in the world.

(4) **Primary Producer:** Algae are primary producers of food in large bodies of fresh, brackish and sea waters.

(5) **Phycocolloid (Hydrocolloids): These are:**

(i) **Carrageenn** from *Chondrus* is an emulsifier and clearing agent.

(ii) **Agar** from *Gelidium* and *Gracilaria* is used as culture medium, canning fish and meat.

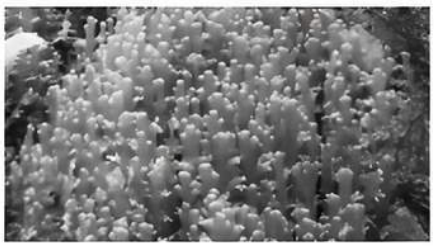
(iii) **Algin** from *Laminaria, Fucus,* and *Sargassum* is used in stabilising emulsions.

TOPIC 3

BRYOPHYTES

Bryophytes are also known as amphibians of plant kingdom as they need soil as well as water (sexual reproduction) to complete their life cycle. The plant body of bryophytes is more differentiated than algae.

Bryophytes include wide variety of mosses and liverworts found in wet, shaded areas.



Bryophytes

Characteristics of Bryophytes

Bryophytes usually grow during the rainy season on damp soil, rocks, and walls. Vegetative reproduction occurs by fragmentation of tubers, gemmae, buds, and so on.

Gametophyte: Constitutes primary plant body, free-living, haploid, produces gametes, roots are absent but there are rhizoids. Multicellular jacketed sex organs - antheridium (male sex organ) producing biflagellate antherozoids that fuse with flask-shaped archegonium (female sex organ) producing a zygote that does not immediately begin reduction division (meiosis).

Sporophyte: Multicellular body produced after fusion of gametes, not free-living, completely dependent on gametophyte for nutrition, some cells of the sporophyte undergo meiosis to produce haploid spores that germinate to produce gametophyte.

Classification of Bryophytes

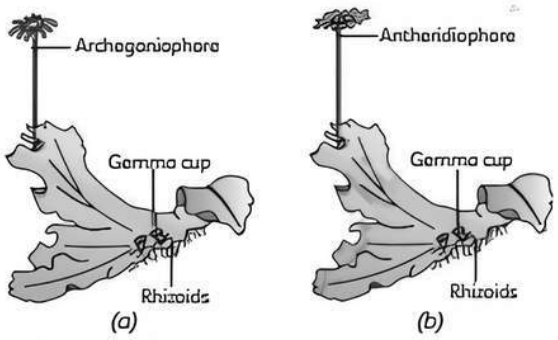
Bryophytes can be divided into :

1) Liverworts
2) Mosses

Liverworts

Liverworts are often present in wet, shady habitats such as stream banks, marshy terrain, damp soil, tree barks, and deep woods. A liverwort's plant body (*e.g., Marchantia*) is a thalloid. The thallus is dorsoventrally placed due to which it adheres to the substrate tightly. The leafy members feature small leaf-like appendages on the stem-like structures in two rows.

Asexual reproduction in liverworts occurs through thalli fragmentation. It can also occur *via* formation of specialised structures known as gemmae. Gemmae are green, multicellular, asexual buds that grow in small receptacles on the thalli called gemma cups.



Marchantia: (a) Female thallus (b) Male thallus

Caution

➥ *Students usually get confused between gemmae and gemma cups. Gemmae and Gemma cups are only slightly different from each other. Gemma cups are cup-like structures that contain gemmae. The gemmae are tiny discs of haploid tissue that give birth to new gametophytes directly. Rainfall disperses them from gemma cups.*

The gemmae separate from the parent body and germinate, resulting in the formation of new individuals. Male and female sex organs are produced on the same or different thalli during sexual reproduction. The sporophyte can be differentiated into foot, seta and capsule. Examples of liverworts are *Riccia, Porella* and *Marchantia.*

Mosses

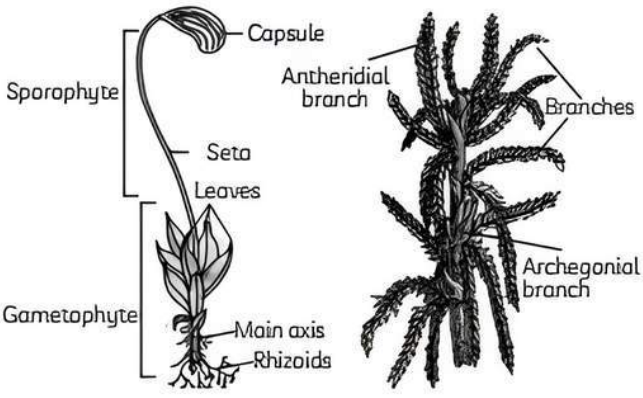
The life cycle of mosses is possibly the most important aspect of them. The most important stage of moss life cycle, *i.e.*, gametophyte stage consists of further two stages:

(1) The protonema stage is the first stage, which develops directly from a spore. It is a creeping stage that is green, branched, and usually filamentous.

(2) The second stage is the leafy stage, which develops as a lateral bud from the secondary protonema. They are made up of upright, slender axes with spirally arranged leaves. They are connected to the soil *via* rhizoids that are multicellular and branching. The sex organs are present in this stage.

Mosses reproduce vegetatively by fragmentation and budding in the secondary protonema. The sex organs, antheridia (male) and archegonia (female) are present at the top of the leafy branches during sexual reproduction. Zygote developed after fertilisation forms a sporophyte, consisting of a foot, seta and capsule. The capsule carries spores that are formed after meiosis. Mosses generally have a more elaborated mechanism of spore dispersal.

Examples of mosses are *Funaria, Polytrichum* and *Sphagnum.*



Funaria *Sphagnum*

Differences between Liverworts and Mosses

S. No.	Liverworts	Mosses
(1)	The plant body is dorsiventral.	The plant body has radial symmetry.
(2)	The plants may be thallose or foliose.	The plants are always leafy.
(3)	Leaves, when present, are without a midrib.	The leaves generally have midrib.
(4)	Branching is generally dichotomous.	Branching is lateral and extra-axillary.
(5)	Rhizoids are unicellular.	Rhizoids are multicellular.
(6)	Seta develops rapidly towards the maturity of spores.	Seta grows slowly over a long period and fully developed before spore matters.
(7)	Capsule often possesses elaters.	Elaters are absent.
(8)	A protonema stage is absent.	A filamentous protonema occurs.

Economic Importance of Bryophytes:

(1) *Sphagnum* moss species provide peat, which has long been utilised as fuel. *Sphagnum* may also be used as packing material for the shipment of living materials due to its ability to hold water.

(2) Mosses and lichens are also the first species to colonise rocks and thus aid in ecological succession. They break down rocks, preparing the substrate for increased plant development.

(3) Mosses can also form a dense mat on upper layer of soil and reduces the impact of rain and prevent soil erosion.

TOPIC 4

PTERIDOPHYTES

Pteridophytes are the first terrestrial plant that has vascular tissue (xylem and phloem). They do not produce flowers or seeds, hence, they are frequently referred to as "cryptogams".

Pteridophyte

They have sporophytic plant bodies inconspicuous gametophytes containing small sessile antheridia and partially embedded archegonia with a 4-rowed neck.

Vascular tissue develops for the first time in pteridophyte. They occur throughout the plant body.

Characteristics of Pteridophytes

(1) Meiospores are formed inside sporangia by sporic meiosis. The leaves bear sporangia are known as sporophylls.

(2) Spores may be similar (homosporous) as in most of the pteridophytes (*E.g. Pteris and Adiantum*). Some plants are heterosporous, *i.e.*, with two types of spores, microspores and megaspores. Species that bear the heterospores are *Marsilea, Salvinia and Selaginella*.

(3) Sperms can be biflagellate or multiflagellated. They require an external water supply or water body to reach archegonia.

(4) Pteridophytes are generally present in damp, cool shady place. Some of them can live in sandy soil. *Azolla, Salvinia and Marsilea* are some examples of aquatic pteridophytes.

Pteridophytes are said to be the earliest plants to develop on land. It is thought that life started in the waters and gradually adapted to dry land over millions of years of development. They are cryptogams, without seeds, and are the first terrestrial plants to possess vascular tissues xylem and Phloem. Pteridophytes are seedless plants and reproduce by spores. They feature a distinct plant body that is divided into true root, stem, and leaves. The leaves are either small called microphylls (as in *Selaginella*) or large called macrophylls (as in ferns). The main plant body of pteridophytes is a sporophyte bearing sporangia subtended by leaf-like appendages called sporophylls. To safeguard the sensitive growth regions, the leaf tips curl inwards. In some cases,

like in *Selaginella* and *Equisetum*, sporophylls form distinct compact structures called strobili or cones. Spores are formed in spore mother cells by meiosis in sporangia.

Reproduction in pteridophytes is described as follows:

(1) The spores germinate and give rise to prothallus, which is tiny, free-living, primarily photosynthetic thalloid gametophytes.

(2) These gametophytes require cool, wet, shaded conditions to thrive. Because of this very restricted need, as well as the necessity for water for fertilisation, the expansion of living pteridophytes is limited and geographically confined.

(3) Male and female sex organs, known as antheridia and archegonia, are found in gametophytes.

(4) Water is essential for the transmission of antherozoids–male gametes discharged by antheridia–to the archegonium's mouth.

(5) The zygote is formed when a male gamete fuses with an egg in the archegonium.

(6) After that, the zygote develops into a multicellular, well-differentiated sporophyte.

(7) When the spores of pteridophytes are of the same kind, the plants are known as homosporous whereas genera like *Selaginella* and *Salvinia* are heterosporous that produce two types of spores— macro (large) and micro (small).

(8) Megaspores and microspores both germinate, generating female and male gametophytes respectively.

(9) Female gametophytes are retained mostly on parent sporophytes for varied durations of time.

(10) Female gametophytes are the sites for transforming zygotes into young embryos. This event serves as a precursor to the seed pattern, which is regarded as a critical step in evolution.

Classification of Pteridophytes

Pteridophyta is classified into four main classes represented as follows:

Pteridophyta			
Psilopsida	**Lycopsida**	**Sphenopsida**	**Pteropsida**
Most primitive	"Club Moss"	"Morsetails"	"Ferns"
Rhizoids present	Rhizoids present.	Roots present.	Roots present.
Leaves mostly absent	Leaves present.	Scaly leaves present.	Leaves present.

Pteridophyta			
Psilopsida	**Lycopsida**	**Sphenopsida**	**Pteropsida**
Homo-sporous	Homo-sporous/ hetero-sporous synangi-um.	Homospo-rous sporo-phyte.	Homospo-rous/het-erosporous sporophyte.
E.g., *Psilotum*	E.g., *Selagi-nella and Lycopodi-um.*	E.g., *Equisetum.*	E.g., *Pteris, Dryopteris and Adian-tum*

Psilopsida (Psilophyta)

(1) They are the most primitive vascular pteridophytes.

(2) Roots are absent. Instead, rhizoids are present.

(3) Stem is dichotomously branched.

(4) It has two parts, aerial and rhizomatous. Aerial stems are green and photosynthetic.

(5) Leaves may be present or absent.

(6) Sporangia develop over the aerial stem either terminally or axially.

(7) Two primitive forms found in fossil state are *Cooksonia* and *Rhynia*. Living forms are known as living fossils.
Examples: *Psilotum* and *Tmesipterus*.

Lycopsida (Lycopods)

(1) Primitive vascular plants which have differentiated root, stem and leaves.

(2) Leaves are microphyllous; *i.e.*, they do not produce a leaf gap in a vascular strand of the stem.

(3) Sporophylls form sporangiferous spikes or strobili.

(4) Sporangia develop either axially or adaxially.

(5) Branching is dichotomous or pseudodichotomous.
Examples: *Lycopodium, Selaginella*

Sphenopsida

(1) Also called "horsetails", these plants have photosynthesising, "segmented," hollow stems that are sometimes filled with pith.

(2) A whorl of leaves forms the junction between each section.

(3) Plants' subsurface sections are made up of jointed rhizomes from which roots and aerial axes arise.

(4) Intercalary meristems sprout in each segment of the stem and rhizome as the plant grows taller. In contrast, most seed plants develop from an apical meristem, which means that new growth originates solely from growing points (and widening of stems).

(5) Some horsetails have cones (strobili) at the terminals of their stems. These cones are made up of spirally organised sporangiophores with sporangia on their edges.
Example: *Equisetum.*

Pteropsida

(1) The Pteropsida are the most developed group of lower vascular plants. Ferns are the most extensively spread pteridophytes.

(2) The subterranean rhizomatous stem of the sporophyte can be elongated or tuberous. In certain circumstances, the rhizome is coated with hairs known as *ramenta*.

(3) The leaves are aerial and megaphyllous, while the remainder of the plant is underground. Roots, like those of other pteridophytes, are always adventitious.
Examples: *Adiantum, Pteris* and *Dryopteris.*

Economic Importance of Pteridophytes

(1) Food: Like other plants, pteridophytes contain a decent source of food for animals. Sporocarps of *Marsilea*, a water fern, yield starch that is cooked and consumed by some tribes.

(2) Soil Binding: By their growth, Pteridophytes bind the soil even along hill slopes. They protect soil from soil erosion.

(3) Scouring: *Equisetum* stems have been used in scouring (utensils cleaning) and polishing of metals. *Equisetum* species are also known as scouring rushes.

(4) Nitrogen Fixation: A water fern named *Azolla* has a symbiotic association with cyanobacteria which carry out nitrogen fixation. *Eg. Anabaena azollae* used to be inoculated in the paddy fields to work as biofertilizers.

(5) Medicines: An anthelmintic drug is obtained from rhizome of *Dryopteris.*

(6) Ornamental: Ferns are grown as ornamental plants for their delicate and graceful leaves.

Differences between Bryophytes and Pteridophytes

S. No.	Bryophytes	Pteridophytes
(1)	Plant body is gametophytes.	Plant body is sporophyte.
(2)	Vascular tissues are absent.	Vascular tissues are present.
(3)	Sporophyte is parasitic over gametophyte.	Both sporophyte and gametophyte are independent.
(4)	Plant body can be thallose or foliose.	Plant body can be differentiated into stem, leave and roots.
(5)	True stems and leaves are absent.	Plants possess true stems and leaves.
(6)	Roots are absent. Instead, they have rhizoids.	Roots are present.
(7)	Haploid or gametophytic phase is long-lived while the sporophytic phase is short lived.	Diploid or sporophytic phase is longer lived while the gametophytic phase is shorter lived.
(8)	Antheridium is stalked.	Antheridium is sessile.
(9)	Archegonium is commonly exposed.	Archegonium is partially embedded.
(10)	Neck of archegonium is formed of 5-6 rows of cell.	Neck of archegonium has four rows of cells.

Example 1.5: Explain briefly the following terms with suitable examples:

(A) Protonema **(B) Antheridium**
(C) Archegonium **(D) Diplontic**
(E) Sporophyll **(F) Isogamy**

Ans. (A) Protonema: It is the haploid phase of the bryophyte lifespan in which a thread-like chain of cells arises. In mosses, the protonema develops directly from a spore.

(B) Antheridium: The male sex organ of bryophytes and pteridophytes is called the antheridium. It generates male gametes. Many fungi and algae, for example, produce antheridia throughout their reproductive phases.

(C) Archegonium: It is the flask-shaped female reproductive organ of bryophytes. It produces a single egg. They are jacketed and multicellular, with a neck and a swelling venter, and may be found in pteridophytes, gymnosperms, and bryophytes.

(D) Diplontic: A life cycle in which the predominant free-living phase is diploid, generating haploid gametes.
Example: *Sargassum*

(E) Sporophyll: It is referred to as a sporangia–bearing, which can be microsporophyll or megasporophyll. These structures come together to produce strobili (cones).
Example: *Pinus.*

(F) Isogamy: Sexual reproduction that occurs by the fusion of two gametes that are either flagellated and comparable in size or non-flagellated (non-motile) but similar in size. Example: *Ectocarpus.*

Example 1.6: Case Based:

The first criterion for plant categorisation is the presence or lack of organs. The existence or lack of distinct conducting tissues for water and food conduction is the next categorisation factor. Do the plants produce seeds? If they do, whether or not the seeds are encased in fruit, is a significant requirement for categorisation. Finally, plants are classified according to the cotyledon number in their seeds. Botanist Eichler divided the Plant Kingdom into two sub-kingdoms, i.e., cryptogams and phanerogams in 1883. As a result, for plant categorisation, these two main sub-kingdoms were considered.

(A) Which of the following examples differ in the presence (and absence) of a seed habit?

(a) *Marchantia* and *Selaginella*

(b) *Sargassum* and *Ginkgo*

(c) *Riccia* and *Chlamydomonas*

(d) *Chara* and *Equisetum*

(B) Botanist Eichler divided the Plant Kingdom into two sub-kingdoms– cryptogams and phanerogams in 1883. These two categories are still followed.

(I) *Riccia* (II) *Marchantia*

(III) *Chara* (IV) *Equisetum*

(V) *Pinus* (VI) *Spirogyra*

(VII) *Ulothrix*

Choose the option that correctly matches cryptogams and phanerogams respectively.

(a) (I), (II), (III), (IV), (VI), (VII) – Phanerogams; (V) – Cryptogams

(b) (I), (II), (III), (IV), (VI), (VII) – Cryptogams; (V) – Phanerogams

(c) (I), (II), (III), (VI), (VII) – Cryptogams; (IV), (V) – Phanerogams

(d) (I), (II), (VI) – Cryptogams; (III), (IV), (V), (VII) – Phanerogams

(C) What exactly are the organs referred to in the first line of the paragraph? Justify with examples.

(D) The plant body in higher plants is well differentiated and well developed. Roots are the organs used for the purpose of absorption. What is the equivalent of roots in the less developed lower plants?

(E) Assertion (A) : The existence or lack of distinct conducting tissues for water and food conduction is the next categorisation factor.

Reason (R) : Pteridophytes consist of well-defined vascular tissue.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

Ans. (A) *(b) Sargassum and Ginkgo*

Explanation: *Sargassum* is a pteridophyte with an absence of seeds as well as hidden reproductive organs. *Ginkgo* is a gymnosperm and hence shows seed habit.

(B) *(I), (II), (III), (IV), (VI), (VII) – Cryptogams; (V) – Phanerogams.*

Explanation: The categories are explained as follows:

(I) *Riccia* – Brypophyta - Cryptogams

(II) *Marchantia* - Brypophyta - Cryptogams

(III) *Chara* - Thallophyta - Cryptogams

(IV) *Equisetum* - Pteridophyta - Cryptogams

(V) *Pinus* -Gymnosperm - Phanerogams

(VI) *Spirogyra* - Thallophyta - Cryptogams

(VII) *Ulothrix* - Thallophyta - Cryptogams

(C) The presence of a distinct plant body and parts such as root, stem, and leaves play a major role in determining the classification of plants. Plants that possess none of these organs are classified under thallophyta *(e.g., Chara* and *Ulothrix)*. Plants possessing rudimentary vascular tissues and root-like and leaf-like structures are classified as bryophytes. Examples of this are *Riccia* and *Marchantia*. Certain other plants possess well-defined roots, stems and leaves which are further classified in the rest of the plant kingdom.

(D) In less developed lower plants, roots are represented by root-like structures called rhizoids (bryophytes and pteridophytes). These plants lack well-differentiated plant tissues such as true leaves, stems, and roots, which are only found in higher plants (gymnosperms and anglosperms).

(E) *(b) Both A and R are true and R is not the correct explanation of A.*

Explanation: The sentences are both true and somewhat related, but the reason is not the correct explanation of the assertion.

OBJECTIVE Type Questions

[1 mark]

Multiple Choice Questions

1. "Bog moss" is also used for which of the following purposes?

(a) Treating cuts and minor bruises.
(b) It is an excellent source of protein.
(c) Packing and transporting of living materials.
(d) It is used to extract hydrocolloid dyes.

Ans. *(c) Packing and transporting of living materials.*

Explanation: *Sphagnum*, also called bog moss or peat moss, is hygroscopic. This means it stores water, and can be used to transport living materials.

2. Which one of the following plants will you pick if you want to study the structure of elaters?

(a) *Chara* (b) *Marchantia*
(c) *Pinus* (d) *Equisetum*

Ans. *(b) Marchantia*

Explanation: Elaters are present for spore dispersal in liverworts. *Marchantia* is the only liverwort present in bryophytes.

3. The fusion of two motile gametes which are dissimilar in size is termed as:

(a) Oogamy (b) Isogamy
(c) Anisogamy (d) Zoogamy

[NCERT Exemplar]

Ans. *(c) Anisogamy*

Explanation: Fusion of two motile gametes which are dissimilar in size is called anisogamy. Oogamy involves only one motile gamete, while in isogamy, the two gametes are morphologically similar in shape and size. Zoogamy refers to the sexual reproduction of animals.

4. Holdfast, stipe and frond constitute the plant body in the case of:

(a) Rhodophyceae (b) Chlorophyceae
(c) Phaeophyceae (d) All of these

[NCERT Exemplar]

Ans. *(c) Phaeophyceae*

Explanation: Phaeophyceae also known as brown algae is normally attached to the substratum by a holdfast and has a stalk, stipe, and leaf-like photosynthetic organ—the frond.

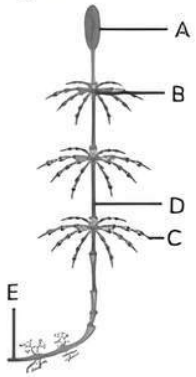
5. Why the vegetative mode of reproduction does not weigh equally to the sexual mode of reproduction?

(a) Vegetative propagation is common in the plant kingdom.
(b) Vegetative reproduction is not so complicated, like sexual reproduction.
(c) Environmental factors easily alter vegetative characters.
(d) None of the above [Diksha]

Ans. *(c) Environmental factors easily alter vegetative characters.*

Explanation: Vegetative reproduction, where the majority of the progeny are clones of the parent plant. Prokaryotes all undergo asexual reproduction to reproduce. When rapid growth is necessary or in stable environments, asexual reproduction may have short-term advantages. However, sexual reproduction provides a net benefit by allowing for a more rapid generation of genetic diversity. Contrary to asexual reproduction, sexual reproduction requires significantly more energy.

6. Which of the following is correct about the following diagram?



(a) A-Strobili; B-Node; C-Branches; D-Internode; E-Rhizomes
(b) A-Strobili; B-Node; C- Internode; D- Sporophyll; E-Rhizomes
(c) A-Sporangium; B-Node; C-Sporophyll; D-Internode; E-Rhizomes
(d) A-Strobili; B-Node; C-Antheridium; D-Archegonium; E-Rhizomes

Ans. *(a) A-Strobili; B-Node; C-Branches; D-Internode; E-Rhizomes*

Explanation: The figure shows a pteridophyte. Distinct cone-like structures in pteridophytes are called strobili. Pteridophytes contain leaf-like structures called sporophylls that are connected together by nodes. Different nodes are connected through internodes. Pteridophytes are anchored to land through root-like structures called rhizomes.

7. Which among the following is incorrect?

(a) Most of the leafy liverworts resemble mosses in their structure.

(b) Liverworts contain oil bodies that are absent in mosses.

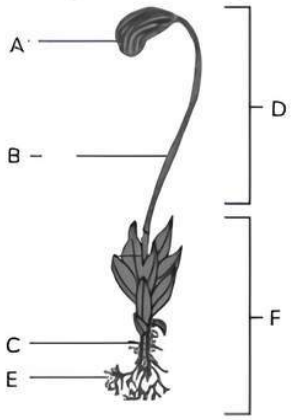
(c) Moses contain lobes in their leaves whereas leafy liverworts don't.

(d) In mosses, leaves are spirally arranged but in leafy liverworts, leaves grow in two or three rows.

Ans. *(c) Moses contain lobes in their leaves whereas leafy liverworts don't.*

Explanation: Most of the leafy liverworts resemble mosses in their structure. Leafy liverworts contain oil bodies that are absent in mosses. Leafy liverworts contain lobes in their leaves whereas mosses don't. In mosses, leaves are spirally arranged but in leafy liverworts, leaves grow in two or three rows.

8. Which among the following is correct?



(a) A-Capsule; B-Seta; C-Rhizoids; D-Gametophyte; E-Foot; F-Sporophyte

(b) A-Capsule; B-Seta; C-Foot; D-Sporophyte; E-Rhizoids; F-Gametophyte

(c) A-Spore Sac; B-Stipe; C-Foot; D-Sporophyte; E-Rhizoids; F-Gametophyte

(d) A-Gemmae; B-Stipe; C-Leaves; D-Sporophyte; E-Rhizoids; F-Gametophyte

Ans. *(b) A-Capsule; B-Seta; C-Foot; D-Sporophyte; E-Rhizoids; F-Gametophyte*

Explanation: After the fusion, the embryo develops into a structure called sporophyte that grows out on gametophyte. It has a long erect stalk called seta that transfers water and nutrients from gametophyte to capsule. Capsule is the portion of sporophyte that bears spores. Foot is the portion of sporophyte that anchors to gametophyte.

Assertion-Reason (A-R)

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

9. Assertion (A): *Sphagnum* moss is hygroscopic and has the ability to store a lot of moisture.

Reason (R): *Sphagnum* moss is involved in fuel generation.

Ans. *(b) Both A and R are true and R is not the correct explanation of A.*

Explanation: *Sphagnum* moss is hygroscopic and has the ability to store a lot of moisture, and is also involved in fuel generation.

10. Assertion (A): *Laminaria* and *Macrocystis* are used in some countries as food, food supplements or fodder.

Reason (R): Both of these come under the group of brown algae.

Ans. *(b) Both A and R are true and R is not the correct explanation of A.*

Explanation: Both the *Laminaria* and *Macrocystis* are brown algae. These are used as food and also used in the form of fodder for cattle.

11. Assertion (A) : Phaeophyceae sometimes produce pyriform structures.

Reason (R) : Union of the pyriform structures leads to sexual reproduction in Phaeophyceae.

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: Pyriform are "pear-shaped" structures with two laterally attached flagella which are used as gametes by Phaeophyceae/ brown algae for the purpose of sexual reproduction.

12. Dried algin is likely unsafe when inserted into the cervix to induce labour, as it has been linked with serious adverse effects. Not enough is known about the use of algin during pregnancy when taken by mouth or when used in any form during breast-feeding. Stay on the safe side and avoid use.

Assertion (A): Algin is obtained from red seaweed and carrageenan is extracted from the brown seaweed.

Reason (R): Algin is used to make medicine while carrageenan is used in preparation of emulsions.

Ans. *(d) A is false but R is true.*

Explanation: Algin and carrageenan are economically important products of algae. Algin is a type of carbohydrate obtained from brown seaweed and is used to make medicine for the treatment of high blood pressure and high cholesterol levels. Carrageenan is an extract from red seaweed and it is used in the preparation of emulsions of ice cream, jellies, sauces, etc.

CASE BASED Questions (CBQs)

[4 & 5 marks]

Read the following passages and answer the questions that follow:

13. *The bryophyte's primary plant body is haploid. There are no roots, but there are roof-like structures called rhizoids. Vegetative reproduction happens by fragmentation of plant body, gemmae, buds, and so on. Sexual organs are multicellular and jacketed.*

(A) If the zygote of a bryophyte consists of 2x number of chromosomes, how many chromosomes should the sporophyte have?

(a) 2x (b) x

(c) 4x (d) None of these

(B) Female multicellular jacketed sex parts in bryophytes are referred to as:

(a) They don't exist (b) Archegonium

(c) Thallogonium (d) Antheridium

(C) From the given paragraph, which of the following statement(s) can you identify as incorrect?

(a) The bryophyte's primary plant body is haploid.

(b) There are no roots, but there are rhizoids. Sexual organs are multicellular and jacketed.

(c) Vegetative reproduction happens by fragmentation of plant body, gemmae, buds, and so on.

(d) All are correct.

(D) Which of the following methods are not used by bryophytes for vegetative reproduction?

(a) Isogamous gamete transport

(b) Fragmentation of plant body

(c) Gemmae cup dispersal

(d) Fragmentation of buds

(E) Which of the following statements could be false with respect to the paragraph mentioned?

(a) Primary plant body of bryophyte is haploid.

(b) Bryophytes have thallus-like organisation.

(c) Bryophytes are more likely to cause erosion due to rhizoids holding onto soil instead of roots.

(d) Bryophytes may also be used as packing material.

Ans. (A) *(a) 2x*

Explanation: Zygote and sporophyte both belong to diplontic generation (2x), this is why the sporophytic generation would have a 2x chromosome number.

Caution

Students usually get confused and mark (b) as a correct answer but students should keep in mind that different cryptogams show different alternations of generations. Attention should be paid to the kind of plant mentioned in the question (here, bryophyte.)

(B) *(b) Archegonium*

Explanation: The female sex organs of bryophytes are known as archegonium, and they generate a female gamete known as an egg. The primary male sexual organ is known as the antheridium, and it produces male gametes known as antherozoids.

(C) *(d) All are correct.*

Explanation: The bryophyte's primary plant body is haploid. There are no roots, but there are rhizoids. Vegetative reproduction happens by fragmentation of plant body, gemmae, buds, and so on. Sexual organs are multicellular and jacketed.

(D) *(a) Isogamous gamete transport*

Explanation: Even though bryophytes do use isogamous gamete transport, they use

it for the purpose of sexual reproduction, but the most common means of reproduction in bryophytes is vegetative reproduction in which the plant body is fragmented into parts to generate new plant bodies.

(E) *(c) Bryophytes are more likely to cause erosion due to rhizoids holding onto soil instead of roots.*

Explanation: Bryophytes have pseudo roots, stems, and leaves-like structures and thus, are called thalloid. Although they are more distinct than thallophytes, they still are thalloid-like structures. Bryophytes securely retain soil and so prevent soil erosion. They can break down larger rocks and turn them into fine particles of soil. These are also utilised as packing and transport materials, as these are excellent water absorbers. Thus, (c) is the incorrect option.

14. *These plants have photosynthesising, "segmented," hollow stems that are sometimes filled with pith. A whorl of leaves forms the junction between each section. Plants' subsurface sections are made up of jointed rhizomes from which roots and aerial axes arise. Intercalary meristems sprout in each segment of the stem and rhizome as the plant grows taller.*

(A) Which class of pteridophytes is referred to in the above mentioned case?

(B) Provide an example of species found in the above mentioned class of pteridophyte.

(C) How do the above mentioned plants differ with respect to their growth in comparison to angiosperms?

Ans. (A) Class Sphenopsida of Pteridophyta is mentioned in the above given case.

(B) A famous and commonly found example of Sphenopsida is *Equisetum*. The class usually represents horsetails.

(C) Most seed plants (angiosperms and gymnosperms) develop from an apical meristem, which means that new growth originates solely from growing points (and widening of stems). This is different in the case of sphenopsids, where plant proliferation occurs due to intercalary meristem growth.

Related Theory

Intercalary meristem growth may also be seen in certain monocots. For the purpose of this exercise however, we consider only cryptogamae due to the mention of "rhizoids" instead of "roots".

VERY SHORT ANSWER Type Questions (VSA)

[1 mark]

15. Food is stored as Floridean starch in Rhodophyceae. Mannitol is the reserve food material of which group of algae?

[NCERT Exemplar]

Ans. Phaeophyceae, the brown algae.

16. The plant body in higher plants is well-differentiated and well-developed. Roots are the organs used for absorption. What is the equivalent of roots in the less developed lower plants?

[NCERT Exemplar]

Ans. Rhizoids

17. What gives Phaeophyceae their characteristic colours?

Ans. Xanthophyll (Fucoxanthin).

18. The gametes and spores of Phaeophyceae have a distinct morphology. Give its name.

[Delhi Gov. QB 2022]

Ans. Pyriform (pear-shaped) bears two laterally attached flagella.

19. Massive plant bodies are seen only in angiosperms and gymnosperms. Name an algal organism that is an exception to this rule.

Ans. *Kelps.*

SHORT ANSWER Type-I Questions (SA-I)

[2 marks]

20. Who proposed the natural system of classification and how was it useful?

Ans. George Bentham and Joseph Dalton Hooker proposed the natural system of classification. This system was developed on the basis of natural affinities among species. Additionally, it took into account not only surface but also interior aspects such as ultrastructure, anatomy, embryology, and phytochemistry.

21. What could have been the phylogenetic purpose of developing two kinds of spores?

Ans. Development of two different kinds of spores, or heterospory, has resulted in embryo development in *in situ*. The embryo is better protected since it receives nutrients from the female gametophyte. Evolutionarily speaking, heterospory resulted in the emergence of seeds, which allowed plants to thrive and survive lengthy periods of adverse environments.

22. How far does *Selaginella*, one of the few living members of lycopodiales (pteridophytes) fall short of seed habit? **[NCERT Exemplar]**

Ans. *Selaginella* produces both macro (big) and micro (small) spores. Megaspores and microspores germinate, producing female and male gametophytes, respectively. *Selaginella*, on the other hand, lacks seed habit due to a lack of integument around the megasporangium.

SHORT ANSWER Type-II Questions (SA-II)

[**3** marks]

23. "Pteridophytes are more suitable for dry terrain than bryophytes". Defend or argue against this statement.

Ans. Although bryophytes and pteridophytes had water-dependent gametes, the advent of conducting vessels in pteridophytes could have permitted life in a terrestrial environment. Pteridophyte conducting vessels gather water from damp soil and transfer it to the cells. Bryophytes, on the other hand, do not have this alternative and rely exclusively on the water that reaches the aerial section of the plant; as a result, they must exist in humid or rainy environments.

Related Theory

Pteridophytes dominated the terrestrial environment prior to the genesis of phanerogamic plants (plants with seeds). The Carboniferous period's enormous pteridophyte forests are responsible for the creation of coal deposits, primarily in Europe, Asia, and North America.

24. Why bryophytes are known as amphibians of the plant kingdom? **[Diksha]**

Ans. Like amphibians in the animal kingdom, bryophytes require water for the process of fertilisation, and can otherwise spend their life cycles on land. Water is also involved in the dehiscence of antheridium and archegonium. Water conduction occurs by capillary action because it lacks appropriate vasculature.

Thus, for a bryophyte living on land, a thin layer of water is necessary, making its habitat "amphibious".

25. (A) In which group of algae, mannitol is found as the reserve food material?

(B) In the Phaeophyceae group of algae, the gametes and spores have distinct morphology. Give its name.

(C) In green algae, a structure called pyrenoid is present. Define its use.

Ans. (A) In the Phaeophyceae group or the brown algae, mannitol is found as the reserve food material.

(B) In the Phaeophyceae group of algae, the gametes and spores are Pyriform (pear-shaped). They bear two laterally attached flagella.

(C) In green algae, a structure called pyrenoid is present. It is located in the chloroplast and used as a starch-storing organelle.

LONG ANSWER Type Questions (LA)

[**4** & **5** marks]

26. Heterospory, *i.e.* formation of two types of spores – microspores and megaspores is a characteristic feature in the life cycle of a few members of pteridophytes and all spermatophytes. Do you think heterospory has some evolutionary significance in the plant kingdom? **[NCERT Exemplar]**

Ans. The majority of pteridophytes have spores that are all of the same kind; these plants are referred to as homosporous. Heterosporous genera include *Selaginella*, *Salvinia*, *Marsilea*, and *Azolla*, which generate two types of spores, macro (big) and micro (small). Megaspores and microspores germinate, producing female and male gametophytes, respectively.

Female gametophytes are retained upon the parent sporophytes for variable durations of time in these plants. Female gametophytes are in charge of transforming zygotes into embryos. This event serves as a precursor to the seed habit, regarded as a critical step in evolution.

PHANEROGAMAE 2

TOPIC 1

GYMNOSPERMS

Phanerogamae are plants that bear seeds thus, also known as seed-bearing plants. These plants have visual sex organs and also known as spermatophytes. They are the most advanced plants possessing true roots, leaves, stems and well-developed vascular bundles. There are two types of phanerogams named as Gymnosperms and Angiosperms.

Pinus, *Cedrus* and *Cycas* are examples of gymnosperms and these are found in gardens of homes, parks and hotels as ornamental plants.

Gymnosperms are the plants in which the ovules are not enclosed by the ovary wall and thus, remain exposed and naked both pre and post-fertilisation. Developing seeds are naked. It includes a variety of trees of all sizes from shrubs to medium -sized trees or tall trees.

Important

➥ *The giant redwood tree Sequoia is one of the tallest tree species.*

Plant Body of Gymnosperms

Root system

Generally, tap root system is found, fungal association in the form of mycorrhiza can be seen in *Pinus*, and specialised roots called coralloid roots are found in *Cycas* which are associated with nitrogen-fixing cyanobacteria that help to fix atmospheric nitrogen into the soil.

Stem

The stems may be unbranched (*Cycas*) or branched (*Pinus* and *Cedrus*).

Leaves

Leaves may be simple or compound leaves. The pinnate leaves of *Cycas* can last for several years. Gymnosperm leaves are well-adapted to hold out against the extremes of temperature, humidity, and wind. Their needle-like leaves reduce surface area, as well as their thick cuticle and sunken stomata helps to reduce transpiration (water loss) rate.

Reproduction in Gymnosperms

They produce two types of spores, *i.e.* haploid microspores and megaspores (both are haploid in nature), therefore known as heterosporous. Spores are produced in sporangia that are present on sporophylls. Sporophylls are spirally arranged along an axis to form compact strobili or cones.

Strobili which bear microsporophylls and microsporangia are known as male strobili or microsporangiate. Microspores develop into the male gametophyte (highly reduced), known as pollen grains, their development takes place inside the microsporangia.

Strobili that bears megasporophylls or megasporangia is known as megasporangiate or the female strobili. Megaspore mother cell (MMC) is differentiated from one of the cells of nucellus, it is protected by envelopes and forms a composite structure called an ovule. Ovules are found on megasporophylls which are aggregated to form the female strobili or cone. MMC undergoes meiotic division to produce four megaspores enclosed within the megasporangium. One of the megaspores enclosed within the megasporangium, develops into multicellular female gametophyte, it possesses two or more archegonia or female sex organs. This multicellular female gametophyte is retained within the megasporangium.

Important

➥ *The male or female cones or strobili may be borne on the same tree (Pinus). However, in Cycas male cones and megasporophylls are borne on different trees.*

In male and female gametophytes, they do not have an independent free-living existence in this environment, instead, it remains within the sporangia and is retained on sporophyte. Pollen grains are released from the microsporangium, carried by the wind, and come into contact with the opening of the ovule produced on megasporophylls. Pollen tube is developed, which grows towards archegonia in the ovules it carries the male gametes near the archegonia's opening where fertilisation occurs, zygote is formed, zygote develops into an embryo, and ovules mature into seeds. Seeds can be either bare or uncovered.

Economic Importance of Gymnosperms

Gymnosperms are economically very significant. Conifers are employed in paper, furniture, and

lumbering industries. White spruce is used in the music industry to make instruments like violins. For example, *Ginkgo, Pinus, Cycas*, and some others are used as a good sources of food. They are also commonly utilised in the pharmaceutical industries to make a variety of drugs to treat infectious diseases and allergies such as cold, cough, asthma, and bronchitis. They are also utilised as ornamental plants and trees and are planted in gardens, parks, and other locations because of their beautiful leaves.

Pinus

Cycas

Example 2.1: What is heterospory? Briefly comment on its significance. Give two examples.

Ans. Heterospory refers to the production of two distinct kinds of spores in the same plant. Heterospory's significance:

(1) In gymnosperms and angiosperms, heterospory stimulates seed development.

(2) It is necessary for male and female gametophyte differentiation.

(3) *Salvinia* and *Selaginella* are two examples.

Sequoia

Example 2.2: Case Based:

A child saw a plant in his school garden and he noticed that its seeds were naked, he pulled off a small plant and saw that the roots were a taproot system. He did not understand and was confused why it is so that seeds are naked while when we eat fruits normally seeds are found inside the fruit. He asked his teacher, and the teacher explained the difference and also specified the kingdom to which this plant belongs and he also listed out some more characteristics.

(A) Name the division of the plant kingdom to which this plant belongs to:

(a) Bryophytes (b) Pteridophytes
(c) Gymnosperms (d) Angiosperms

(B) Reproductive units of this division are:

(a) Cones (b) Flowers
(c) Thallus (d) Spores

(C) Write the economic importance of this division.

(D) Comment on the body type of the plant discussed above.

(E) Assertion (A): Roots called coralloid roots are found in *Cycas*.
Reason (R): It is a fungal association.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

Ans. **(A)** *(c) Gymnosperms*

Explanation: Gymnosperms, the word means (*gymnos*: naked, *sperma*: seeds). These are the plants in which the ovules are not enclosed by the ovary wall and thus remain exposed and naked both pre and post-fertilisation. Developing seeds are naked.

(B) *(a) Cones*

Explanation: They produce two kinds of spores *i.e.*, haploid microspores and megaspores therefore known as heterosporous. Spores are produced in sporangia that are found on sporophylls. Sporophylls are spirally arranged along an axis to form compact strobili or cones.

(C) Economic importance of gymnosperms are as follows :

(1) Gymnosperms are very significant economically. Conifers are employed in the paper, furniture, and lumbering industries.

(2) White spruce is used in the music industry to make instruments like violins. Examples: *Ginkgo, Pinus, Cycas,* and others are used as a good sources of food.

(3) They are also commonly utilised in the pharmaceutical industries to make a variety of drugs to treat infectious diseases and allergies such as cold, cough, asthma, and bronchitis.

(4) They are also utilised as decorative plants and trees, and are planted in gardens, parks, and other locations because of their lovely leaves. (*Any two*)

(D) Tap root system is found, fungal association in the form of mycorrhiza can be seen in *Pinus* and specialised roots called coralloid roots are found in *Cycas* which are associated with nitrogen-fixing cyanobacteria that help to fix atmospheric nitrogen into the soil.

Related Theory

The stems may be unbranched as seen in the Cycas or branched as found in Pinus and Cedrus. Simple or compound leaves have been discovered. The pinnate leaves of Cycas, for example, can last for several years. Gymnosperm leaves are well-adapted to resist extremes of temperature, humidity, and wind, and their needle-like leaves reduce surface area, as well as their thick cuticle and recessed stomata, which reduce water loss.

(E) *(c) A is true but R is false.*

Explanation: Specialised roots called coralloid roots are found in *Cycas* which are associated with nitrogen-fixing cyanobacteria that help to fix atmospheric nitrogen into the soil.

OBJECTIVE Type Questions

[1 mark]

Multiple Choice Questions

1. Reproductive parts of gymnosperms are:

(I) Cone
(II) Megasporangium
(III) Microsporangium
(IV) Microsporophylls

Options:

(a) Only (I) **(b) (I) and (III)**
(c) Only (IV) **(d) All of these**

Ans. *(d) All of these*

Explanation: Strobilus or cone is the reproductive structure of gymnosperms. Both male and female strobili can be present on the same (in *Pinus*) or on different trees (in *Cycas*). Gymnosperm plants are heterosporous, which means they produce different spores, *i.e.*, haploid microspores and megaspores.

The male strobili or male cones have microsporophylls, which have the microsporangia that produce the haploid microspores. While the female strobili or female cones have megasporophylls. They bear the ovules having the megasporangium. Thus, produces the haploid megaspores and a megaspore mother cell.

2. Gymnosperms are:

(a) heterosporous **(b) homosporous**
(c) algosporous **(d) isosporous**

Ans. *(a) heterosporous*

Explanation: Gymnosperms are heterosporous, which means they produce different spores, *i.e.* the haploid microspores and megaspores. These two kinds of spores are produced within the sporangia that are borne on sporophylls, which are arranged spirally along an axis to form compact strobili or cones.

3. Mycorrhiza is found in which of the following plants?

(I) *Pinus* **(II) *Yam***
(III) *Cedrus* **(IV) *Apple***

Options:

(a) Only (I) (b) (I) and (III)

(c) Only (IV) (d) All of these

Ans. *(b) (I) and (III)*

Explanation: Mycorrhiza is the symbiotic association between fungus and roots of vascular plants. In this, the plant obtains phosphate and other minerals through the fungus, while the fungus obtains sugars from the roots of plants. This mycorrhizal association is present in conifers such as *Pinus*, *Cedrus*, etc.

4. **Naked seeds are found in:**

(a) Pteridophytes (b) Gymnosperms

(c) Bryophytes (d) All of these

Ans. *(b) Gymnosperms*

Explanation: Gymnosperms are plants in which the ovules are not enclosed by the ovary wall and thus remain exposed and naked both pre and post-fertilisation. They possess naked seeds.

Related Theory

➥ *Gymnosperms include a variety of trees of all sizes from medium height shrubs to tall trees.*

5. **Coralloid roots are the characteristic feature of which plant?**

(a) *Cycas* (b) Mustard

(c) *Polysiphonia* (d) *Ectocarpus*

Ans. *(a) Cycas*

Explanation: Small specialised coralloid roots are present in *Cycas*. These roots are present in clusters at the base of the stem and protrude over the ground. It is greenish in colour and dichotomously branched.

6. **The fruiting body of gymnosperms consisting of both micro and megasporophylls is called ..... .**

(a) Cones (b) Body

(c) Gemma (d) Pyrenoid

Ans. *(a) Cones*

Explanation: The fruiting body of gymnosperms consists of both micro and megasporophylls. Sporophylls are specially arranged along an axis to form compact strobili and cones.

7. **Conifers are adapted to tolerate extreme environmental conditions because of:**

(a) thick cuticles

(b) presence of vessels

(c) broad hard leaves

(d) superficial stomata [Diksha]

Ans. *(a) thick cuticles*

Explanation: Gymnosperm leaves are well-adapted to tolerate temperature, humidity, and wind extremes. The needle-like leaves of conifers minimize the surface area. Their thick cuticle and recessed stomata also aid in water conservation.

Assertion-Reason (A-R)

Given below are two statements labelled as Assertion (A) and Reason (R). Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true and R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true.

8. ***Cycas Revoluta* or the Sago Palm is a beautiful easy care houseplant with a mischievous twist that easily fools people in three ways. Firstly, despite its common name of "Sago Palm", it's not actually a palm because it's a Cycad (although the care requirements are similar).**

Assertion (A): ***Cycas* have small specialised roots called coralloid roots.**

Reason (R): **They are associated with nitrogen-fixing cyanobacteria.**

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: *Cycas* possess small specialised roots called coralloid roots which are associated with N_2- fixing cyanobacteria that fixes atmospheric nitrogen into the soil.

9. **Assertion (A):** Gymnosperms have the ability to show polyembryony.

Reason (R): They have two or more archegonia.

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: Gymnosperms have the ability to show polyembryony as they have two or more archegonia.

10. **Assertion (A):** Gymnosperms are also known as flowering plants.

Reason (R): They produce naked seeds.

Ans. *(d) A is false but R is true.*

Explanation: Gymnosperms bear naked seeds, and lack the formation of fruits and flowers. Angiosperms are known as the flowering plants.

11. **Assertion (A):** Gymnosperms are heterosporous.

Reason (R): They produce haploid microspores and megaspores.

Ans. *(a) Both A and R are true and R is the correct explanation of A.*

Explanation: Gymnosperms produce two kinds of spores, *i.e.* haploid microspores and megaspores and therefore known as heterosporous.

Related Theory

➥ *Spores are produced in sporangia that are found on sporophylls. Sporophylls are spirally arranged along an axis to form compact strobili or cones.*

CASE BASED Questions (CBQs)

[**4** & **5** marks]

Read the following passages and answer the questions that follow:

12. *Roots of these plants have fungal association in the form of mycorrhiza, possess needle-like leaves to reduce surface area, prevent water loss and are economically very important.*

(A) Identify the species and identify the plant kingdom to which it belongs.

(B) Why are they important?

(C) What kind of leaves do plants of this kingdom possess?

Ans. (A) *Pinus*, Gymnosperms

(B) These are employed in the paper, furniture, and lumbering industries, *e.g.*, Conifers.

(C) Gymnosperm leaves are well-adapted to resist extremes of temperature, humidity, and wind, and possess needle-like leaves which reduce surface area.

13. *Gymnosperms belong to the kingdom 'Plantae' and sub-kingdom 'Embryophyta'. The fossil evidence suggested that they originated during the Palaeozoic era, about 390 million years ago.*

Basically, gymnosperms are plants in which the ovules are not enclosed within the ovary wall, unlike angiosperms. It remains exposed before and after fertilisation and before developing into a seed. The stem of gymnosperms can be branched or unbranched. The thick cuticle, needle-like leaves, and sunken stomata reduce the rate of water loss in these plants.

The gymnosperms consist of conifers, cycads, gnetophytes and the species of Ginkgophyta division and Ginkgo biloba.

(A) Identify the economic importance of *Ginkgo biloba*.
(a) In makeup
(b) In cooking
(c) In the treatment of HIV-AIDS
(d) All of the above

(B) This division of plants shows:
(a) Heterospory (b) Isogamy
(c) Anisogamy (d) Monospory.

(C) Cycads are:
(a) dioecious (b) monoecious
(c) hermaphrodites (d) bisexual

(D) In which areas gymnosperms are generally found?
(a) Colder (b) Moist
(c) Hotter (d) Coastal

(E) Choose the correct statement regarding conifers.
(a) These are the least common species among the gymnosperm family.
(b) They shed their leaves in the winter.
(c) These are mainly characterised by male and female cones which form needle-like structures.
(d) These are usually found in tropical zones.

Ans. (A) *(b) In cooking*

Explanation: *Ginkgo biloba* trees have a large number of applications ranging from medicine to cooking. Its leaves are ingested as a remedy for memory-related disorders like Alzheimer's. These are also resilient against insect infestations.

(B) *(a) Heterospory*

Explanation: Gymnosperms produce two kinds of spores, *i.e.* haploid microspores and megaspores, therefore they are known as heterosporous. Spores are produced in sporangia that are found on sporophylls. Sporophylls are spirally arranged along an axis to form compact strobili or cones.

(C) *(a) dioecious*

Explanation: Cycads are dioecious which means their individual plants are either all male or female.

Related Theory

Cycads are seed-bearing plants and the majority of the members are now extinct. They flourished during the Jurassic and late Triassic eras.

(D) *(a) Colder*

Explanation: Gymnosperms are usually found in colder regions where snowfall occurs. However, cycads are found in dry and tropical regions.

(E) *(a) These are the least common species among the gymnosperm family. and*

(c) These are mainly characterised by male and female cones which form needle-like structures.

Explanation: Conifers are the most commonly known species among the gymnosperm family. They are evergreen; hence they do not shed their leaves in the winter. These are mainly characterised by male and female cones which form needle-like structures.

Related Theory

Coniferous trees are usually found in temperate zones where the average temperature is 10°C. Giant sequoia, pines, cedar and redwood are examples of conifers.

VERY SHORT ANSWER Type Questions (VSA)

[1 mark]

14. Name any three groups of plants that bear archegonia (female reproductive organ).

Ans. Bryophytes, pteridophytes, and gymnosperms are the three groups of plants that bear archegonia.

Related Theory

Though it is the characteristic feature of bryophytes and cryptograms (plants that do not produce seeds) but is usually found in some gymnosperms also, e.g., cycads and conifers.

15. Gymnosperms can show polyembryony. Why do you think so? [Delhi Gov. QB 2022]

Ans. Gymnosperms have the ability to show polyembryony as they have two or more archegonia.

16. Gymnosperms are phanerogams. Justify.

Ans. Phanerogams are plants that have well -differentiated reproductive tissues which ultimately make seeds. Gymnosperms fall under this category. The plants of this group bear naked seeds means ovules are not enclosed by any ovary wall and also the seeds that develop post-fertilisation are naked too.

Related Theory

Seeds are the result of the reproductive process. They consist of the embryo along with stored food, which helps in the initial growth of the embryo during germination.

17. Name a species of gymnosperms having coralloid roots.

Ans. *Cycas* are species of gymnosperms that have small specialised roots called coralloid roots which are associated with N_2-fixing cyanobacteria. The stems are unbranched. Its main function is nitrogen fixation for plants.

SHORT ANSWER Type-I Questions (SA-I)

[2 marks]

18. Discuss the phylogenetic relationship of *Cycas* with Pteridophytes.

Ans. *Cycas* is an evergreen plant which looks like a palm tree. It exhibits a phylogenetic relationship with pteridophytes. The evolutionary characters include:

(1) Shedding of seed when the embryo is immature.
(2) Slow growth.
(3) Monocyclic wood.
(4) Little secondary growth.
(5) Leaf-like megasporophylls.
(6) Circinate ptysix.
(7) Persistent leaf bases. (*Any four*)

19. Write the names of:

(A) Smallest gymnosperm.

(B) Tallest gymnosperm.

Ans. (A) The smallest gymnosperm is the *Zamia pygmaea*. This plant reaches a height of 25 cm.

(B) The tallest gymnosperm is the giant redwood tree *Sequoia*. This plant reaches to height of about 100 metres.

20. The leaves in gymnosperms are adapted to withstand xerophytic conditions. Justify.
[Delhi Gov. QB 2022]

Ans. Gymnosperm leaves are highly adapted to tolerate temperature, humidity, and wind extremes. The needle-like leaves of conifers diminish the surface area. Their deep stomata and thick cuticles also minimise water loss. Gymnosperms do not have male and female gametophytes that live separate, independent lives as bryophytes and pteridophytes do. They continue to exist inside the preserved sporangia on the sporophytes.

21. Explain about the economic importance of resin.

Ans. Resin is a semifluid secreted by special tubes of a number of conifers. It helps in sealing female cones after pollination, scale leaves around leaf bases and apical buds. It is distilled to obtain turpentine and resin. Turpentine is used for thinning paints, vanishes, etc. and the resin is used for sealing joints of wheels and preparation of writing paper, oil, clothes, etc.

SHORT ANSWER Type-II Questions (SA-II)

[3 marks]

22. How are the male and female gametophytes of pteridophytes and gymnosperms different from each other? [NCERT Exemplar]

Ans.

S. No.	Pteridophytes	Gymnosperms
(1)	They have free-living male and female gametophytes.	They do not have free-living male and female gametophytes.
(2)	Flagellated male gamete.	Non-flagellated male gamete.
(3)	Water is essential for fertilisation.	Water is not essential.
(4)	Pollen tubes are not formed.	Pollen tubes are formed.
(5)	Archegonia with neck canal cells.	Neck canal cells are absent.
(6)	Female egg is not enclosed in the ovule.	Female egg is enclosed in the ovule.

23. Describe the important morphological characteristics of gymnosperms.

Ans. The important morphological characteristics of gymnosperms are:

(1) Gymnosperms are evergreen, woody, perennial plants. It includes medium-sized trees or tall trees and shrubs.

(2) In conifers, needle-like leaves are present which reduces their surface area. These also have thick cuticles and sunken stomata which help in reducing water loss.

(3) Gymnosperms possess exposed or naked seeds.

(4) The roots are generally tap roots. In some genera (*Pinus*), roots show mycorrhizal association, while in some others (*Cycas*) coralloid roots are associated with N_2-fixing cyanobacteria are present.

(5) Plants are heterosporous, *i.e.* they produce haploid microspores and megaspores.

(6) Their leaves are well-adapted to withstand extremes of temperature, humidity and wind. (*Any three*)

24. Describe the plant body of gymnosperms in detail.

Ans. Roots: Tap root system is found, fungal association in the form of mycorrhiza can be seen in *Pinus* and specialised roots called coralloid roots are found in *Cycas* which are associated with nitrogen-fixing cyanobacteria that help to fix atmospheric nitrogen into the soil.

Stems: The stems may be unbranched as seen in the *Cycas* or branched as found in *Pinus* and *Cedrus*. Leaves found are either simple or compound. For example, in *Cycas*, the pinnate leaves persist for some years.

Leaves: Leaves of gymnosperms are very well-adapted to withstand extremes of temperature, humidity and wind, its needle-like leaves reduce the surface area, also have thick cuticles on leaves and possess sunken stomata which reduce water loss.

LONG ANSWER Type Questions (LA)

[**4** & **5** marks]

25. Reproduction in gymnosperms is comparatively different from that in other plants. Explain reproduction in gymnosperms.

Ans. Gymnosperms produce two kinds of spores *i.e.*, haploid microspores and megaspores and therefore known as heterosporous. Spores are produced in sporangia that are found on sporophylls. Sporophylls are spirally arranged along an axis to form compact strobili or cones. Strobili which bear microsporophyll and microsporangia are known as male strobili or microsporangiate. Microspores develop into the male gametophyte, which is known as pollen grains, its development takes place inside the microsporangia. Strobili that bears megasporophylls or megasporangia is known as macrosporangiate or the female strobili. Megaspore Mother Cell (MMC) is differentiated from one of the cells of nucellus, it is protected by envelopes and forms a composite structure called an ovule. Ovules are found on megasporophylls which are arranged to form the female strobili. MMC is divided by meiotic division to produce four megaspores. One of the megaspores develops into multicellular female gametophyte, it possesses two or more archegonia or female sex organs. This multicellular female gametophyte is retained within the megasporangium.

26. (A) The drug ephedrine is obtained from which plant and it comes under which class?

(B) The above mentioned drug is used to treat which type of ailments?

(C) Name and explain about some other products of therapeutic use from gymnosperms.

Ans. (A) The drug ephedrine is obtained from the plant *Ephedra*; it is a member of the gymnosperm and belongs to the class Gnetopsida.

(B) Ephedrine is an antibiotic. It is used to treat asthma and other respiratory disorders.

(C) Some other products of therapeutic use from gymnosperms are:

(1) Taxol is a drug which is obtained from the bark of yew, *i.e. Taxus*. It is used in cancer treatment.

(2) The resinous oil of pine, fir and spruce is used as a disinfectant.

27. Shreya's teacher asked her to perform an activity in which she had to go to a nursery where she see various types of gymnosperms and after that she had to write the economic importance of those plants. Write a few points as Shreya.

Ans. The economic importance of gymnosperms are:

(1) Saw dust from conifers is employed in making linoleum and plastics.

(2) The seeds of gymnosperms are used to produce edible oils and perfumes.

(3) Gymnosperms are a good source of timber. They produce softwood which is useful in making furniture.

(4) A number of gymnosperm woods such as *Pinus*, *Larix*, etc., are used in the manufacture of paper.

(5) Some of the species of gymnosperms are a good source of starch and are also used in the production of sago. It serves as a major staple food for lowland or indigenous peoples.

(6) Wine is also manufactured from the seeds and stems of the plant *Cycas revoluta*.

(7) Many gymnosperms have ornamental values such as *Araucaria* (Avenue tree), *Juniperus*, *Cycas* (Leafy ornamental) and *Thuja* (Small shrub). (*Any five*)