Plant Kingdom

PLANT KINGDOM

A. The Big Picture First

```
                    PLANTS
                       |
          ------------------------------------------
          |                                        |
  CRYPTOGAMS                  PHANEROGAMS
 (no seeds, "hidden                (seeds, "visible
  reproduction")                   reproduction")
              |                                   |
  -------------------------------          ----------------------
  |             |                 |             |                      |
Algae   Bryophytes  Pteridophytes Gymnosperms Angiosperms
                                          (naked seed) (covered seed)
```

"Cryptogam" and "Phanerogam" mean from the roots (crypto = hidden, phanero = visible)

B. Algae

algae = mostly aquatic, chlorophyll-bearing, simple plant body (no true root/stem/leaf).

Further classified into Three classes/categories —

Class	Common name	Pigment	Stored food	Example
Chlorophyceae	Green algae	Chlorophyll a & b	Starch	*Chlamydomonas, Spirogyra*
Phaeophyceae	Brown algae	Fucoxanthin	Mannitol, laminarin	*Ectocarpus, Fucus*
Rhodophyceae	Red algae	r-phycoerythrin	Floridean starch	*Polysiphonia*

Mnemonic: "Green-Starch, Brown-Mannitol, Red-Floridean" — say it like a chant.

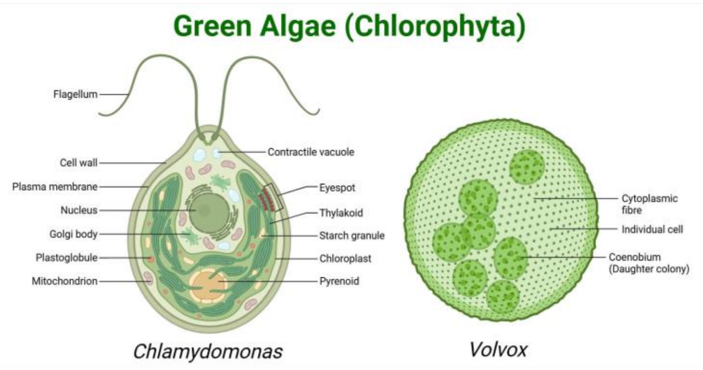
Algae matter ecologically (they produce a large share of the world's oxygen) — *this is a common NEET trivia line.*

Algae Definition

"Alga is a term that describes a large and incredibly diverse group of eukaryotic, photosynthetic lifeforms. These organisms do not share a common ancestor and hence, are not related to each other (polyphyletic)."

Multicellular examples of algae include the **giant kelp** and **brown algae**. Unicellular examples include diatoms, Euglenophyta and Dinoflagellates.

Most algae require a moist or watery environment; hence, they are ubiquitous near or inside water bodies. Anatomically, they are similar to another major group of photosynthetic organisms – the land plants. However, that is where the differences end as algae lack many structural components typically present in plants, such as true stems, shoots, and leaves. Furthermore, they also do not have vascular tissues to circulate essential nutrients and water throughout their body.



Characteristics of Algae

Specific general characteristics of algae are common to plants as well as animals.

Algal cells are **eukaryotic**. For instance, algae can **photosynthesize** like plants, and they possess specialized structures and cell-organelles, like **centrioles and flagella**, found only in animals. The algal cell walls consist of **mannans, cellulose and Galatians**. Listed below are some of the general characteristics of algae.

- Algae are photosynthetic organisms
- Algae can be either unicellular or multicellular organisms
- Algae lack a well-defined body, so, structures like roots, stems or leaves are absent
- Algaes are found where there is adequate moisture.
- Reproduction in algae occurs in both asexual and sexual forms. Asexual reproduction occurs by spore formation.
- Algae are free-living, although some can form a symbiotic relationship with other organisms.

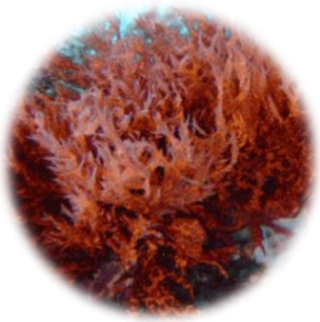
Types of Algae

There are many types of algae. However, these are some of the more prominent types:

Red Algae

Also called **Rhodophyta**, it is a distinctive species found in marine as well as freshwater ecosystems. The pigments **phycocyanin and phycoerythrin** are responsible for the characteristic red colouration of the algae.

Other pigments that provide green colouration (such as chlorophyll a) are present. However, they lack chlorophyll b or beta-carotene.



The red algae, or Rhodophyta, are one of the oldest groups of eukaryotic algae. The Rhodophyta also comprises one of the largest phyla of algae, containing over 7,000 currently recognized species with taxonomic revisions ongoing.

Green Algae

It is a large, informal grouping of algae having the primary photosynthetic pigments **chlorophyll a and b**, along with auxiliary pigments such as xanthophylls and beta carotene.

Higher organisms use green algae to conduct photosynthesis for them. Other species of green algae have a symbiotic relationship with other organisms.

Members are unicellular, multicellular, colonial and flagellates. Prominent examples of green algae include Spirogyra, Ulothrix, Volvox, etc.

Not an Algae: Blue-Green Algae

In the past, blue-green algae were one of the most well-known types of algae. However, since blue-green algae are prokaryotes, they are not currently included under algae (because all algae are classified as eukaryotic organisms).

Also called cyanobacteria, these organisms live in moist or aquatic environments just like other algae. These include dams, rivers, reservoirs, creeks, lakes and oceans. This class of bacteria obtains energy through the process of photosynthesis. Ecologically, some species of blue-green algae are significant to the environment as it fixes the nitrogen in the soil. Hence, these are also called nitrogen-fixing bacteria. E.g. Nostoc, Anabaena, etc.

However, other types of blue-green algae can be toxic to human beings. They can either be neurotoxic (affects the respiratory or nervous system, causing paralysis) or hepatotoxic (causes the liver to fail). Moreover, some can act as indicators of environmental health, signalling the extent of pollution.

Examples of Algae

Prominent examples of algae include:

- Ulothrix
- Fucus

Commented [P1]: An accessory pigment is a light-absorbing compound in photosynthetic organisms that works with chlorophyll a to capture light energy.

Commented [P2]: A symbiotic relationship is a close, long-term interaction between two different species.

- Porphyra
- Spirogyra

Algal Biofuel

Recent developments in science and technology have enabled algae to be used as a source of fuel. Global demand for petroleum products and declining environmental health have prompted the use of eco-friendly alternatives such as algal biofuel. Hence, algae fuel is an increasingly viable alternative to traditional fossil fuels. It is used to produce everything from “green” diesel to “green” jet fuel. It is similar to the other biofuels made from corn and sugar cane.

#NTK (NEED TO KNOW)

1. What are Algae?

Algae is a large, diverse group of eukaryotic, photosynthetic organisms that are not necessarily related to each other.

2. How are algae different from traditional plants?

Unlike traditional plants, algae do not have true roots, stems and leaves. Hence, they need to be near a moist or watery environment to survive. In other words, they do not possess vascular tissue necessary for the conduction of water and minerals.

3. Briefly outline the types of algae.

Algae are primarily classified into the following types:

- Blue-green Algae
- Red Algae
- Green Algae

4. State the general characteristics of algae.

- Algae are either unicellular or multicellular in nature
- Found in moist places
- Mode of reproduction can be sexual as well as asexual
- Asexual reproduction occurs by spore formation
- Sexual reproduction occurs by the physical contact of haploid gametes
- Lacks a well-defined body
- They are photosynthetic in nature
- Are mostly free-living

5. State 4 examples of algae.

- Volvox
- Spirogyra
- Ulothrix
- Fucus

6. Are algae bacteria or a plant?

Algae are neither bacteria nor plants. The term algae is used to describe a large collection of photosynthetic, eukaryotic organisms.

7. Are algae toxic to humans?

Algae are generally harmless to humans. However, certain species of algae can form algal blooms, which can have detrimental effects on human health and the environment.

8. How are algae useful?

Algae are known to fix 50% carbon dioxide. Being photosynthetic, they increase the oxygen content of their environment. They are primary producers and many organisms derive food from them. Many commercial products are obtained from algae such as align, etc.

9. Why are algae important?

Algae form the primary source of food for many organisms in the food chain. From an economical perspective, algae are very useful for creating biomass or fertilizers as they grow very fast.

10. What are algal blooms?

Algal bloom is the rapid increase in the algal population in a water body such as rivers or lakes. Often, it is characterized by discolouration of the water and a peculiar odour.

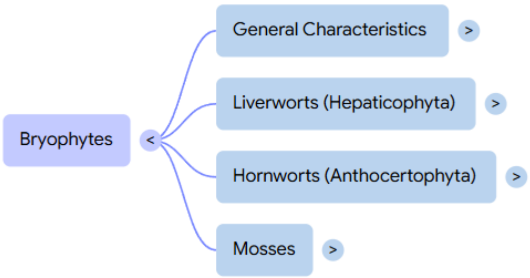
C. Bryophytes

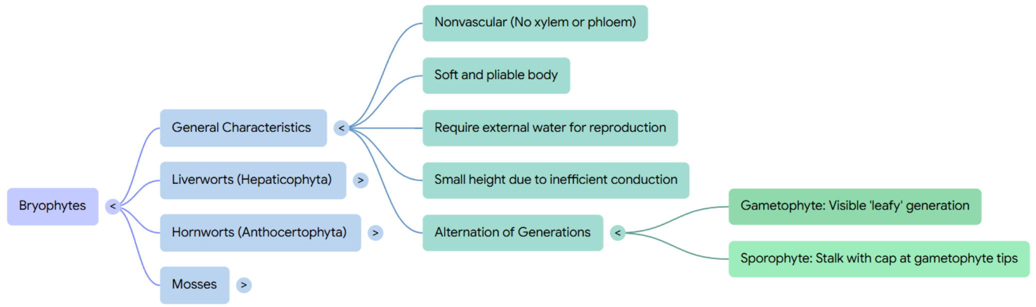
AKA, **"Amphibians of the plant kingdom"** — live on land but need water to reproduce (swimming sperm). "Why do you think they're called that, given what you know about amphibian animals?"

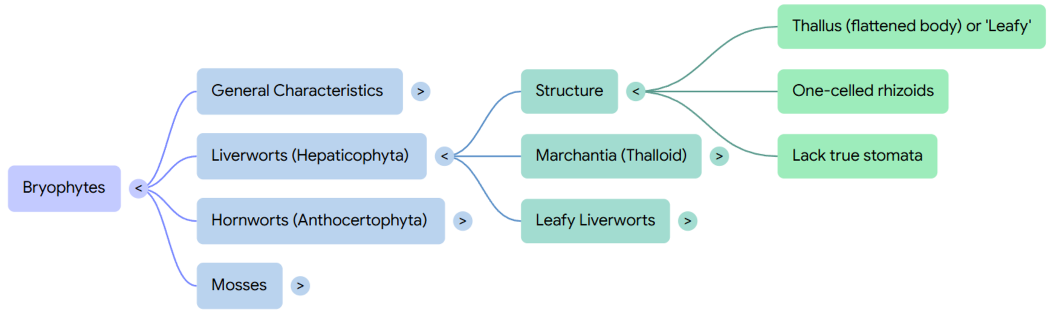
Body: thalloid (flat, e.g. liverwort *Marchantia*) or leafy (e.g. moss *Funaria*)

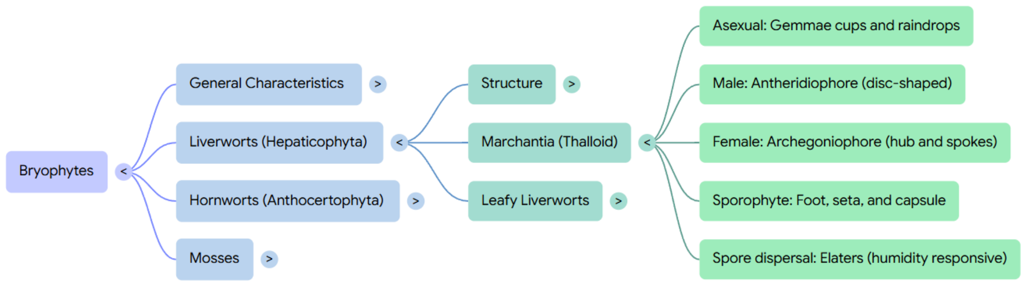
- No true vascular tissue
- **Gametophyte is the dominant, independent stage**; sporophyte is small and depends on the gametophyte — *this single fact is a favorite NEET distinction point across all plant groups*.

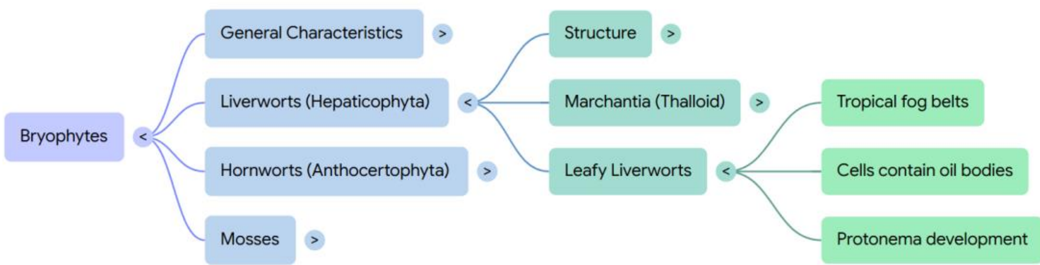
Bryophytes form a crucial group in the plant kingdom and are often regarded as the "amphibians of the plant world."

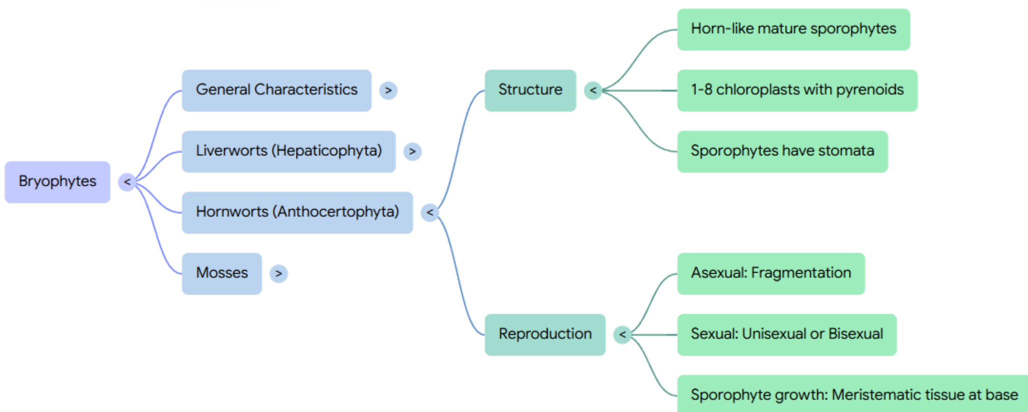


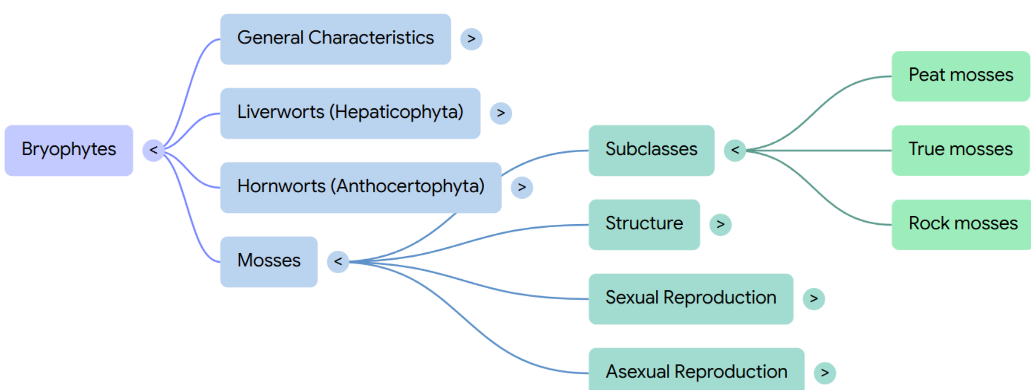

Bryophytes
General Characteristics
Liverworts (Hepaticophyta)
Hornworts (Anthocertophyta)
Mosses
Nonvascular (No xylem or phloem)
Soft and pliable body
Require external water for reproduction
Small height due to inefficient conduction
Alternation of Generations
Gametophyte: Visible 'leafy' generation
Sporophyte: Stalk with cap at gametophyte tips

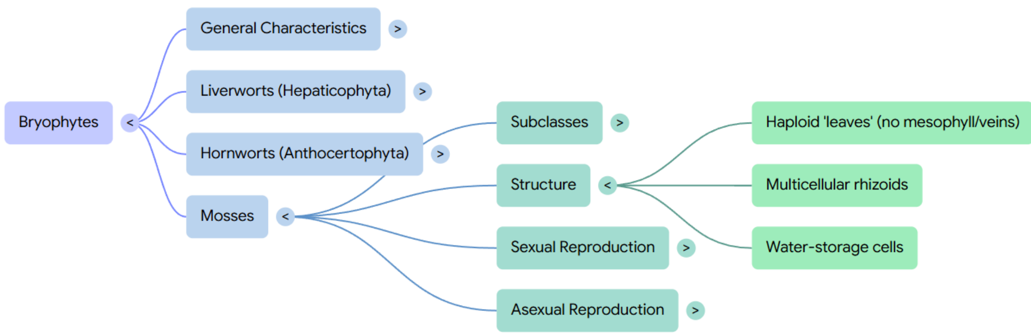

Bryophytes
General Characteristics
Liverworts (Hepaticophyta)
Hornworts (Anthocertophyta)
Mosses
Structure
Marchantia (Thalloid)
Leafy Liverworts
Thallus (flattened body) or 'Leafy'
One-celled rhizoids
Lack true stomata

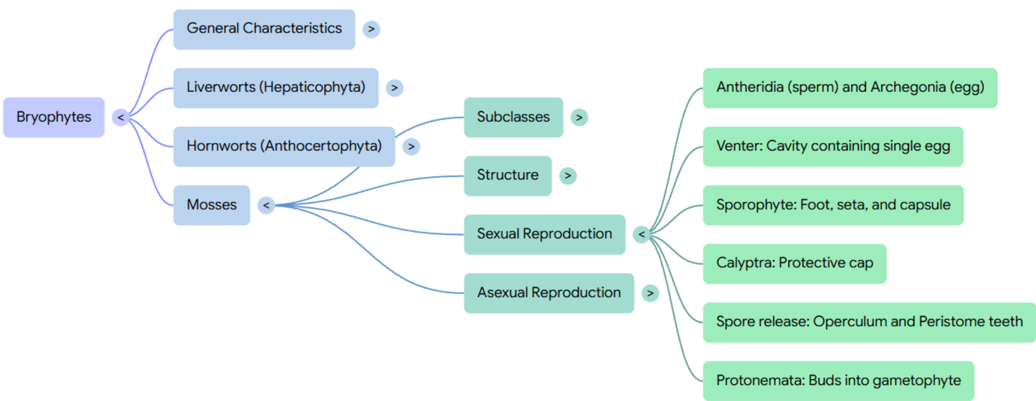

Bryophytes
General Characteristics
Liverworts (Hepaticophyta)
Hornworts (Anthocertophyta)
Mosses
Structure
Marchantia (Thalloid)
Leafy Liverworts
Asexual: Gemmae cups and raindrops
Male: Antheridiophore (disc-shaped)
Female: Archegoniophore (hub and spokes)
Sporophyte: Foot, seta, and capsule
Spore dispersal: Elaters (humidity responsive)

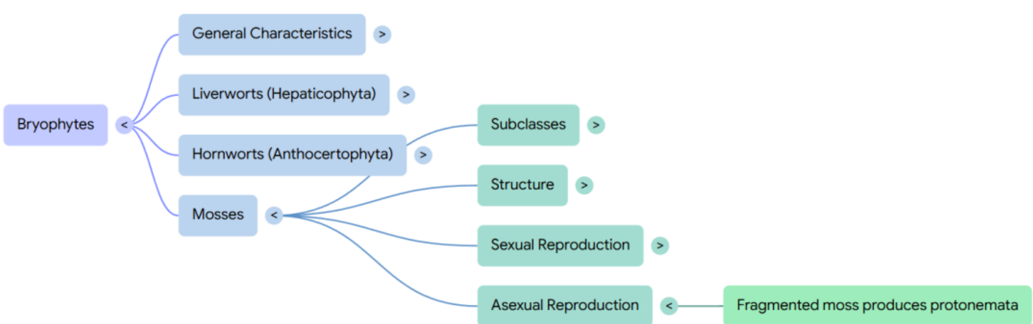

Bryophytes
General Characteristics
Liverworts (Hepaticophyta)
Hornworts (Anthocertophyta)
Mosses
Structure
Marchantia (Thalloid)
Leafy Liverworts
Tropical fog belts
Cells contain oil bodies
Protonema development


Bryophytes
General Characteristics
Liverworts (Hepaticophyta)
Hornworts (Anthocertophyta)
Mosses
Structure
Reproduction
Horn-like mature sporophytes
1-8 chloroplasts with pyrenoids
Sporophytes have stomata
Asexual: Fragmentation
Sexual: Unisexual or Bisexual
Sporophyte growth: Meristematic tissue at base


Bryophytes
General Characteristics
Liverworts (Hepaticophyta)
Hornworts (Anthocertophyta)
Mosses
Subclasses
Structure
Sexual Reproduction
Asexual Reproduction
Peat mosses
True mosses
Rock mosses







What Are Bryophytes? - Meaning and Introduction

Bryophytes are simple, non-vascular land plants that thrive in moist environments. **They include mosses, liverworts, and hornworts**. Unlike higher plants, bryophytes lack true roots, stems, and leaves. Instead, they have thalloid or leafy bodies and depend on water for reproduction. Since they do not produce seeds or flowers, they rely on spores for propagation. Bryophytes act as a connecting link between algae (aquatic plants) and vascular plants (like ferns and seed plants) in plant evolution.

Core Ideas and Fundamentals of Bryophytes

Amphibians of the Plant Kingdom

Bryophytes are called amphibians of the plant kingdom because they live primarily on land but need water for sexual reproduction. This unique feature marks them as a transitional group between aquatic algae and fully terrestrial plants.

Thallus Structure and Lack of Vascular Tissue

The body of bryophytes is often undifferentiated or only loosely organized into leaf-like and stem-like structures. Unlike higher plants, bryophytes do not have true vascular tissue (xylem and phloem), so they absorb water and nutrients over their entire surface.

Alternation of Generations

Bryophytes exhibit a clear alternation of generations in their life cycle. The dominant phase is the gametophyte (haploid), which is longer-lived and more noticeable. The sporophyte (diploid) phase is dependent on the gametophyte for nutrition and support.

Reproduction in Bryophytes

Bryophytes reproduce via spores. Sexual reproduction requires water as the male gametes (antherozoids) are motile and swim to reach the female gamete (egg) in the archegonium (female organ). After fertilization, the sporophyte arises directly from the parent gametophyte.

Important Sub-Concepts in Bryophytes

1. Major Groups of Bryophytes

Bryophytes are classified into three major groups, each with distinct characteristics. Understanding them helps in correct identification and answering classification questions in NEET.

- **Liverworts (Hepaticopsida):** Flattened, lobed thallus; simpler structure; common example - Riccia, Marchantia.
- **Mosses (Bryopsida):** Leafy appearance, erect stature, more evolved; example - Funaria, Polytrichum.
- **Hornworts (Anthocerotopsida):** Unique horn-like sporophyte; example - Anthoceros.

2. Bryophyte Life Cycle: Haplo-Diplontic

The bryophyte life cycle alternates between haploid (gametophyte) and diploid (sporophyte) phases. The gametophyte is dominant, bearing sex organs - antheridia (male) and archegonia (female). Following fertilization, the sporophyte develops, producing spores through meiosis, which germinate into new gametophytes.

3. Ecological and Economic Roles

Bryophytes play vital roles in their habitats:

- Soil formation and prevention of soil erosion (mosses cover rocks and soil surfaces).
- Formation of peat by Sphagnum moss (used as fuel and soil conditioner).
- Providing habitat and moisture for microfauna in terrestrial ecosystems.

Key Principles and Relationships in Bryophytes
Alternation of Generations Explained

The concept of alternation of generations is central to bryophyte biology:

1. The **gametophyte** (n) produces male and female gametes via mitosis.
2. Gametes fuse (fertilization) producing a zygote (2n) which remains attached to the gametophyte.
3. The zygote develops into a **sporophyte** (2n), dependent on the gametophyte.
4. The sporophyte produces haploid spores via meiosis, which germinate into new gametophytes.

Table: Main Differences Between Bryophyte Groups

Feature	Liverworts	Mosses
Main Plant Body	Thalloid or leafy, dorsiventral	Erect, leafy
Rhizoids	Unicellular	Multicellular
Sporophyte	Simple; often lacks elaborate structures	Well-developed with foot, seta, capsule

This table summarizes key distinctions that help in NEET MCQs on bryophyte identification and features.

Features and Limitations of Bryophytes

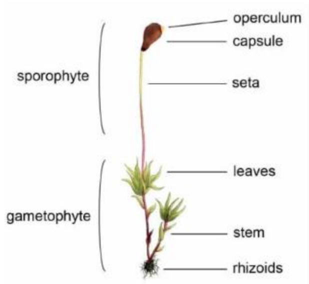
- **Key Features:** Simple organization; dominant gametophyte stage; reliance on water for reproduction; spore-based propagation; lack true vascular tissues, roots, stems, and leaves.
- **Limitations:** Restricted to moist, shaded environments due to absence of vascular tissue and need for water during fertilization; limited size and structural complexity.

D. Pteridophytes

Hook: **first plants with true vascular tissue (xylem/phloem) and true root-stem-leaf** — first plants that could grow tall and live properly on land.

- Examples: *Selaginella, Pteris, Equisetum*
- Here it flips: **sporophyte is dominant**, gametophyte is small (called prothallus)

"In bryophytes, ___ is dominant. In pteridophytes, ___ is dominant."



The term “Pteridophyta” originates from the Greek words “Pteron,” meaning “feather,” and “phyton,” meaning “plant,” i.e., plants with feather-like fronds. The pteridophytes formed a dominant part of the Earth’s vegetation about 282-230 million years ago during the Palaeozoic era.

The Late Palaeozoic era can be regarded as the age of pteridophytes because during this period, pteridophytes were the dominant land plants on Earth. There are about 12,000 species of pteridophytes across the world.

Key Features

1. The first vascular cryptogams having true roots, stems, and leaves are the pteridophytes.
2. They have a primarily dominant and autotrophic generation of sporophyte, which is diploid.
3. Water and food conduction is made by vascular tissues like xylem and phloem.
4. During fertilization, water is needed where the sperm swims to meet the egg.
5. There is an obvious alternation of already presented generations.
6. They may be homosporous, producing a single type of spore, or heterosporous, with two types: microspores and megaspores.
7. Leaves can be microphyllous (small with one vein) or megaphyllous (large with many veins).

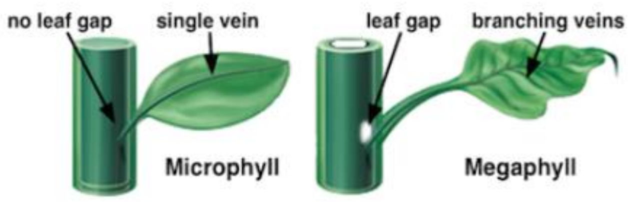
Commented [P3]: a long leaf, often divided into parts along the edge, of some plants or trees

Commented [P4]: **The Paleozoic Era** is the first of three geological eras of the Phanerozoic Eon.

Commented [P5]: "alternation of generations" (also known as *metagenesis*) is a core biological concept describing a life cycle where an organism alternates between two different physical forms to complete its life cycle: an asexual form and a sexual form.
How Alternation of Generations Works-
Instead of having just one body type that grows up and reproduces (like humans do), these organisms alternate between two distinct generations that look entirely different from one another:

```
SPOROPHYTE (Diploid/ 2n)
Creates Spores via Meiosis
        |
        v
GAMETOPHYTE (Haploid / n)
Creates Eggs & Sperm via Mitosis
```

1.**The Sporophyte Generation (Asexual):** This form has a full set of chromosomes (diploid, 2n). It produces **spores** that can survive harsh conditions and travel long distances through the wind or water.
2.**The Gametophyte Generation (Sexual):** When a spore lands, it grows into a completely different-looking plant. This form has only half the chromosomes (haploid) and produces **gametes** (eggs and sperm) that fertilize each other to create a new sporophyte.



Evolutionary Significance of Pteridophytes: The Earliest Vascular Land Plants

Pteridophytes are the first organisms that evolved another significant step in the evolution of the land plants due to the development of vascular tissues. Such tissues enabled the transportation of water and nutrients with the efficiency that fostered or led to increased structural complexity and the consequent ability to colonize terrestrial environments. They came out in the late ***Paleozoic era***, which was considered a significant transition between non-vascular bryophytes and vascular plants. The transformation further led to the evolution of gymnosperms and angiosperms.

Major Classes of Pteridophytes

1. **Psilopsida**: These are primitive pteridophytes lacking true roots with simple stems. One is Psilotum.

Diagram of Psilotum

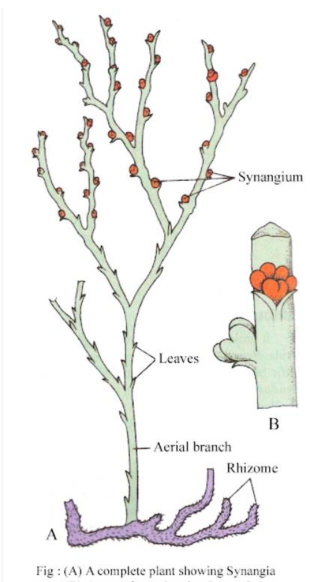


Fig : (A) A complete plant showing Synangia
(B) A part of stem bearing Synangia.

2. **Lycopsida**: They are club mosses and spike mosses because they look like moss. They are microphyllous, and they reproduce through spores. E.g., Lycopodium, Selaginella.
3. **Sphenopsida**: Horsetails: their stems are segmented by whorls of leaves, and are propagated by cone-like strobili. One of them is Equisetum.

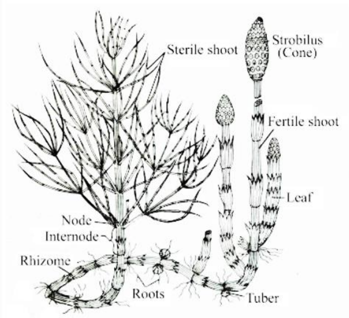


Fig: *Equisetum spp.* Sporophytic plant body showing habit.

4. **Pteropsida**: This one comprises the true ferns with large and divided leaves known as the fronds. It is the highest in pteridophytes. Some of them are Adiantum and Pteris.

 # Alternation of generations in the life cycle of Pteridophytes

Pteridophytes show an evident alternation of generations:

- The predominant stage is the diploid sporophyte, producing the haploid spores by meiosis in sporangia.
- The spores give rise to the gametophyte (or prothallus), a free-living, haploid plant. It produces both male (antheridia) and female (archegonia) sex organs in the homosporous species.
- The fertilization takes place on the gametophyte, and the fertilized egg develops to form a new sporophyte.

Reproduction in Pteridophyta: By Sporangia, Spores, and Prothallus

Pteridophytes reproduce through both sexual and asexual reproduction:

Asexual reproduction– During asexual reproduction, the formation of spores takes place. Sporangia are formed within spores; they can either be solitary or in a cluster (sorus).

Sexual reproduction– sexual reproduction takes place through the gametophyte. The antheridia in the male germinate and produce motile sperm that swim in water to fertilize the female archegonia.

Most ferns have a heart-shaped, photosynthetic, small gametophyte (prothallus), which is green.

In homosporous species, there is only one type of spore, and the result is a bisexual gametophyte. Heterosporous forms produce two kinds of spores, allowing the formation of unisexual gametophytes.

Commented [P6]: a long leaf, often divided into parts along the edge, of some plants or trees

Commented [P7]: 1. Sporophyte = main plant
- The main/large plant is called the **sporophyte**.
- It is **diploid (2n)**.
- Inside structures called **sporangia**, it produces **spores**.
- Spores are made by **meiosis**, so they are **haploid (n)**.

2. Spore → Gametophyte
- The haploid **spore** grows into a small plant called the **gametophyte** or **prothallus**.
- It is **haploid (n)**.
- In **homosporous plants**, this one gametophyte produces **both**:
  - **Antheridia** → male sex organ → produces male gametes
  - **Archegonia** → female sex organ → produces female gametes

3. Fertilization happens
- Male gamete + Female gamete → **Zygote (2n)**
- Fertilization occurs **on the gametophyte**.

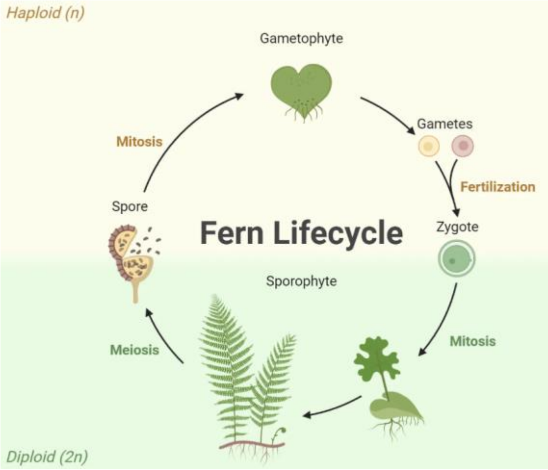
4. Zygote → New sporophyte
- The zygote grows into a **new diploid sporophyte**.
- This becomes the main plant again.

 # Remember it like this:
Sporophyte (2n)
↓ *meiosis*
Spore (n)
↓ *grows*
Gametophyte (n)
↓ *produces male + female gametes*
Fertilization
↓
Zygote (2n)
↓ *grows*
New Sporophyte (2n)

Commented [P8]: Homosporous = one type of spore
That **one type of spore** grows into a **gametophyte that has both male and female sex organs**.
So:
One type of spore → Bisexual gametophyte → produces **male + female gametes**

Commented [P9]: Heterosporous = two different types of spores
These two spores develop into **two different gametophytes**:
- **Male spore → Male gametophyte →** produces male gametes
- **Female spore → Female gametophyte →** produces female gametes

So:
2 types of spores → 2 types of gametophytes → separate male & female



Fern Lifecycle

#Microphylls and Macrophylls Leaves in Pteridophytes

There are two kinds of leaves in pteridophytes:

In primitive groups such as **Lycopsida,** leaves are small, often single-veined, and are known as microphylls.

The larger, more complex leaves containing more than one vein and leaf gaps are called megaphylls (or macrophylls), which are found among ferns (Pteropsida).

#The evolution of vascular Tissues and the emergence of actual roots, stems, as well as leaves in Pteridophytes

The development of the first true vascular tissues by plants occurred in pteridophytes:

A xylem serves as a transportation system that leads the water and dissolved minerals through the roots and to the rest of the plant.

Photosynthetic products (sugars) move out of the leaves to non-green tissues via the phloem.

They possess adventitious roots that are growing out of the rhizome roots.

The stems are aerial or underground rhizomes, and they are commonly dichotomously or laterally branching.

There is a clear distinction of the leaves that can be grouped in a whorl, spiral, or cluster.

#Forms of Stele (Vascular Cylinder):

The stele is the main vascular cylinder of the roots and stems. There are various kinds of stelae in pteridophytes, which are:

Commented [P10]: A rhizome is a modified plant stem that grows horizontally underground or just along the soil surface, sending out roots downward and shoots upward, Unlike a true root, a rhizome features nodes, buds, and tiny scale-like leaves.

Commented [P11]: Dichotomous branching is a growth pattern where a plant's growing tip splits into two equal, Y-shaped forks

Commented [P12]: A **lateral branch** is a side shoot or secondary arm that grows outward from the main trunk, stem, or primary branch of a plant or tree

Protostele: This is the most primitive one. It is made up of a solid core, which is xylem covered with phloem. Examples: haplostele and actinostele.

Siphonostele: This has a central pith bordered by concentric vascular tissue.

Phloem in ectophloic siphonostele occurs only on the outer surface of the xylem.

Phloem is on one side and outside the amphiphloic siphonostele.

Solenostele is one form of amphiphloic siphonostele, having a continuous or a complete vascular ring.

Dictyostele: A siphonostele dissected and with leaf gaps such that the siphonostele appears like a net. In highly evolved ferns such as *Adiantum*.

Plectostele: Vascular tissue is interrupted as strands with no central pith and randomly located. It occurs in certain ferns and horsetails.

Atactostele and Eustele: The vascular bundles will be distributed (atactostele) or in a partnership (eustele). These are evolutionary developments that are witnessed in seed plants.

Commented [P13]: An **ectophloic siphonostele** is a type of plant vascular arrangement (stele) where a central pith is surrounded by a ring of xylem, with a ring of phloem located only on the outer side of the xylem

Commented [P14]: An **amphiphloic siphonostele** is a type of plant vascular arrangement where a central core of pith is surrounded by a hollow cylinder of xylem, with rings of phloem located on both the outer and inner sides of the xylem

Commented [P15]: what are vascular bundles?
Vascular bundles are the plant's **transport pipes**:
- **Xylem** → carries water
- **Phloem** → carries food

Atactostele, "Atacto" = scattered
The vascular bundles are **scattered randomly throughout the stem**.
Imagine **many straws scattered inside a glass**.
Atactostele → vascular bundles are scattered

Eustele
In **eustele**, vascular bundles are **arranged in a ring** around the central part of the stem.
Imagine **straws arranged in a circle**.
Eustele → vascular bundles arranged in a ring

 # Ecological Functions of Pteridophytes

The pteridophytes are ecologically important in several ways:

- They assist in moisture preservation in the forest environment through the covering of soil.
- Pteridophytes are natural pioneer species, particularly in degraded habitats.
- Host nesting locations and microhabitats for insects, amphibians, and other small living beings are also provided by pteridophytes.

 # Economic Applications of Pteridophytes

In different aspects, pteridophytes are economically important:

Ornamentals: Ornamental cultivation of ferns such as Nephrolepis, Adiantum, and Asplenium is generally common.

Medicinal: Different species are traditional painkillers for diseases such as fever, wounds, stomach pains, among others.

Water fern or Azolla is a kind of biofertilizer that is used in growing rice because of its symbiosis with *Anabaena*, in which it fixes nitrogen.

Pteridophytes act as air pollution and environmental health bioindicators because they react to changes in the environment.

There are edible species that are eaten as vegetable food in most societies.

Fern leaves are also ritually used in cultural traditions, particularly in South Asian and Pacific cultures.

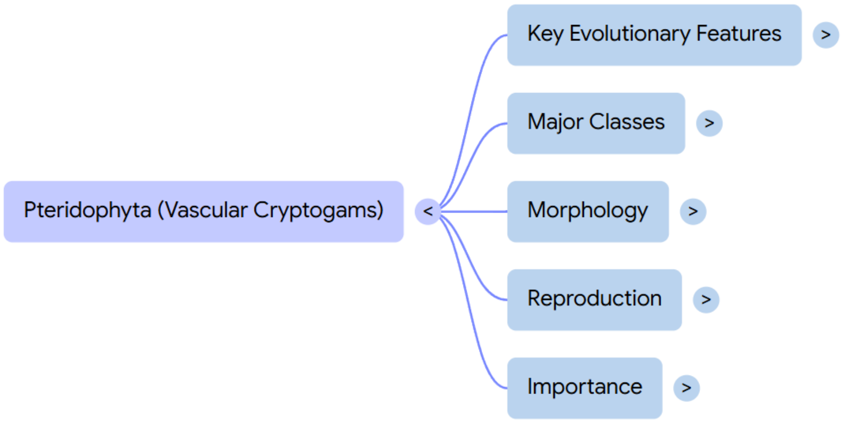
Pteridophytes Fossil Record

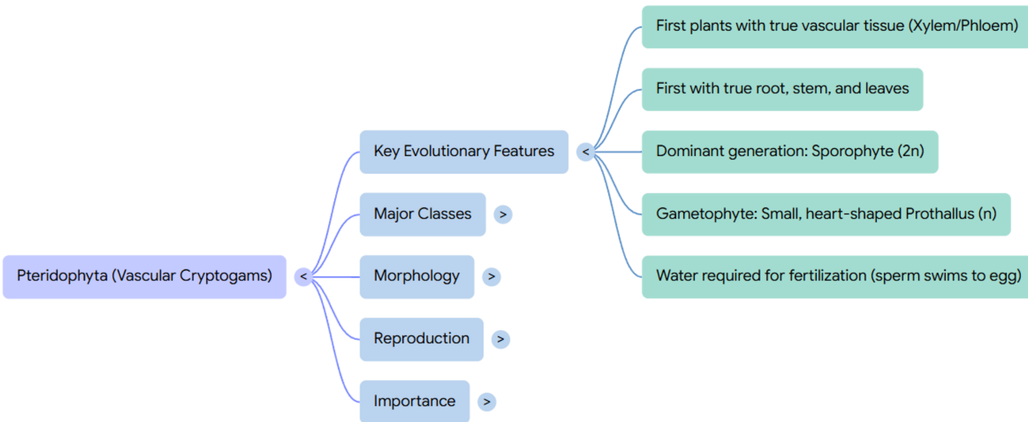
Pteridophytes were dominant forms of plants in the Carboniferous period (about 300 million years ago). They added a lot of organic matter in creating coal beds. In the Swamp Forest of prehistoric time, the presence of fossil genera such as Lepidodendron, Sigillaria, and Calamites is to be seen.

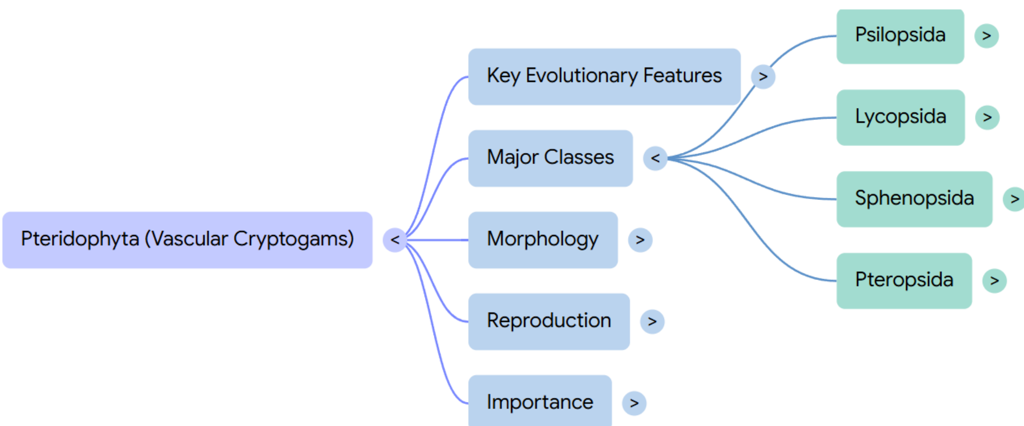
Comparison of Pteridophytes, Bryophytes, and Gymnosperms

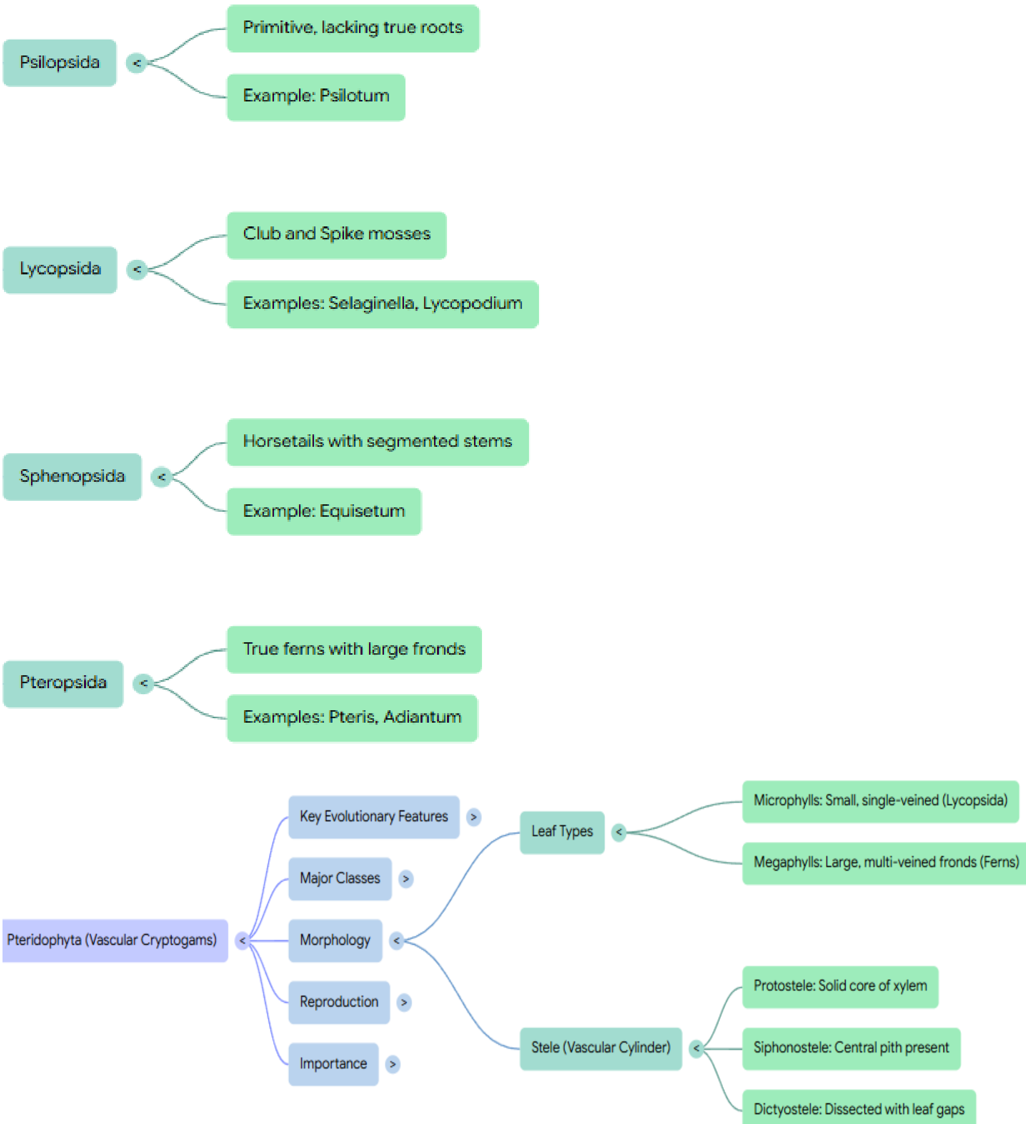
Feature	**Bryophytes**	**Pteridophytes**	**Gymnosperms**
Vascular Tissue	Absent	Present	Present
Dominant Phase	Gametophyte	Sporophyte	Sporophyte
Reproduction	Takes place through spores	Takes place through spores	Takes place through Seeds (naked)
Fertilization	Needs water	Needs water	Autonomous of water
Habitat	Moist/shady	Moist/shady	Terrestrial (varied)
Examples	Mosses, Liverworts	Ferns, Horsetails	Pine, *Cycas*

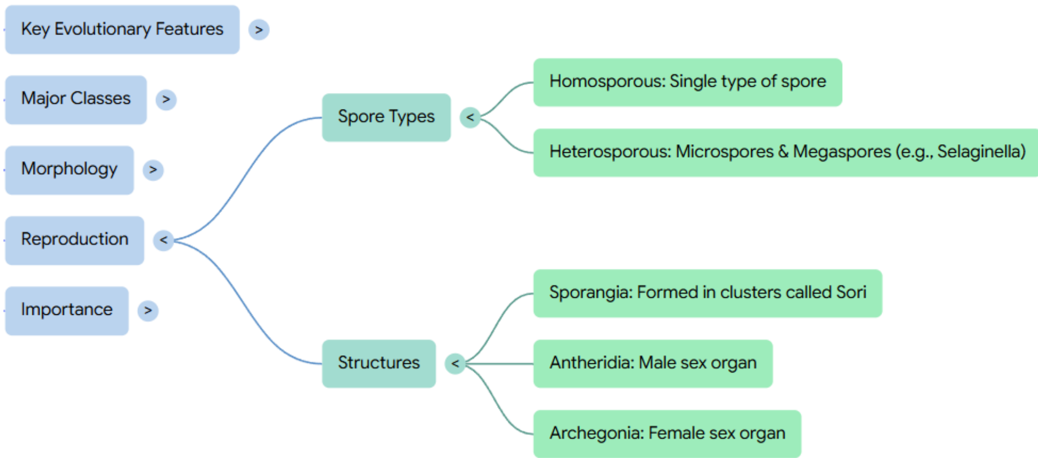
Recap

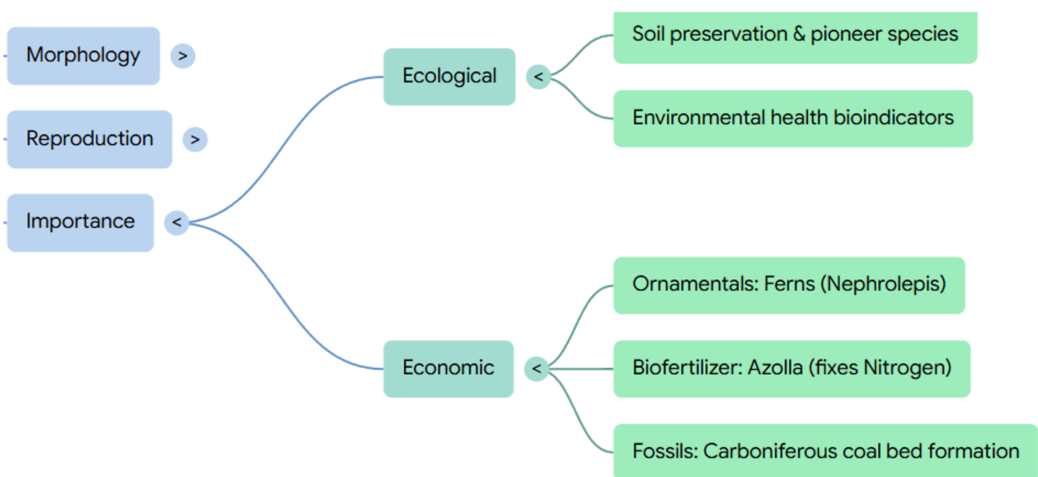



Pteridophyta (Vascular Cryptogams)
Key Evolutionary Features
Major Classes
Morphology
Reproduction
Importance
First plants with true vascular tissue (Xylem/Phloem)
First with true root, stem, and leaves
Dominant generation: Sporophyte (2n)
Gametophyte: Small, heart-shaped Prothallus (n)
Water required for fertilization (sperm swims to egg)


Pteridophyta (Vascular Cryptogams)
Key Evolutionary Features
Major Classes
Morphology
Reproduction
Importance
Psilopsida
Lycopsida
Sphenopsida
Pteropsida


Psilopsida
Primitive, lacking true roots
Example: Psilotum
Lycopsida
Club and Spike mosses
Examples: Selaginella, Lycopodium
Sphenopsida
Horsetails with segmented stems
Example: Equisetum
Pteropsida
True ferns with large fronds
Examples: Pteris, Adiantum
Pteridophyta (Vascular Cryptogams)
Key Evolutionary Features
Major Classes
Morphology
Reproduction
Importance
Leaf Types
Microphylls: Small, single-veined (Lycopsida)
Megaphylls: Large, multi-veined fronds (Ferns)
Stele (Vascular Cylinder)
Protostele: Solid core of xylem
Siphonostele: Central pith present
Dictyostele: Dissected with leaf gaps





E. Gymnosperms

Hook: "gymno" = naked → **naked seeds, not enclosed in a fruit**

- Examples: *Pinus*, *Cycas*, *Cedrus*
- Heterosporous (two types of spores — micro and mega), cones instead of flowers

Gymnosperms (from Greek: gymnos = naked, sperma = seed) are a group of woody, perennial, seed-producing plants characterized by unenclosed or naked seeds. Unlike angiosperms, their ovules are not enclosed by an ovary wall and remain completely exposed both before and after fertilization. In the evolutionary lineage of terrestrial flora, they represent an essential transitionary bridge between spore-producing vascular cryptogams (Pteridophytes) and seed-enclosed flowering plants (Angiosperms).

■ NEET CONCEPT BOOSTER: PLOIDY OF ENDOSPERM

• Gymnosperm Endosperm: Formed before fertilization. It is haploid (n) and represents the female gametophyte itself.

• Angiosperm Endosperm: Formed after double fertilization (triple fusion). It is triploid (3n). This is a classic, high-frequency NEET distinction!

1. **MORPHOLOGICAL ADAPTATIONS & ASSOCIATIONS**

Gymnosperms range from medium-sized shrubby trees to some of the largest forest giants on Earth (e.g., Sequoia sempervirens, the giant redwood, which is one of the tallest living tree species). Their vegetative body is a diploid sporophyte (2n) well-adapted to withstand extreme environmental stress.

Root System and Symbiotic Associations (Highly High-Yield for NEET):

• Taproot System: Gymnosperms typically possess a deep-penetrating taproot system to firmly anchor their tall structures.

• Mycorrhizal Roots: In the genus Pinus, roots exhibit a symbiotic relationship with soil fungi (Mycorrhiza). The fungal hyphae vastly increase surface area for mineral (mainly phosphorus) and water absorption from nutrient-poor soils.

• Coralloid Roots: In the genus Cycas, specialized apogeotropic (growing upwards, out of the soil) roots called coralloid roots are formed. These roots are associated with nitrogen-fixing cyanobacteria (primarily Nostoc and Anabaena) to supply nitrogenous compounds.

Stem and Leaf Variations:

• Stem Branching: Stems can be unbranched (e.g., Cycas, giving a palm-like appearance) or branched (e.g., Pinus, Cedrus, forming conical configurations).

• Leaves: May be simple or compound. In Cycas, the pinnately compound leaves persist at the apex for several years. Conifers (like pines) bear needle-like leaves.

• Xerophytic Adaptations: To prevent water loss in arid, cold, or wind-swept climates, conifer leaves possess a thick cuticle, reduced surface area, and deep sunken stomata

2. ANATOMY OF VASCULAR TISSUE & WOOD

While gymnosperms have highly developed vascular bundles, their xylem and phloem elements exhibit primitive anatomical features compared to angiosperms. This makes their vascular structure a key area of study.

• Xylem: Composed primarily of tracheids which conduct water. True vessels (vessel elements) are completely absent from their xylem. The sole exception is the advanced class Gnetales (Gnetophyta), which possesses true vessels—an evolutionary link to angiosperms.

• Phloem: Consists of sieve cells for food transport. True sieve tubes and companion cells are absent. Instead, specialized albuminous cells (Strasburger cells) function alongside sieve cells to regulate transport.

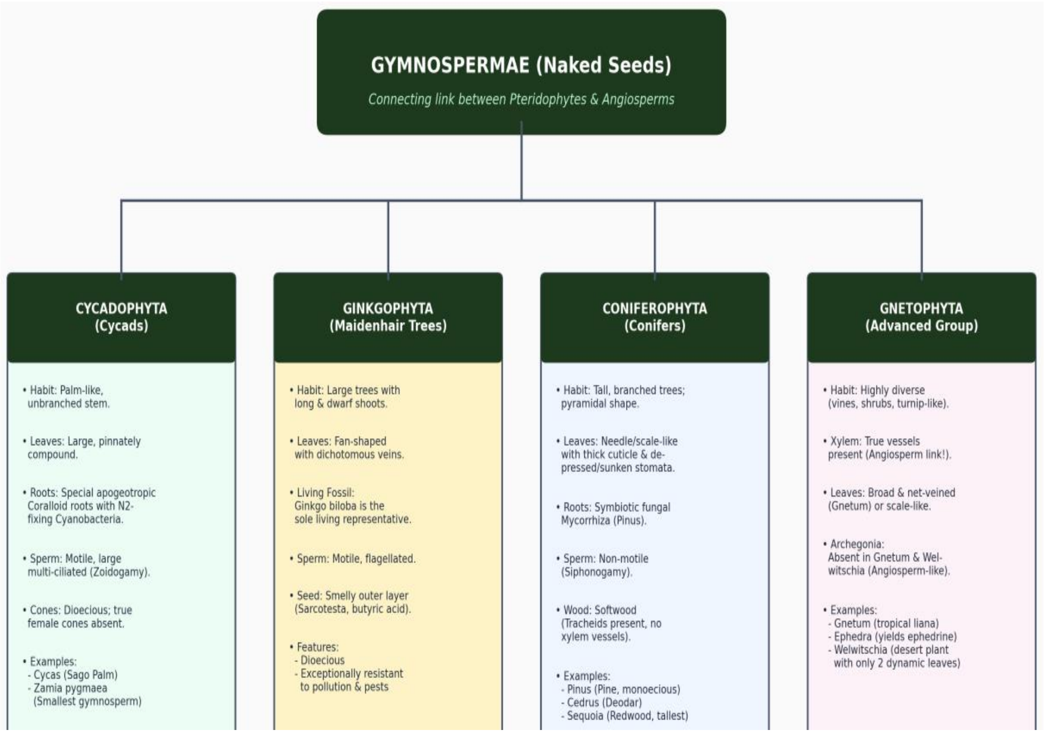
• Softwood vs. Hardwood: Due to the lack of dense vessels and mechanical fibers in their wood, gymnosperm wood is structurally designated as softwood, unlike the vessel-rich hardwood of angiosperms.

Feature	Cycas	Pinus
Stem Habit	Unbranched, columnar, palm-like	Branched, pyramidal forest tree
Root Symbiosis	Coralloid roots with cyanobacteria (Nostoc/Anabaena)	Mycorrhizal roots with fungi
Leaf Morphology	Pinnately compound, large, persist for years	Needle-like leaves, small, high cuticle
Sexuality (Monoecy/Dioecy)	Dioecious (male & female structures on separate trees)	Monoecious (male & female cones on the same tree)
Male Gamete (Sperm)	Large, motile, top-shaped with spiral cilia	Small, non-motile (carried by pollen tube)

Key Differences Between Pinus and Cycas (NEET Hotspots)

3. MAJOR DIVISIONS OF GYMNOSPERMS

Modern gymnosperms are systematically grouped into four distinct lineages or divisions. Each division possesses unique anatomical, morphological, and reproductive characteristics.



Hierarchical Classification and Key Features of Gymnosperm Divisions

A. Cycadophyta (Cycads)

Cycads represent ancient, primitive seed plants that thrive in mild tropical and subtropical climates. They bear pinnately compound, palm-like leaves and have separate male and female plants (dioecious). Important primitive characters: They retain flagellated, motile sperm (multi-ciliated, top-shaped) which swim to reach the egg inside the ovule. This mode of fertilization, which combines siphonogamy with zoidogamy, is a critical evolutionary link.

B. Ginkgophyta (Ginkgos)

This division has only one living representative, Ginkgo biloba (the Maidenhair tree), making it a classic 'living fossil'. They are deciduous trees with fan-shaped leaves that show dichotomous venation. Like cycads, they are dioecious, have motile sperm, and are highly resistant to pests and atmospheric pollution. Female trees produce seeds with a fleshy, yellowish outer coat (sarcotesta) that smells like rancid butter (butyric acid) upon maturity

C. Coniferophyta (Pinophyta - Conifers)

Conifers form the largest and most ecologically dominant group of modern gymnosperms. They dominate boreal forests and are characterized by needle-like leaves, thick cuticles, and sunken stomata. Most conifers are monoecious (e.g., Pinus, where both male and female cones are borne on the same tree). They reproduce strictly through siphonogamy (sperm is non-motile, delivered entirely by a pollen tube). Their wood is highly valued as softwood.

D. Gnetophyta (Gnetophytes)

The most advanced and evolutionary mysterious group. Gnetophytes possess characteristics that are highly similar to angiosperms, such as “true xylem vessels” and “double fertilization-like processes” (though no endosperm is formed). This group is represented by three highly divergent genera:

• Gnetum: Tropical lianas, shrubs or trees with broad, net-veined angiosperm-like leaves.

• Ephedra: Gnarled, xerophytic desert shrubs with jointed photosynthetic stems and scale-like leaves. Source of ephedrine.

• Welwitschia: The weirdest desert plant (Welwitschia mirabilis) of the Namib desert, producing only two strap-like leaves that grow continuously and split over centuries.

4. REPRODUCTIVE CYCLE & SYSTEMATICS

Gymnosperms are strictly heterosporous, producing two separate morphs of spores: microspores (which develop into male pollen grains) and megaspores (which develop into the female gametophyte inside the ovule). These spores are housed within specialized cones or strobili.

• Strobili (Cones): Cones consist of an axis bearing spirally arranged sporophylls. Microsporophylls bear microsporangia which release haploid microspores (pollen grains). Megasporophylls bear megasporangia (ovules).

• Male Gametophyte: Highly reduced. In Pinus, it is composed of only 4 cells (two prothallial cells, one generative cell, and one tube cell). The pollen grain of Pinus is typically winged (anemophilous - wind-pollinated).

• Female Gametophyte: The megaspore mother cell (2n) in the nucellus of the ovule undergoes meiosis to form 4 megaspores. Only one remains functional, growing into the multicellular female gametophyte (n) which houses two or more archegonia.

• Pollination & Fertilization: Pollen is carried by wind currents and enters the micropyle directly (direct pollination). A pollen tube develops and grows towards the archegonia (siphonogamy) to discharge sperm.

• Seed Development: Following fertilization, the zygote (2n) becomes the embryo, the ovule develops into the seed, and the integument forms the seed coat. Because there is no ovary wall, “no fruit is ever formed”.

■ ***NEET HIGH-YIELD CHEAT SHEET (MUST-MEMORIZE)***

• Tallest Gymnosperm: Sequoia sempervirens (Redwood Tree).

• Smallest Gymnosperm: Zamia pygmaea (a cycad).

• Living Fossil: Ginkgo biloba (Maidenhair tree). Also, cycads are considered living fossils.

• Siphonogamy vs. Zoidogamy: Conifers show siphonogamy (non-motile sperm carried via pollen tube). Cycads and Ginkgo show a mix: siphonogamy (to carry pollen into chamber) and zoidogamy (motile flagellated sperm swim to egg).

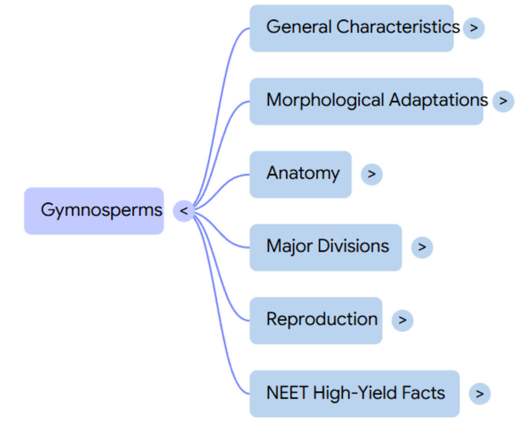
• Sulfur Shower: In pine forests, pollen grains are produced in such massive quantities that when wind disperses them, they form a yellow cloud, often called a 'sulfur shower'.

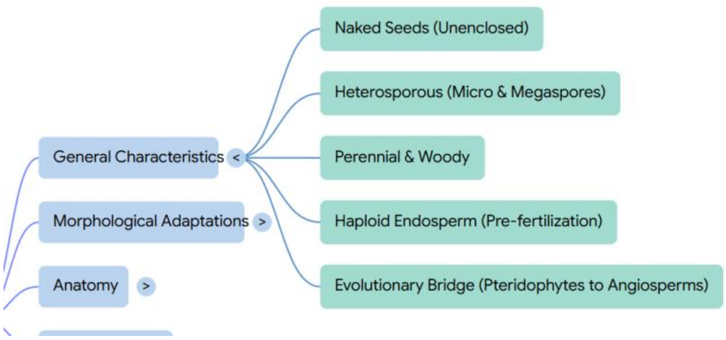
• Vessels in Xylem: Present only in the order Gnetales (Gnetum, Ephedra, Welwitschia). Absent in all other gymnosperms.
• Ephedrine: A potent respiratory drug extracted from the stems of Ephedra used to treat asthma.

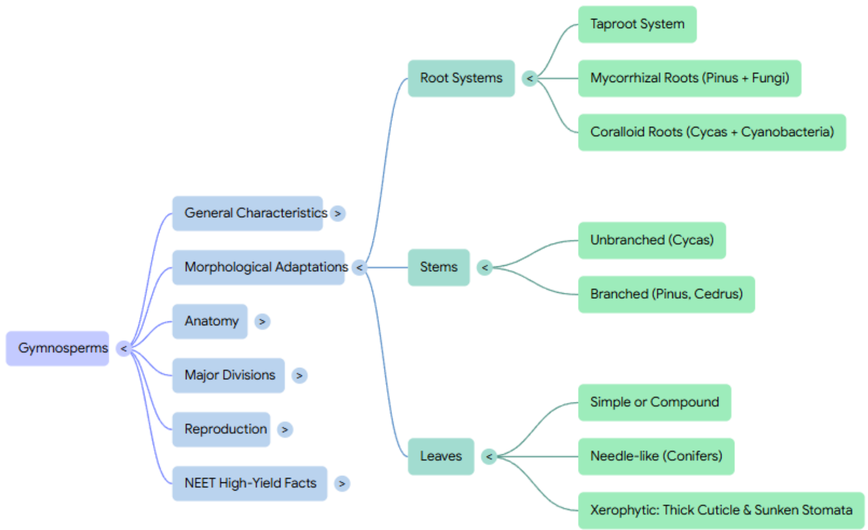
• Sago: Edible starch extracted from the stem of Cycas revoluta (Sago palm).

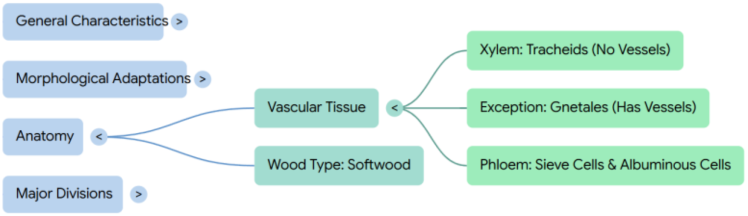
• Direct Pollination: Pollen lands directly on the micropylar drop of the ovule, not on a stigma (as in angiosperms).

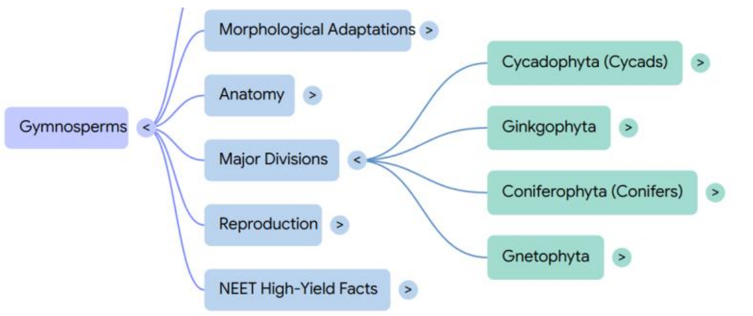
Recap

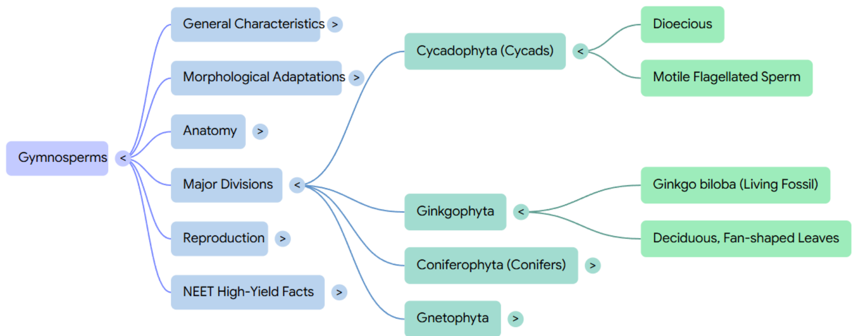


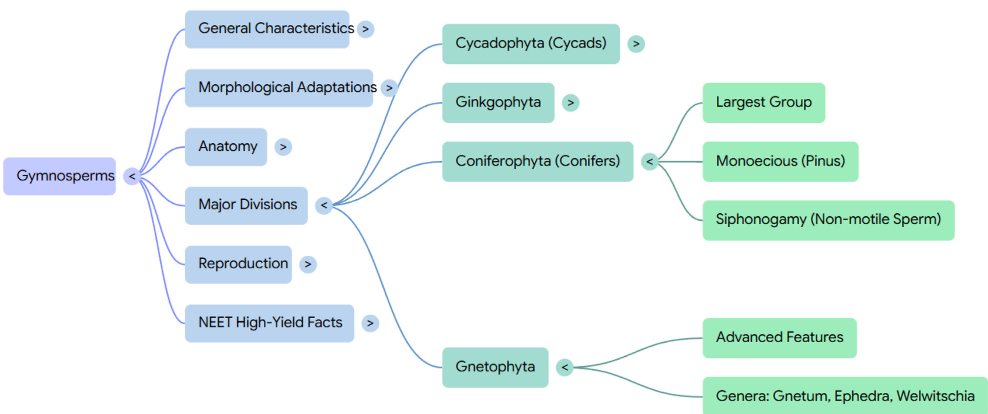


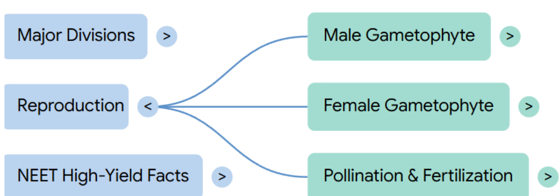

Gymnosperms
General Characteristics
Morphological Adaptations
Anatomy
Major Divisions
Reproduction
NEET High-Yield Facts
Root Systems
Taproot System
Mycorrhizal Roots (Pinus + Fungi)
Coralloid Roots (Cycas + Cyanobacteria)
Stems
Unbranched (Cycas)
Branched (Pinus, Cedrus)
Leaves
Simple or Compound
Needle-like (Conifers)
Xerophytic: Thick Cuticle & Sunken Stomata

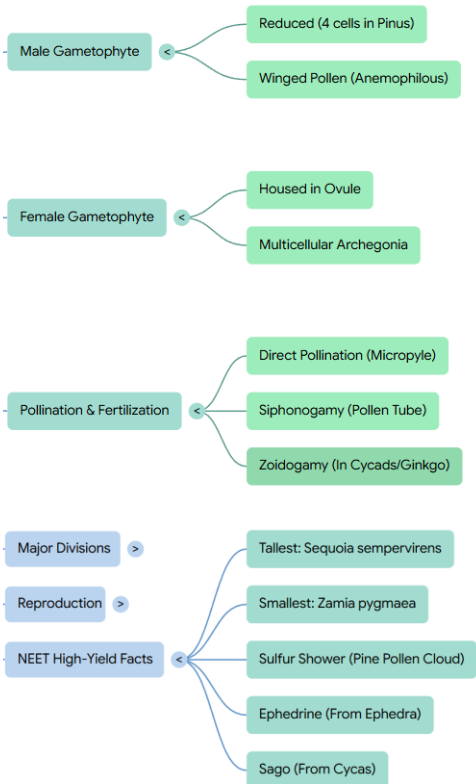

General Characteristics
Morphological Adaptations
Anatomy
Major Divisions
Vascular Tissue
Wood Type: Softwood
Xylem: Tracheids (No Vessels)
Exception: Gnetales (Has Vessels)
Phloem: Sieve Cells & Albuminous Cells


Gymnosperms
Morphological Adaptations
Anatomy
Major Divisions
Reproduction
NEET High-Yield Facts
Cycadophyta (Cycads)
Ginkgophyta
Coniferophyta (Conifers)
Gnetophyta


Gymnosperms
General Characteristics
Morphological Adaptations
Anatomy
Major Divisions
Reproduction
NEET High-Yield Facts
Cycadophyta (Cycads)
Dioecious
Motile Flagellated Sperm
Ginkgophyta
Ginkgo biloba (Living Fossil)
Deciduous, Fan-shaped Leaves
Coniferophyta (Conifers)
Gnetophyta


Gymnosperms
General Characteristics
Morphological Adaptations
Anatomy
Major Divisions
Reproduction
NEET High-Yield Facts
Cycadophyta (Cycads)
Ginkgophyta
Coniferophyta (Conifers)
Largest Group
Monoecious (Pinus)
Siphonogamy (Non-motile Sperm)
Gnetophyta
Advanced Features
Genera: Gnetum, Ephedra, Welwitschia


Major Divisions
Reproduction
NEET High-Yield Facts
Male Gametophyte
Female Gametophyte
Pollination & Fertilization



F. Angiosperms

- Flowering plants, seeds enclosed in a fruit
- Split into **Monocots vs Dicots** — just flag this now, you'll build on it in a later class (cotyledon number, leaf venation, root type — don't dump all of it today)
- One NEET-favorite fact to mention: **double fertilization** is unique to angiosperms

G. Alternation of Generations

IMP: every plant life cycle alternates between a **haploid gametophyte** (produces gametes) and a **diploid sporophyte** (produces spores). What changes across the groups is *which one dominates*:

Group	Dominant phase
Algae (most)	Gametophyte (haplontic)
Bryophytes	Gametophyte
Pteridophytes → Angiosperms	Sporophyte (progressively more dominant)

#NTK: "Notice the trend — as plants evolved and moved fully onto land, the sporophyte took over as the dominant, independent phase, and the gametophyte shrank." ***This one sentence answers a huge number of NEET conceptual questions.***
