

Chapter 29

Plant Diversity I: How Plants Colonized Land

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: The Greening of Earth

- Looking at a lush landscape, it is difficult to imagine the land without any plants or other organisms
- For more than the first 3 billion years of Earth's history, the terrestrial surface was lifeless
- Since colonizing land, plants have diversified into roughly **290,000 living species**
- Plants supply oxygen and are the ultimate source of most food eaten by land animals

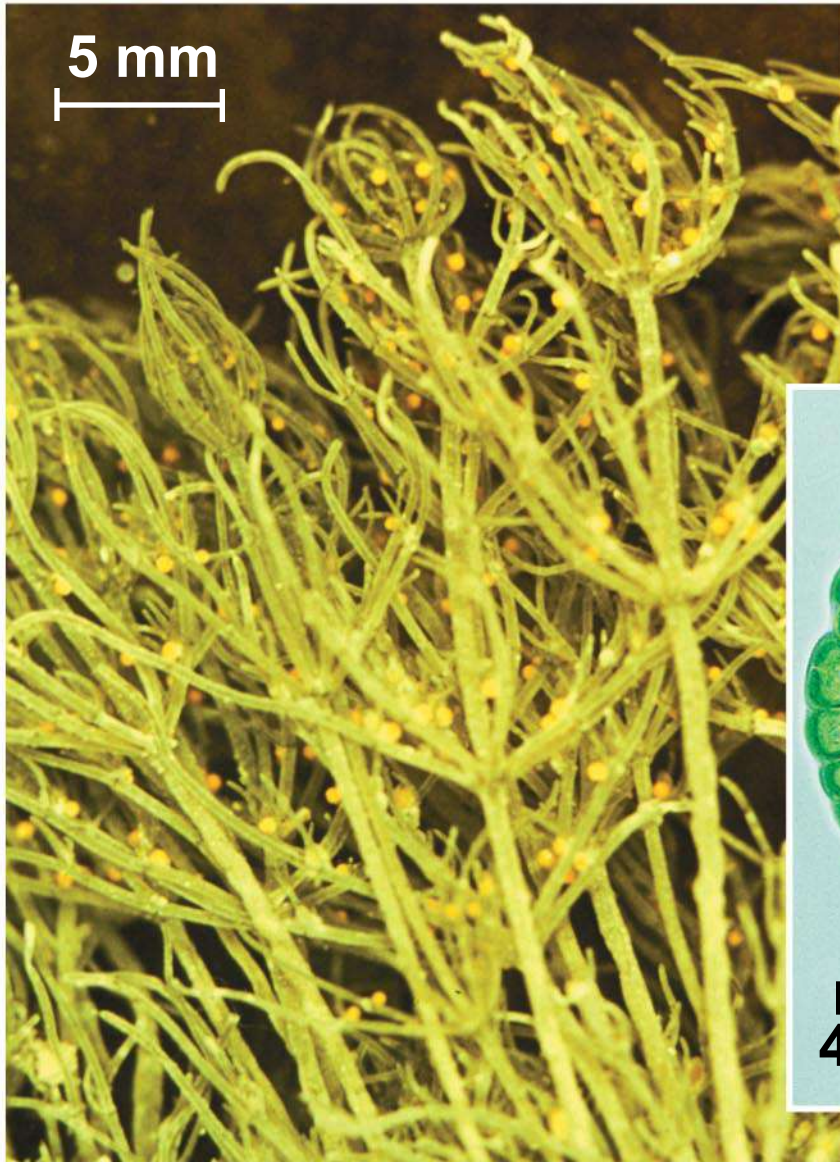


Concept 29.1: Land plants evolved from green algae

- Green algae called **charophytes** are the closest relatives of land plants
- Comparisons of both nuclear and chloroplast genes point to charophytes as the closest living relatives of land plants
- Note that land plants are not descended from modern charophytes, but share a common ancestor with modern charophytes

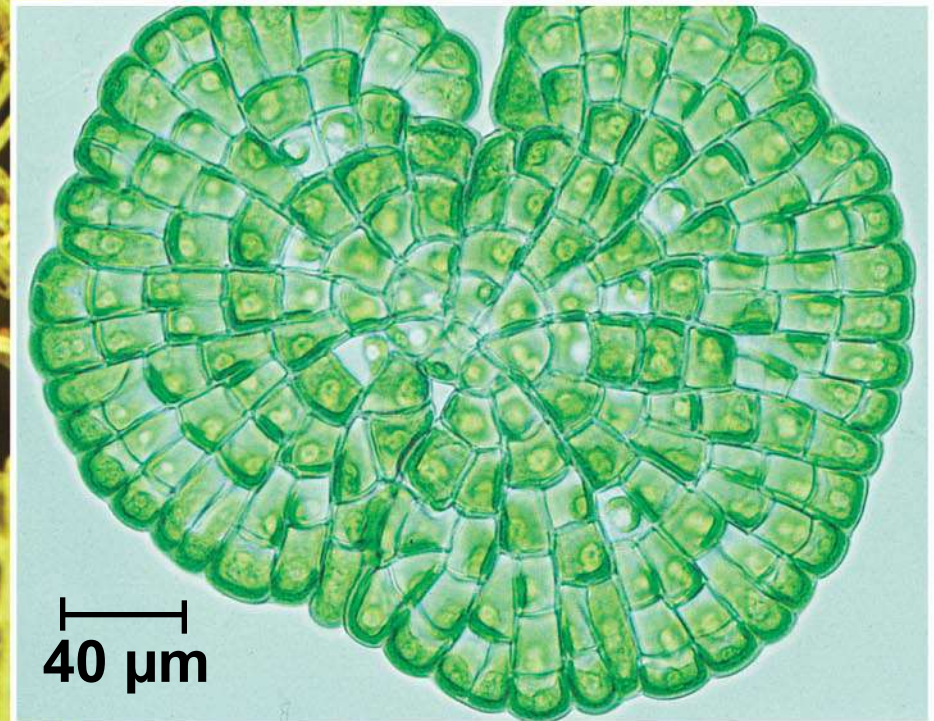
Morphological and Molecular Evidence

- Many characteristics of land plants also appear in a variety of algal clades, mainly algae
- However, land plants share four key traits only with charophytes:
 - Rose-shaped complexes for cellulose synthesis
 - Peroxisome enzymes
 - Structure of flagellated sperm
 - Formation of a **phragmoplast**



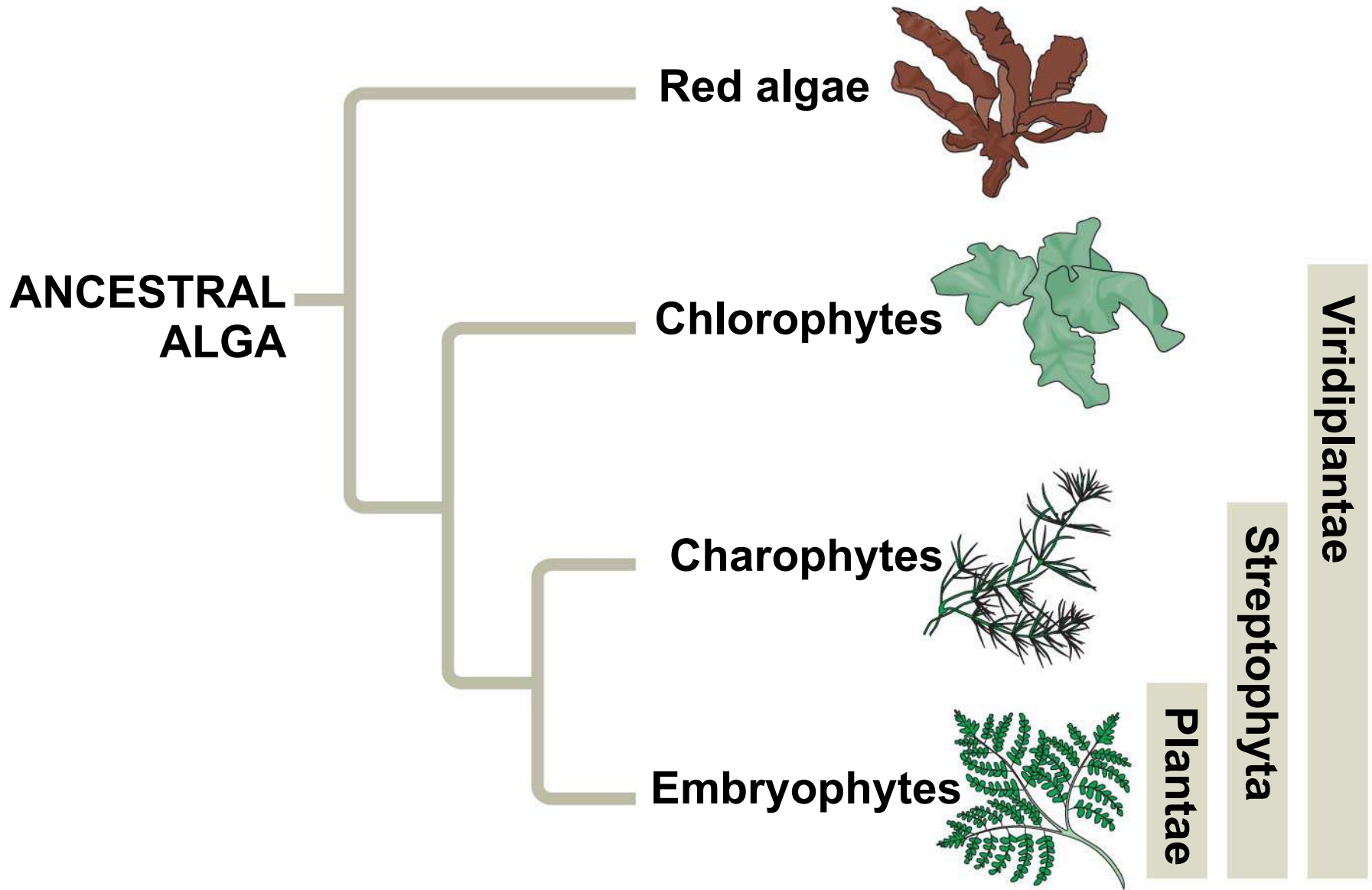
◀ ***Chara* species, a pond organism**

▼ ***Coleochaete orbicularis*, a disk-shaped charophyte that also lives in ponds (LM)**



Adaptations Enabling the Move to Land

- In charophytes a layer of a durable **polymer** called **sporopollenin** prevents exposed zygotes from drying out
- The movement onto land by charophyte ancestors provided **unfiltered sun, more plentiful CO₂, nutrient-rich soil, and few herbivores or pathogens**
- Land presented challenges: **a scarcity of water and lack of structural support**



Derived Traits of Plants

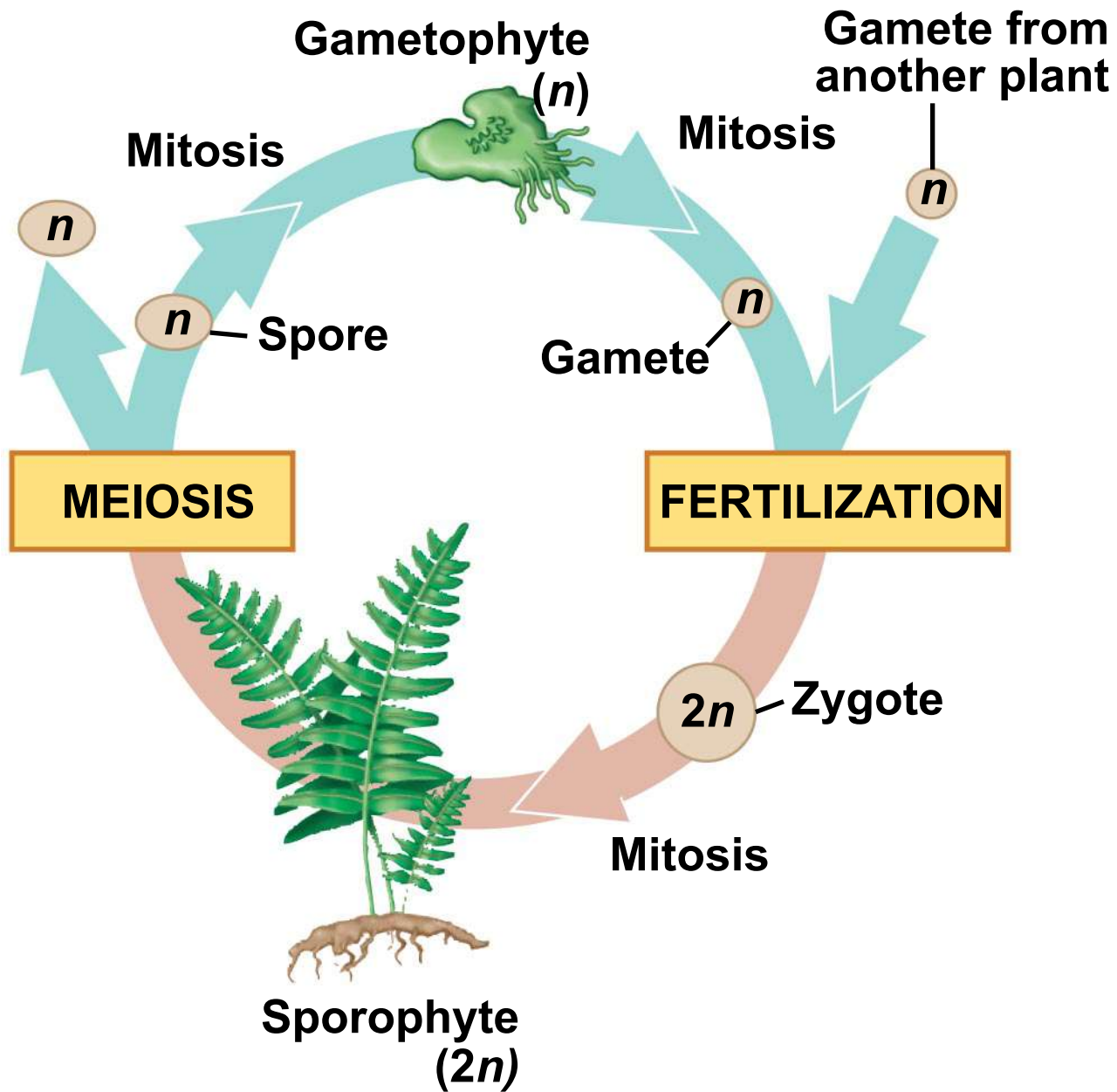
- Four key traits appear in nearly all land plants but are absent in the charophytes:
 - Alternation of generations (with multicellular, dependent embryos)
 - Walled spores produced in sporangia
 - Multicellular gametangia
 - Apical meristems

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- Additional derived traits such as a **cuticle** and secondary compounds evolved in many plant species
 - Symbiotic associations between fungi and the first land plants may have helped plants without true roots to obtain nutrients

Alternation of Generations and Multicellular, Dependent Embryos

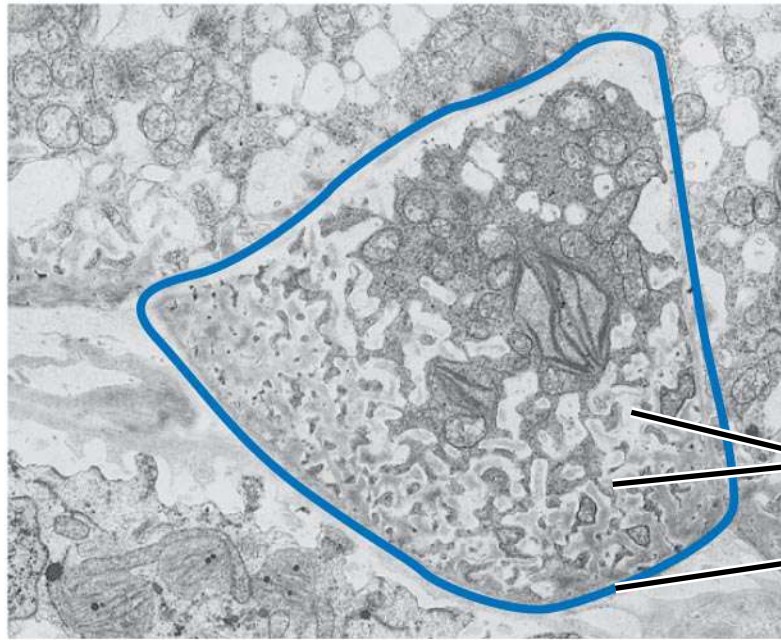
- Plants **alternate between two multicellular stages**, a reproductive cycle called **alternation of generations**
- The **gametophyte** is haploid and produces haploid gametes by mitosis
- Fusion of the gametes gives rise to the diploid **sporophyte**, which produces **haploid spores** by meiosis

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- The diploid embryo is retained within the tissue of the female gametophyte
 - Nutrients are transferred from parent to embryo through **placental transfer cells**
 - Land plants are called **embryophytes** because of the dependency of the embryo on the parent



Alternation of generations

2 μm



Embryo
Maternal tissue



Wall ingrowths

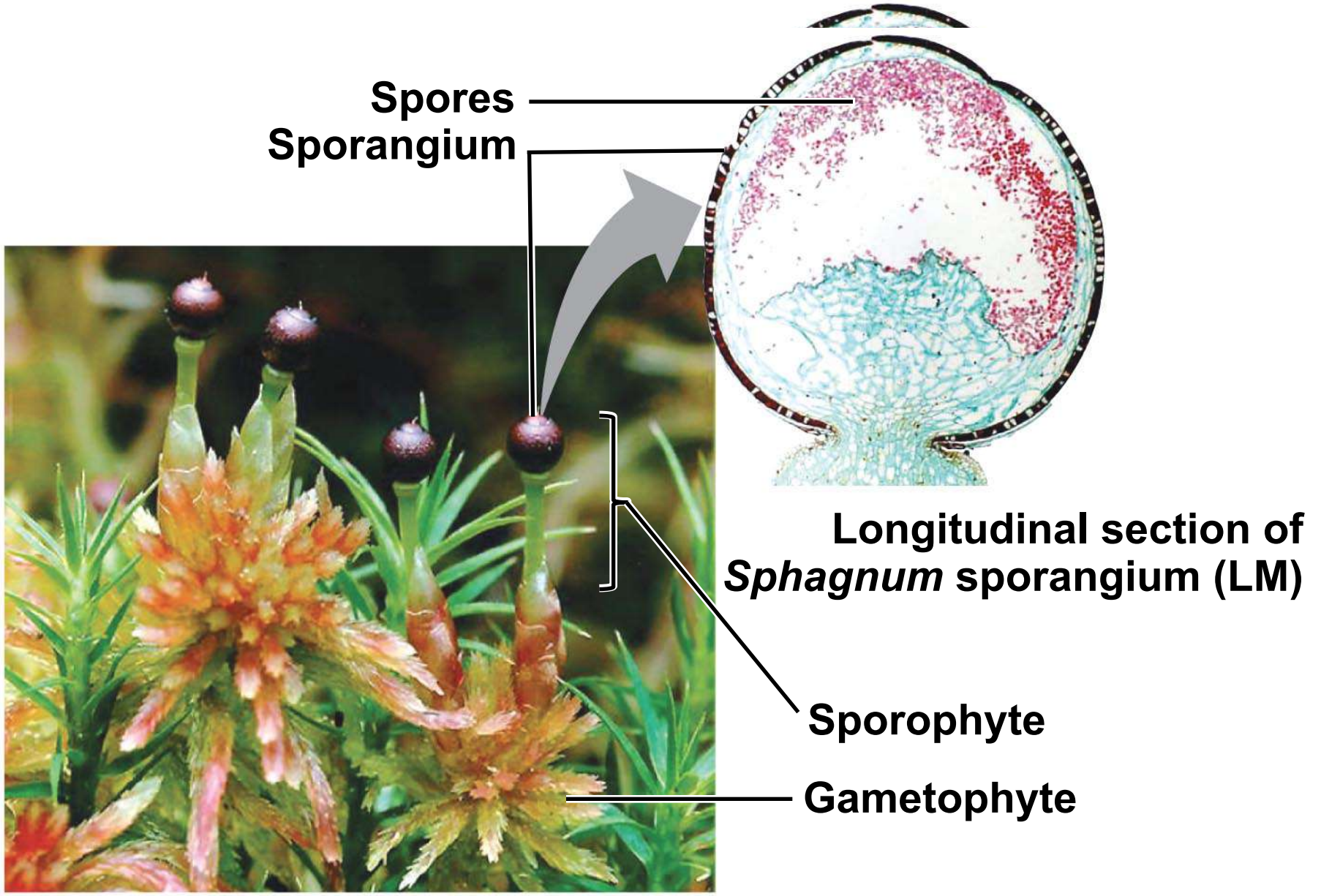
10 μm

Placental transfer cell
(outlined in blue)

**Embryo (LM) and placental transfer cell (TEM)
of *Marchantia* (a liverwort)**

Walled Spores Produced in Sporangia

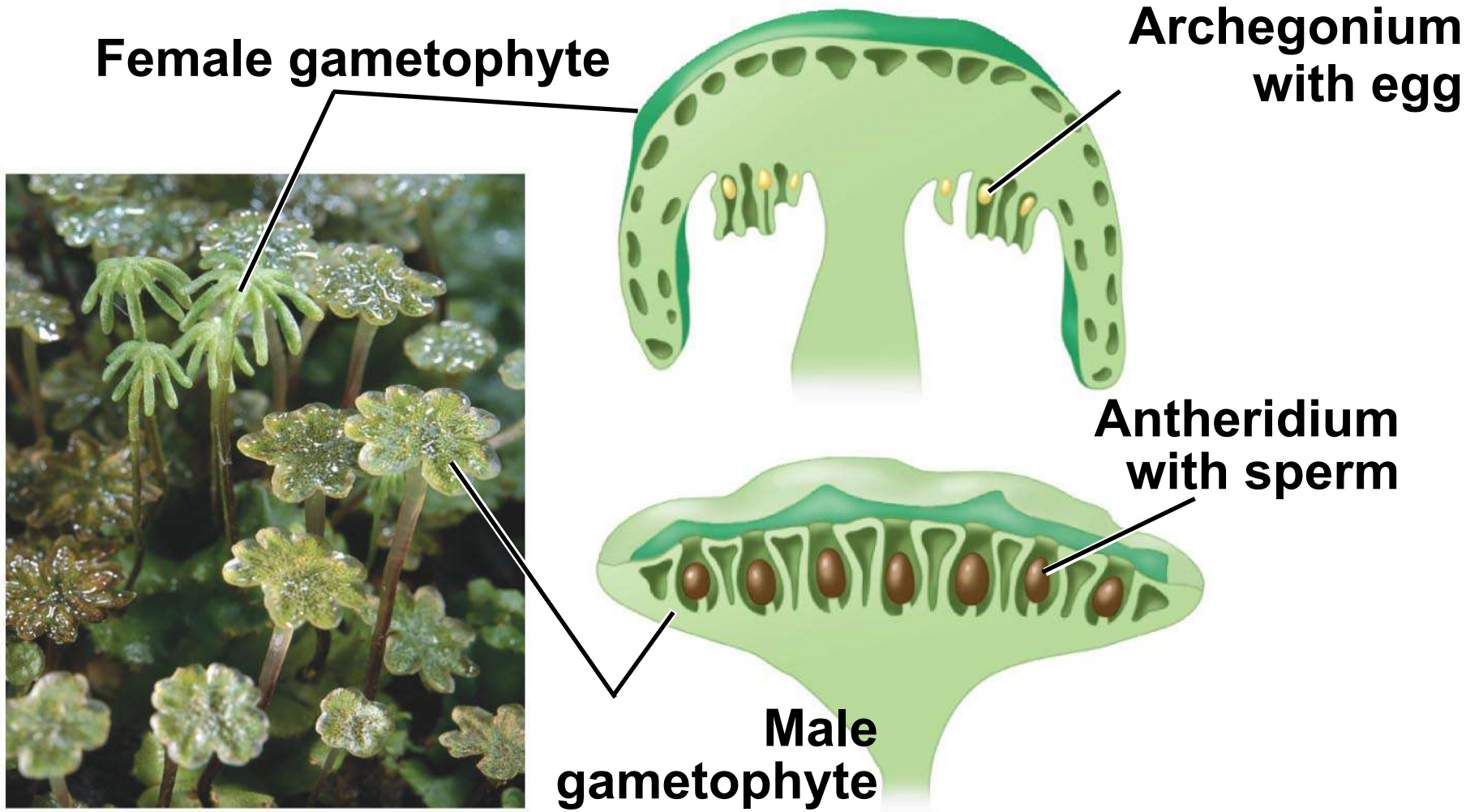
- The sporophyte produces spores in organs called **sporangia**
- Diploid cells called **sporocytes** undergo meiosis to generate haploid spores
- Spore walls contain **sporopollenin**, which makes them resistant to harsh environments



Sporophytes and sporangia of *Sphagnum* (a moss)

Multicellular Gametangia

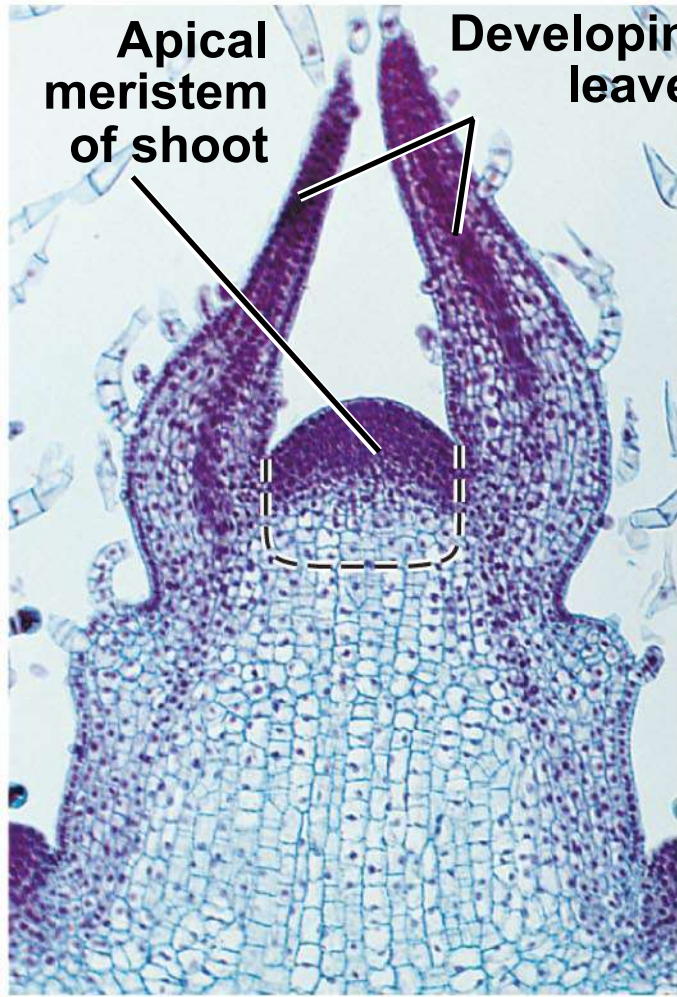
- Gametes are produced within organs called **gametangia**
- Female gametangia, called **archegonia**, produce **eggs** and are the site of fertilization
- Male gametangia, called **antheridia**, are the site of **sperm production** and release



Archegonia and antheridia of *Marchantia* (a liverwort)

Apical Meristems

- Plants sustain continual growth in their **apical meristems**
- Cells from the apical meristems differentiate into various tissues

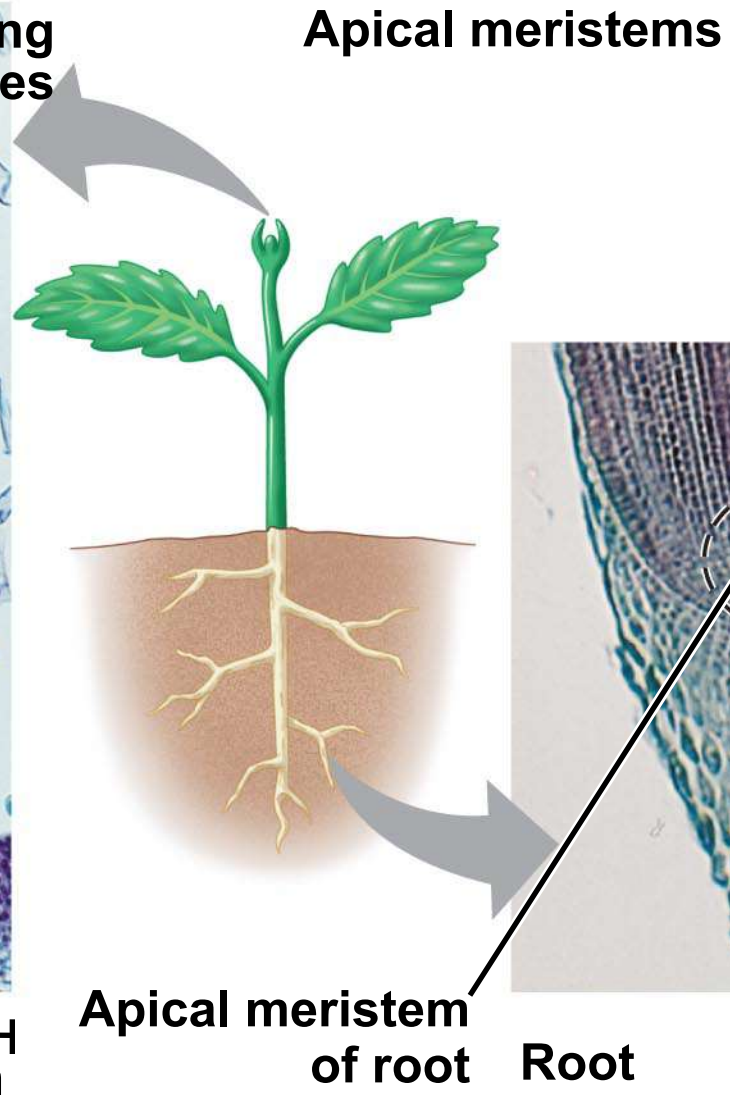


Apical meristem of shoot

Developing leaves

Shoot

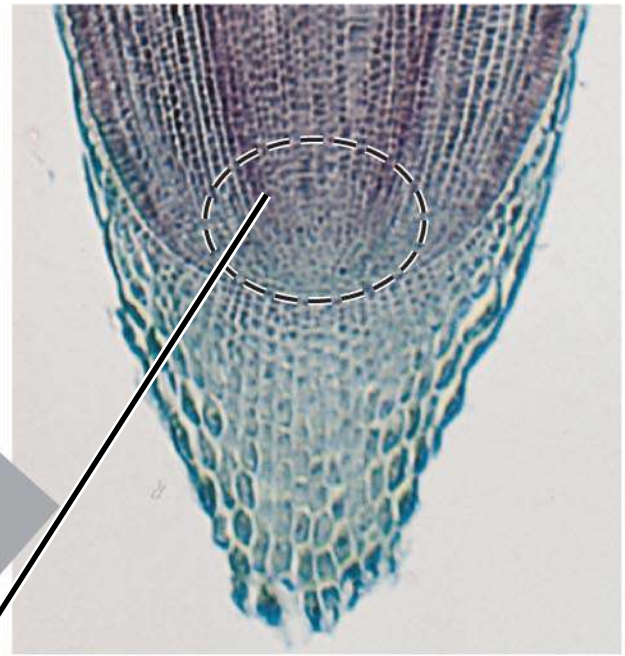
100 μm



Apical meristems

Apical meristem of root

Root



100 μm

The Origin and Diversification of Plants

- Fossil evidence indicates that plants were on land at least 475 million years ago
- Fossilized spores and tissues have been extracted from 475-million-year-old rocks

(a) Fossilized spores



(b) Fossilized sporophyte tissue



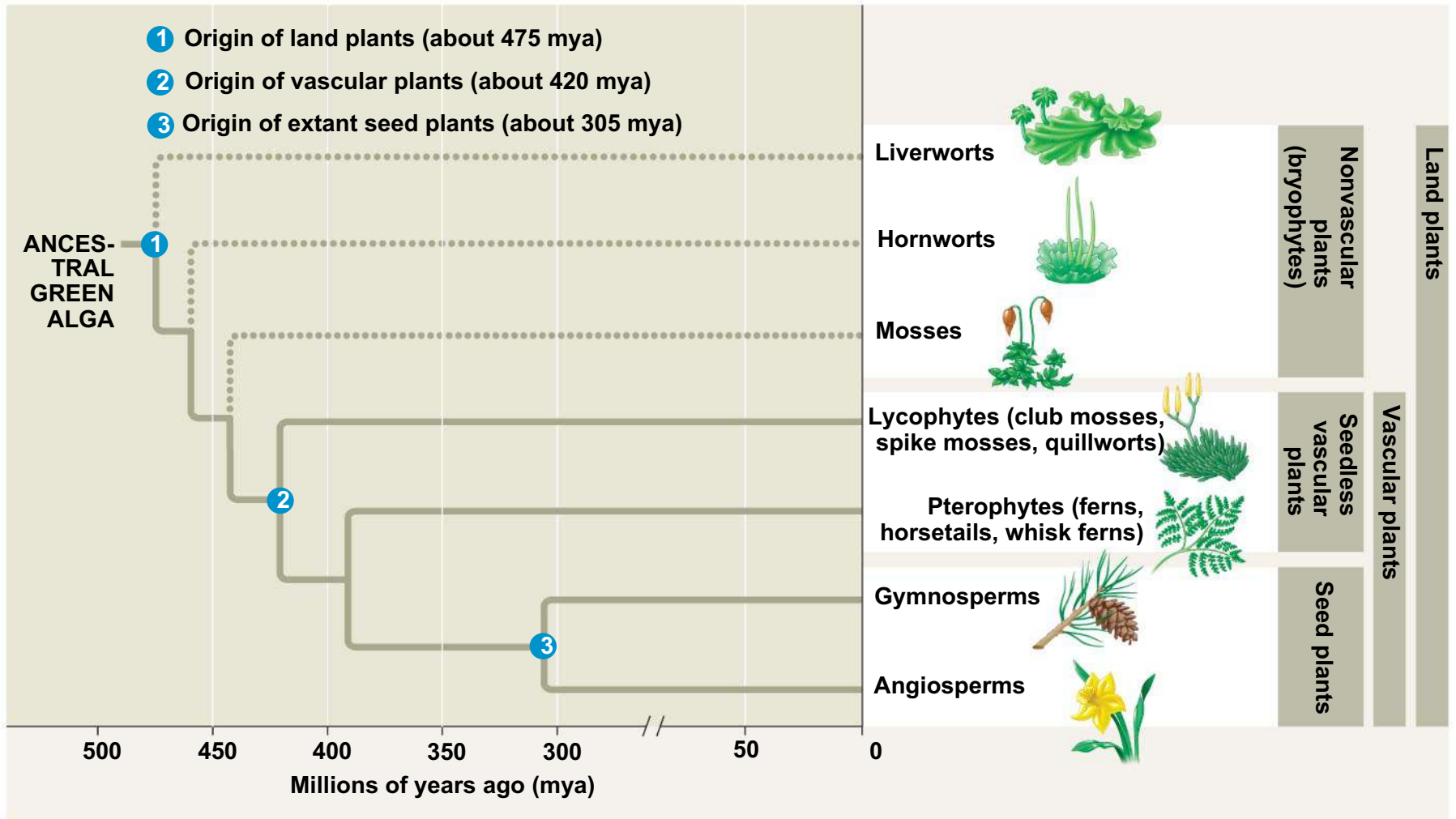
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- Those ancestral species gave rise to a vast diversity of modern plants
 - Land plants can be informally grouped based on the presence or absence of **vascular tissue**
 - Most plants have vascular tissue; these constitute the **vascular plants**
 - **Nonvascular plants** are commonly called **bryophytes**

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- **Seedless vascular plants** can be divided into clades
 - **Lycophytes** (club mosses and their relatives)
 - **Pterophytes** (ferns and their relatives)
 - Seedless vascular plants are paraphyletic, and are of the same level of biological organization, or **grade**

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- A **seed** is an embryo and nutrients surrounded by a protective coat
 - Seed plants form a clade and can be divided into further clades:
 - **Gymnosperms**, the “naked seed” plants, including the conifers
 - **Angiosperms**, the flowering plants

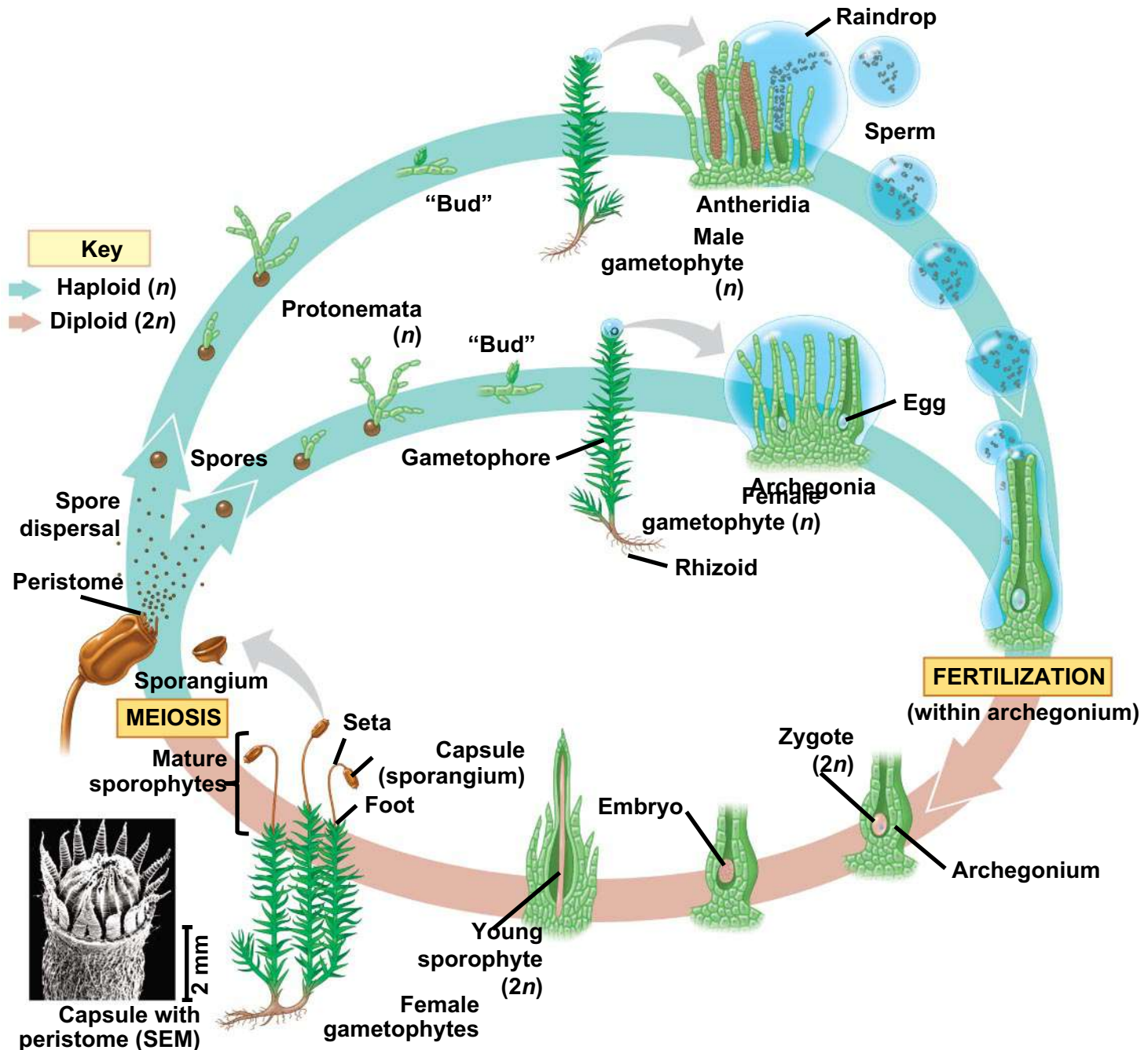
Table 29.1 Ten Phyla of Extant Plants

	Common Name	Estimated Number of Species
Nonvascular Plants (Bryophytes)		
Phylum Hepatophyta	Liverworts	9,000
Phylum Anthoceroophyta	Hornworts	100
Phylum Bryophyta	Mosses	15,000
Vascular Plants		
Seedless Vascular Plants		
Phylum Lycophyta	Lycophytes	1,200
Phylum Pterophyta	Pterophytes	12,000
Seed Plants		
<i>Gymnosperms</i>		
Phylum Ginkgophyta	Ginkgo	1
Phylum Cycadophyta	Cycads	130
Phylum Gnetophyta	Gnetophytes	75
Phylum Coniferophyta	Conifers	600
<i>Angiosperms</i>		
Phylum Anthophyta	Flowering plants	250,000



Concept 29.2: Mosses and other nonvascular plants have life cycles dominated by gametophytes

- Bryophytes are represented today by three phyla of small herbaceous (nonwoody) plants:
 - **Liverworts**, phylum Hepatophyta
 - **Hornworts**, phylum Anthocerotophyta
 - **Mosses**, phylum Bryophyta
- Mosses are most closely related to vascular plants



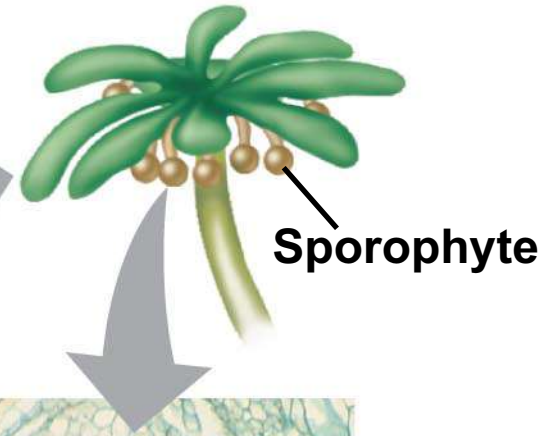
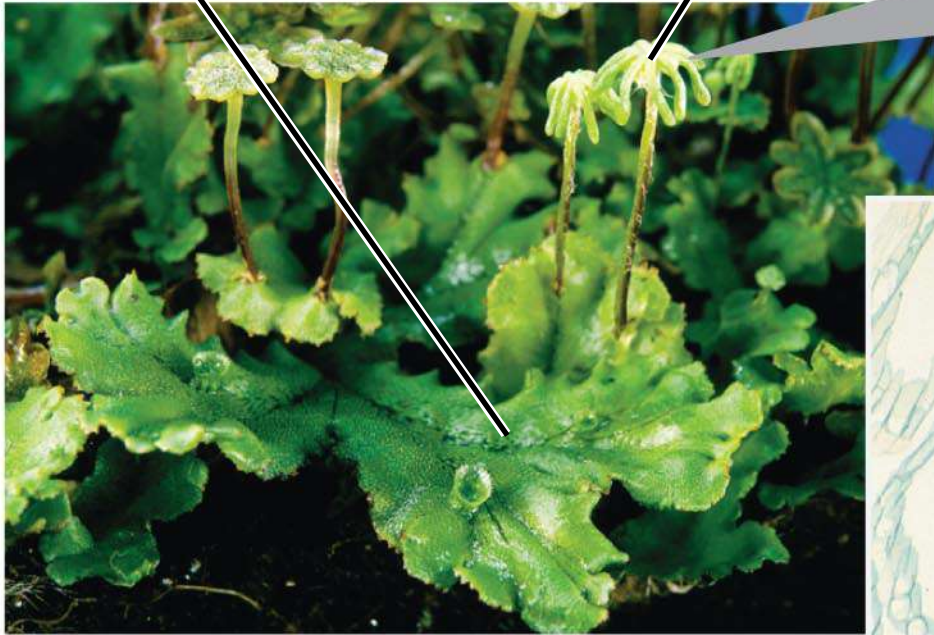
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- **A spore germinates into a gametophyte** composed of a **protonema** and gamete-producing **gametophore**
 - **Rhizoids anchor gametophytes** to substrate
 - The height of gametophytes is constrained by lack of vascular tissues
 - **Mature gametophytes produce flagellated sperm** in antheridia and an egg in each archegonium
 - Sperm swim through a film of water to reach and fertilize the egg

Bryophyte Sporophytes

- Bryophyte sporophytes grow out of archegonia, and are the smallest and simplest sporophytes of all extant plant groups
- A sporophyte consists of **a foot, a seta (stalk), and a sporangium, also called a capsule,** which **discharges spores through a peristome**
- Hornwort and moss sporophytes have **stomata for gas exchange**

Thallus

Gametophore of female gametophyte



Foot

Seta

Capsule (sporangium)



500 μm

Marchantia polymorpha,
a "thalloid" liverwort

Marchantia sporophyte (LM)

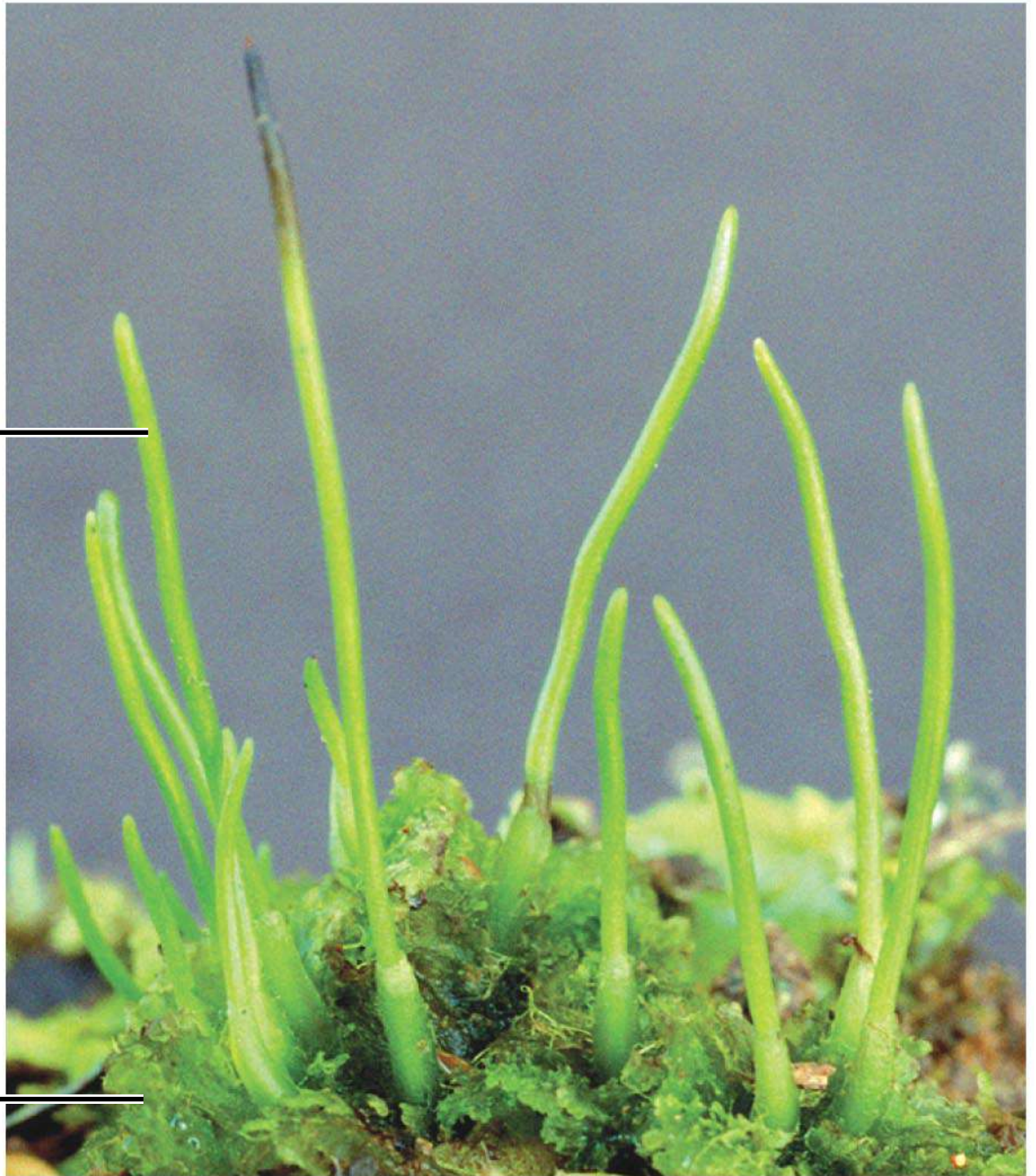


***Plagiochila
deltoidea*,**
a “leafy”
liverwort

An *Anthoceros* hornwort species

Sporophyte —————

Gametophyte —————





***Polytrichum commune*,
hairy-cap moss**

Capsule

Seta

**Sporophyte
(a sturdy
plant that
takes months
to grow)**

Gametophyte

The Ecological and Economic Importance of Mosses

- Mosses are capable of inhabiting diverse and sometimes extreme environments, but are especially common in moist forests and wetlands
- Some mosses might help retain nitrogen in the soil

RESULTS



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- *Sphagnum*, or “peat moss,” forms extensive deposits of partially decayed organic material known as **peat**
 - *Sphagnum* is an important global reservoir of organic carbon



(a) Peat being harvested



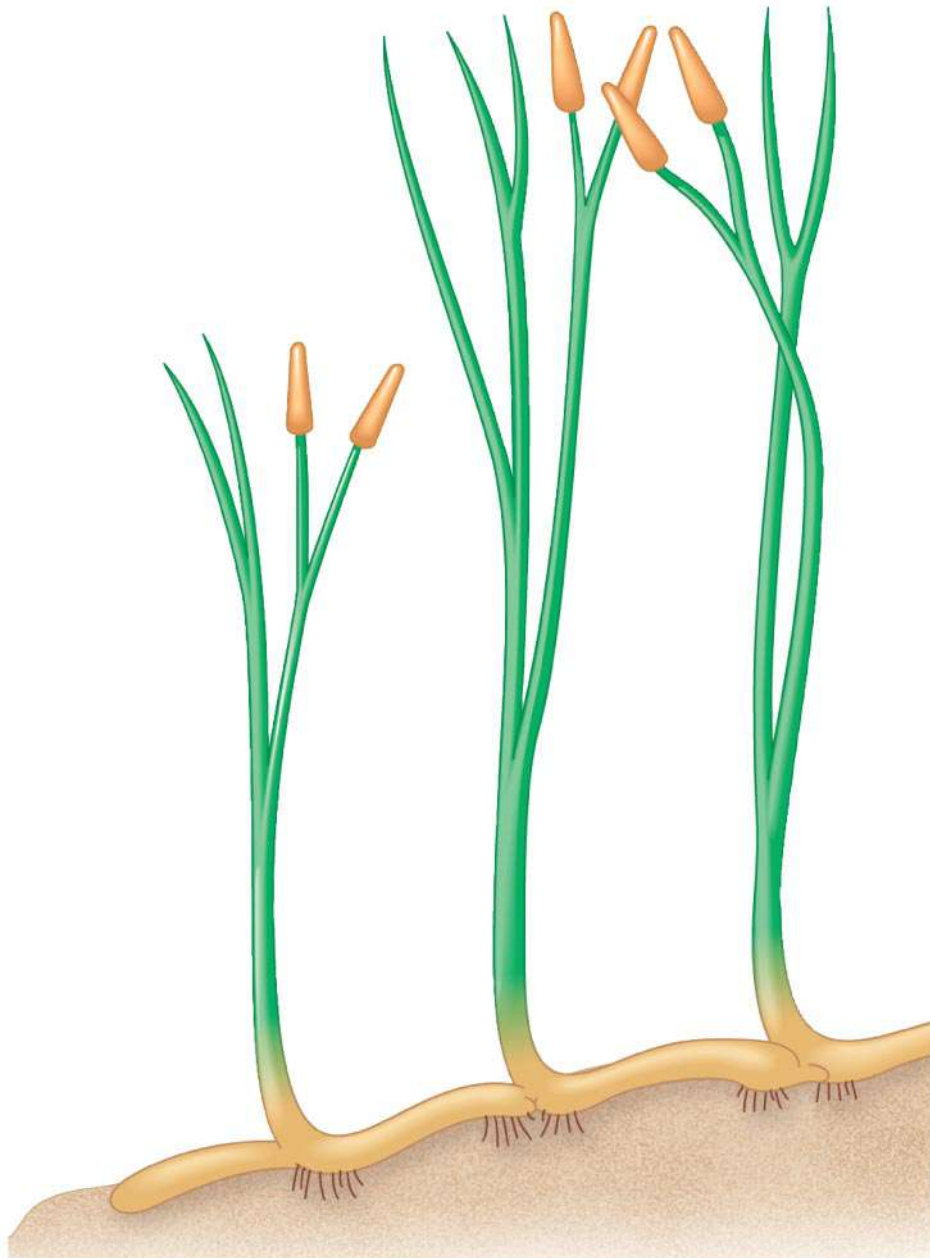
(b) "Tollund Man," a bog mummy

Concept 29.3: Ferns and other seedless vascular plants were the first plants to grow tall

- **Bryophytes and bryophyte-like plants** were the prevalent vegetation during the first 100 million years of plant evolution
- Vascular plants began to diversify during the Devonian and Carboniferous periods
- **Vascular tissue allowed these plants to grow tall**
- **Seedless vascular plants have flagellated sperm and are usually restricted to moist environments**

Origins and Traits of Vascular Plants

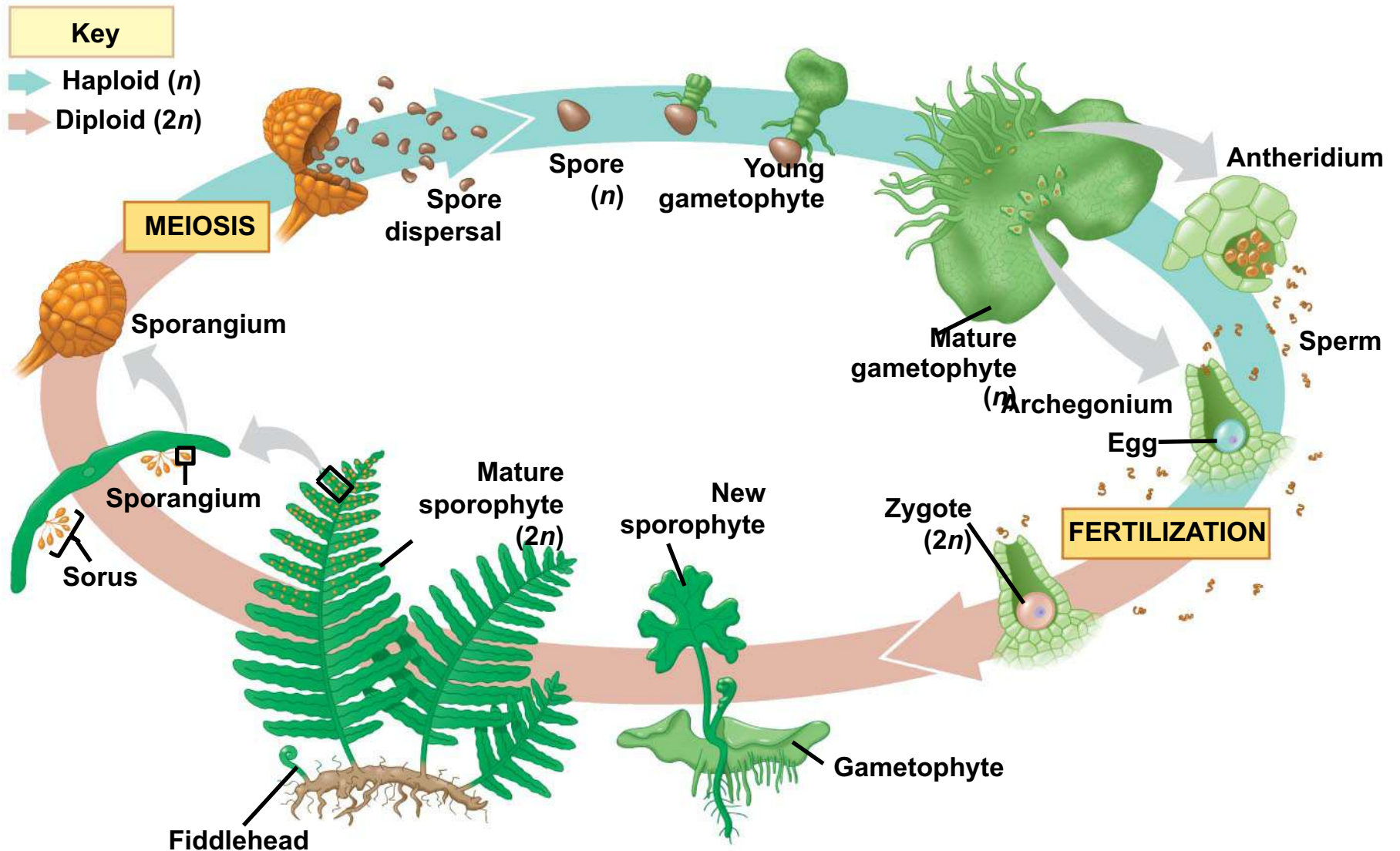
- Fossils of the forerunners of vascular plants date back about 420 million years
- These early tiny plants had independent, branching sporophytes
- Living vascular plants are characterized by:
 - Life cycles with dominant sporophytes
 - Vascular tissues called xylem and phloem
 - Well-developed roots and leaves



Sporophytes of *Aglaophyton major*

Life Cycles with Dominant Sporophytes

- In contrast with bryophytes, sporophytes of seedless vascular plants are the larger generation, as in the familiar leafy fern
- The gametophytes are tiny plants that grow on or below the soil surface



Transport in Xylem and Phloem

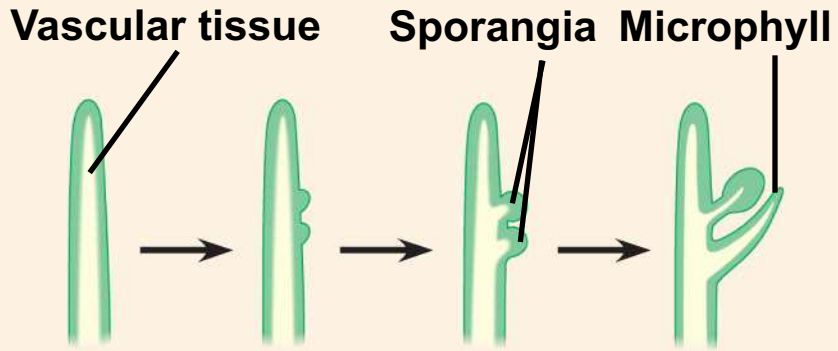
- Vascular plants have two types of vascular tissue: xylem and phloem
- **Xylem** conducts most of the water and minerals and includes dead cells called **tracheids**
- **Phloem** consists of living cells and distributes sugars, amino acids, and other organic products
- Water-conducting cells are strengthened by **lignin** and provide structural support
- Increased height was an evolutionary advantage

Evolution of Roots

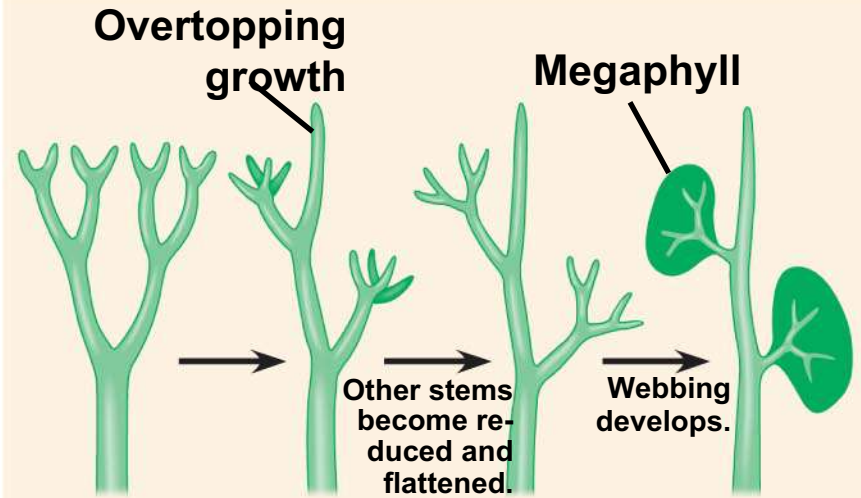
- **Roots** are organs that anchor vascular plants
- They enable vascular plants to absorb water and nutrients from the soil
- Roots may have evolved from subterranean stems

Evolution of Leaves

- **Leaves** are organs that increase the surface area of vascular plants, thereby capturing more solar energy that is used for photosynthesis
- Leaves are categorized by two types:
 - **Microphylls**, leaves with a single vein
 - **Megaphylls**, leaves with a highly branched vascular system
- According to one model of evolution, microphylls evolved first, as outgrowths of stems



(a) Microphylls



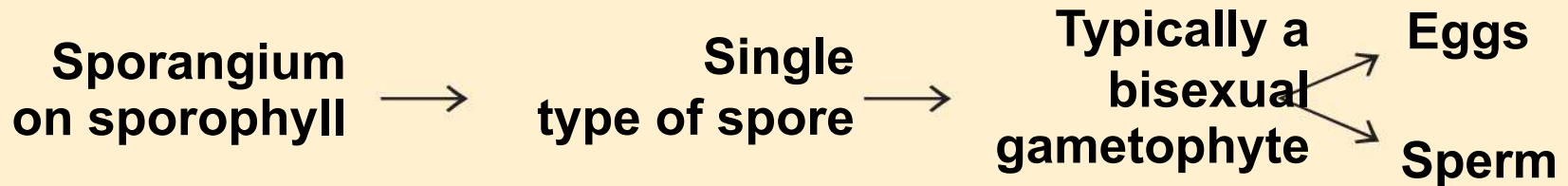
(b) Megaphylls

Sporophylls and Spore Variations

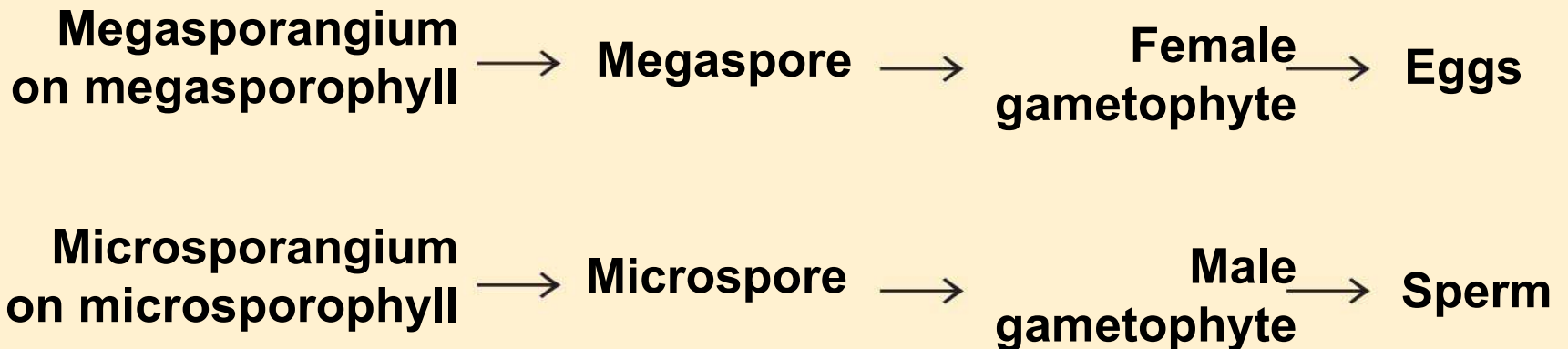
- **Sporophylls** are modified leaves with sporangia
- **Sori** are clusters of sporangia on the undersides of sporophylls
- **Strobili** are cone-like structures formed from groups of sporophylls

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- Most **seedless vascular plants** are **homosporous**, producing one type of spore that develops into a bisexual gametophyte
 - **All seed plants** and some seedless vascular plants are **heterosporous**
 - Heterosporous species produce **megaspores** that give rise to female gametophytes, and **microspores** that give rise to male gametophytes

Homosporous spore production



Heterosporous spore production



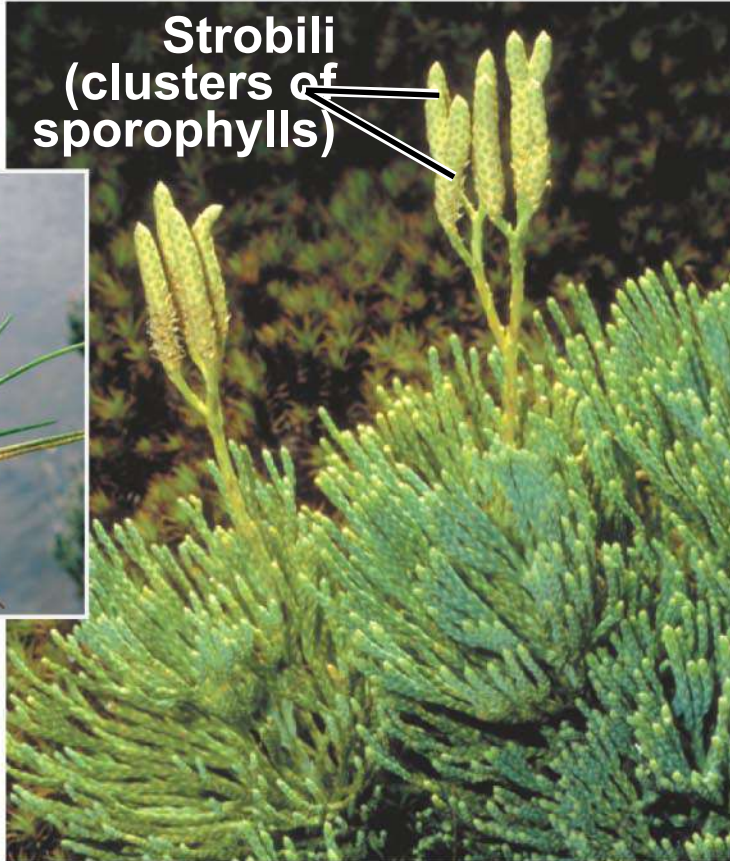
Classification of Seedless Vascular Plants

- There are two phyla of seedless vascular plants:
 - Phylum **Lycophyta** includes club mosses, spike mosses, and quillworts
 - Phylum **Pterophyta** includes ferns, horsetails, and whisk ferns and their relatives

Lycophytes (Phylum Lycophyta)

2.5 cm
|-----|

Isoetes gunnii,
a quillwort



Strobili
(clusters of
sporophylls)

Diphasiastrum tristachyum, a club moss

Selaginella apoda,
a spike moss



1 cm
|-----|

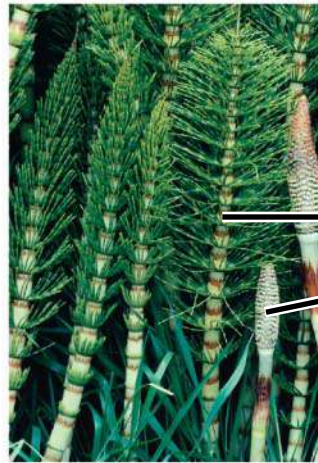


Pterophytes (Phylum Pterophyta)



*Athyrium
filix-femina*,
lady fern

25 cm



*Equisetum
arvense*,
field
horsetail

Vegetative stem

Strobilus on
fertile stem

1.5 cm



*Psilotum
nudum*,
a whisk
fern

2.5 cm

Phylum Lycophyta: Club Mosses, Spike Mosses, and Quillworts

- Giant lycophytes thrived for millions of years in moist swamps
- Surviving species are small herbaceous plants
- Club mosses and spike mosses have vascular tissues and are not true mosses

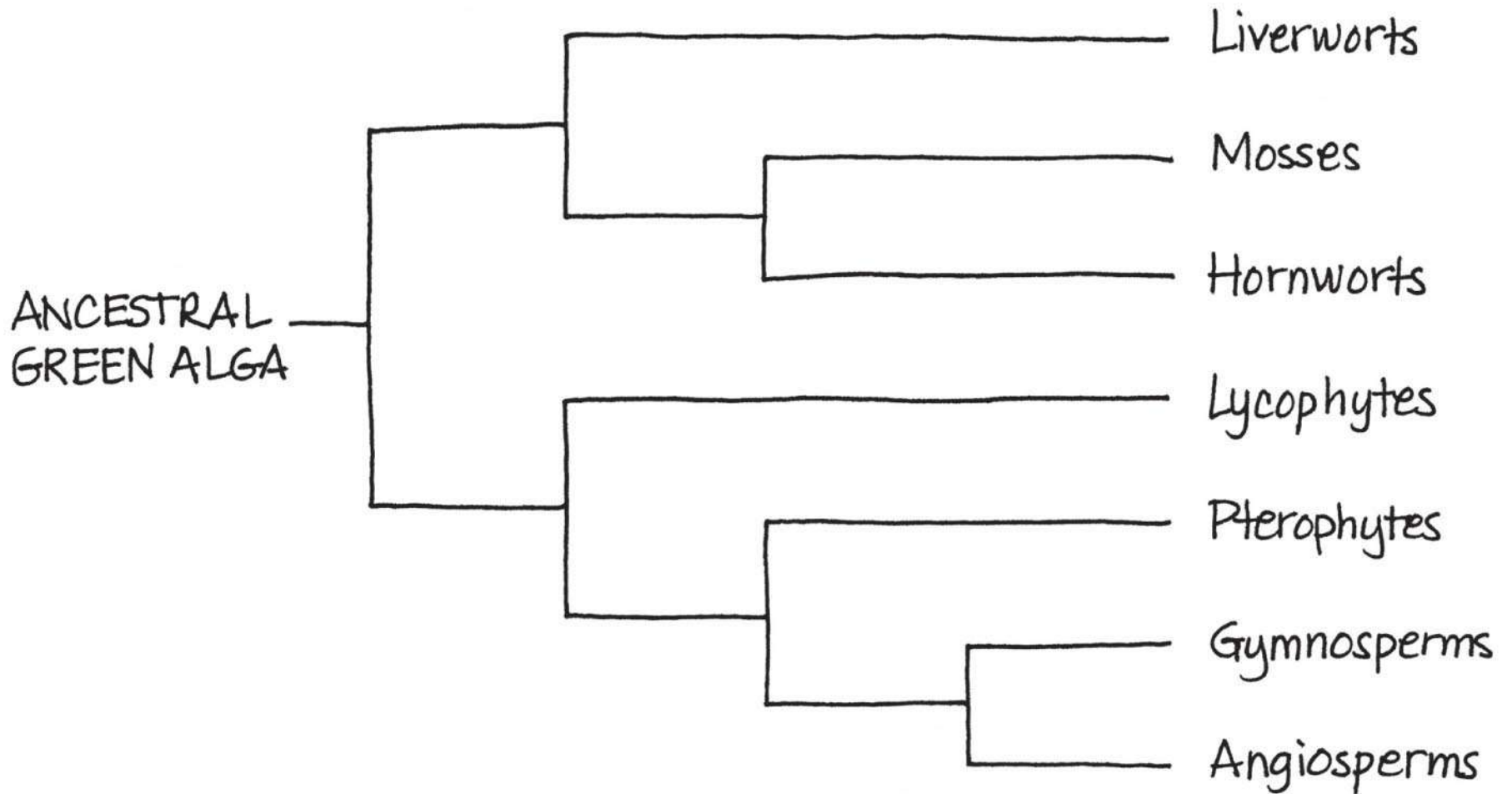
Phylum Pterophyta: Ferns, Horsetails, and Whisk Ferns and Relatives

- **Ferns** are the most diverse **seedless vascular plants**, with more than 12,000 species
- They are most diverse in the tropics but also thrive in temperate forests
- Horsetails were diverse during the Carboniferous period, but are now restricted to the genus *Equisetum*
- Whisk ferns resemble ancestral vascular plants but are closely related to modern ferns

The Significance of Seedless Vascular Plants

- The ancestors of modern lycophytes, horsetails, and ferns grew to great heights during the Devonian and Carboniferous, forming the first forests
- Increased photosynthesis may have helped produce the global cooling at the end of the Carboniferous period
- The decaying plants of these Carboniferous forests eventually became coal





You should now be able to:

1. Describe four shared characteristics and four distinct characteristics between charophytes and land plants
2. Distinguish between the phylum Bryophyta and bryophytes
3. Diagram and label the life cycle of a bryophyte
4. Explain why most bryophytes grow close to the ground and are restricted to periodically moist environments

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5. Describe three traits that characterize modern vascular plants and explain how these traits have contributed to success on land
 6. Explain how vascular plants differ from bryophytes
 7. Distinguish between the following pairs of terms: microphyll and megaphyll; homosporous and heterosporous
 8. Diagram and label the life cycle of a seedless vascular plant