Chapter 29: How plants colonized the land - 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
- Green algae called **charophyceans** are the closest relatives of land plants

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Morphological, Biochemical and Genetic Evidence that land plants are descendents of charophyceans

- Many characteristics of land plants also appear in a variety of algal clades, mainly algae
- However, land plants share four key traits only with charophyceans:
  - Rose-shaped complexes for cellulose synthesis
  - Peroxisome enzymes
  - Structure of flagellated sperm
  - Formation of a phragmoplast
- Comparisons of both nuclear and chloroplast genes point to charophyceans as the closest living relatives of land plants

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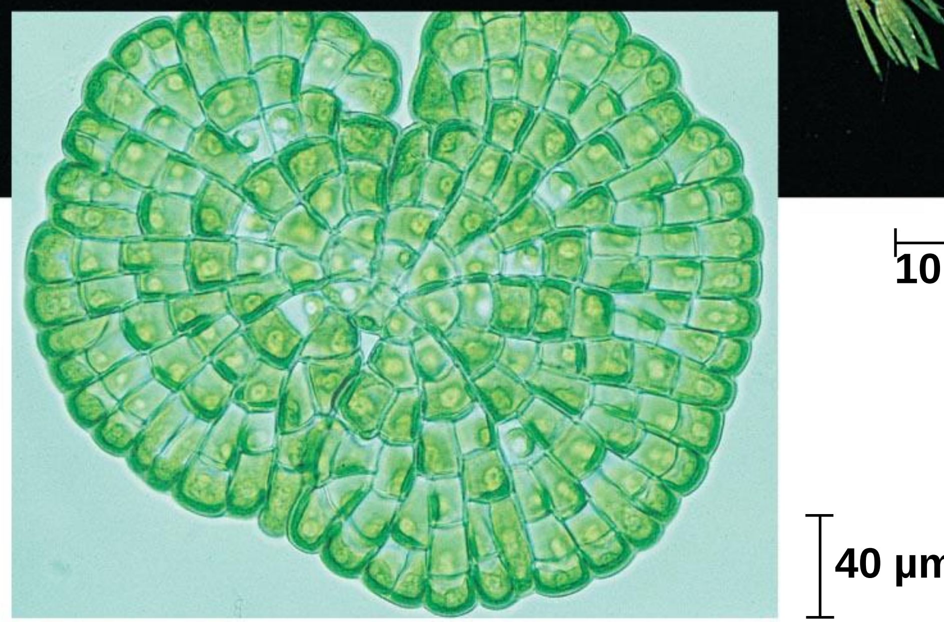
Land plants are descendents of charophyceans

(a) *Chara*, a pond organism (LM).



(b) *Coleochaete orbicularis*, a disk-shaped charophycean (LM).

Adaptations Enabling the Move of plants to Land

- In charophyceans a layer of a durable polymer called **sporopollenin** prevents exposed zygotes from drying out
- The accumulation of traits that facilitated survival on land may have opened the way to its colonization by plants
- Land plants possess a set of derived terrestrial adaptations: Many adaptations emerged after land plants diverged from their charophycean relatives

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Defining the Plant Kingdom

- Systematists are people who are currently debating the boundaries of the plant kingdom
- Some biologists think the plant kingdom should be expanded to include some or all green algae
- Until this debate is resolved, we will retain the embryophyte (enclosed embryo) definition of kingdom Plantae

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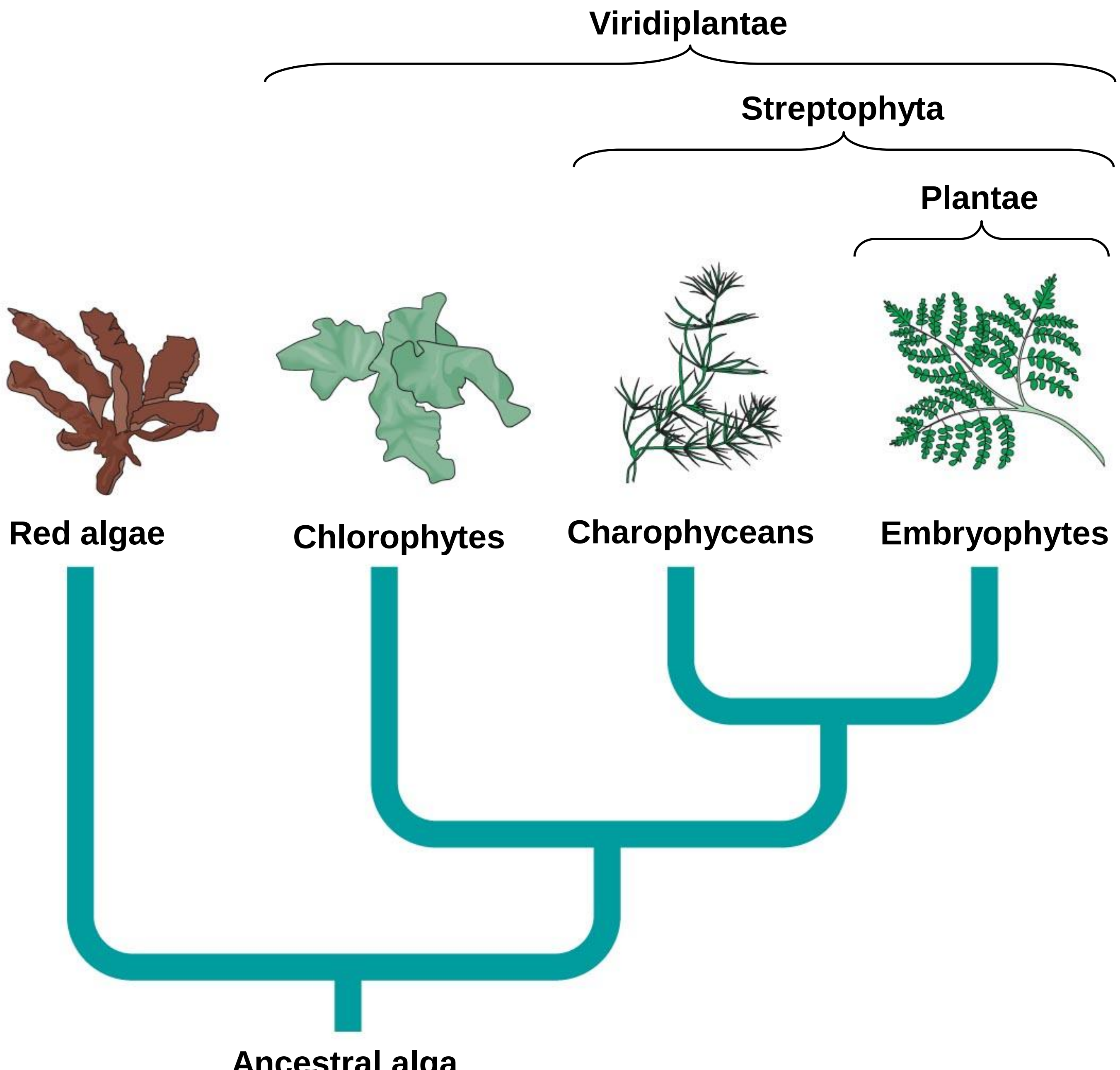
Defining the Plant Kingdom



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Derived Traits of Plants

- Five key traits appear in nearly all land plants but are absent in the charophyceans:
  – Apical meristems – regions of growth in the roots and stems
  – Alternation of generations – between haploid gametophytes and diploid sporophytes
  – Walled spores produced in sporangia (spore formation to make sporophyte)
  – Multicellular gametangia (haploid cells, like sexual gametes, that make up gametophyte)
  – Multicellular dependent embryos

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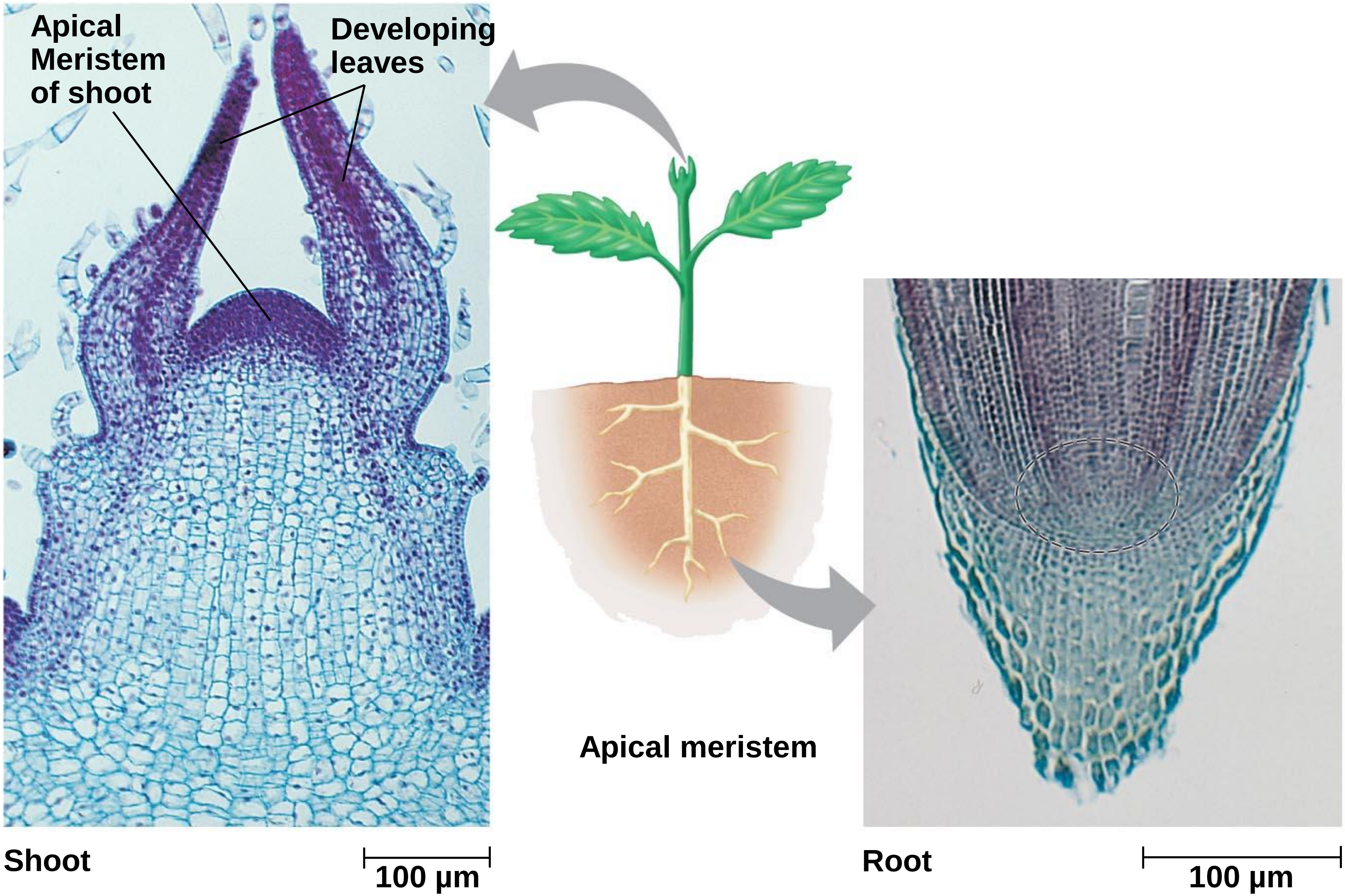
Apical Meristems – regions of cell division/growth at the roots and stems



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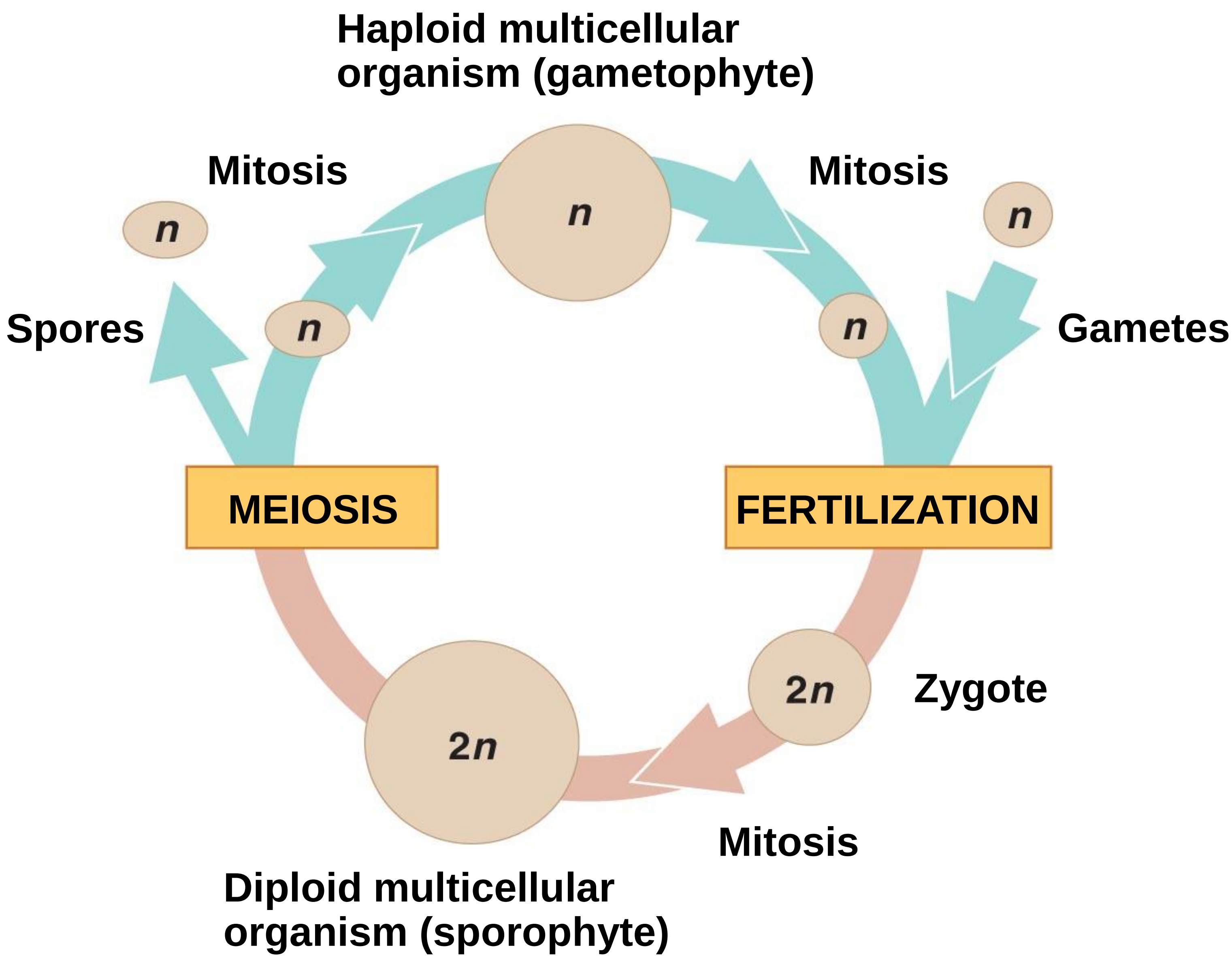
Alternation of Generations



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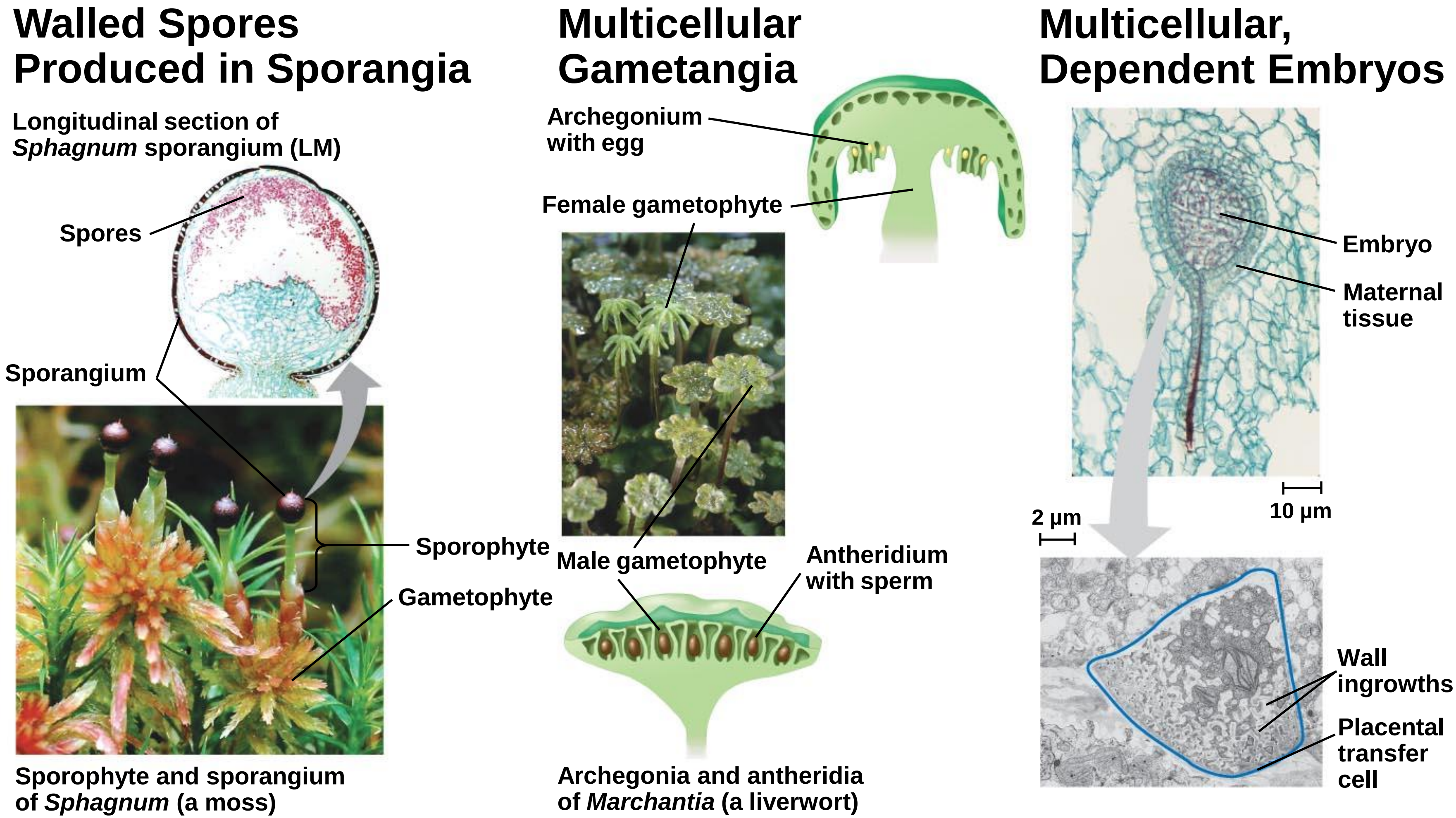

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- Additional derived traits such as a cuticle and secondary compounds evolved in many plant species

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
- Those ancestral species gave rise to a vast diversity of modern plants

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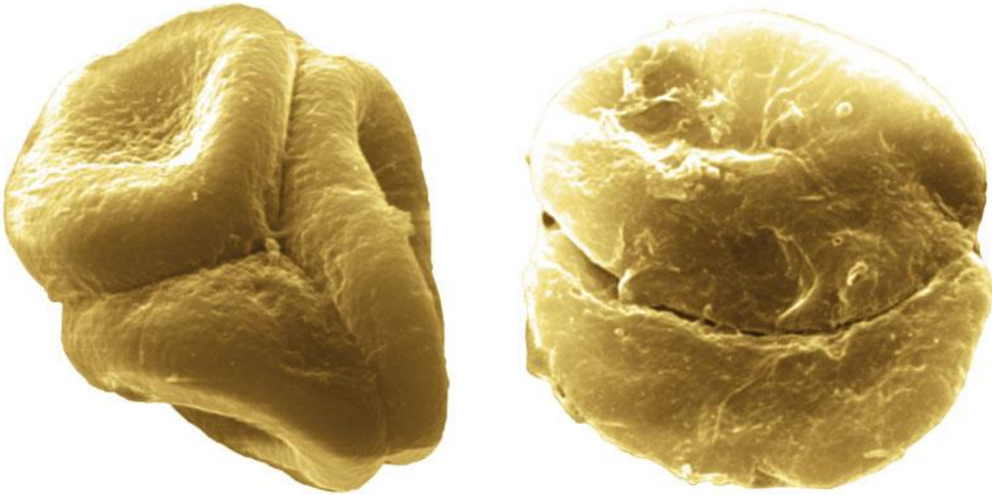
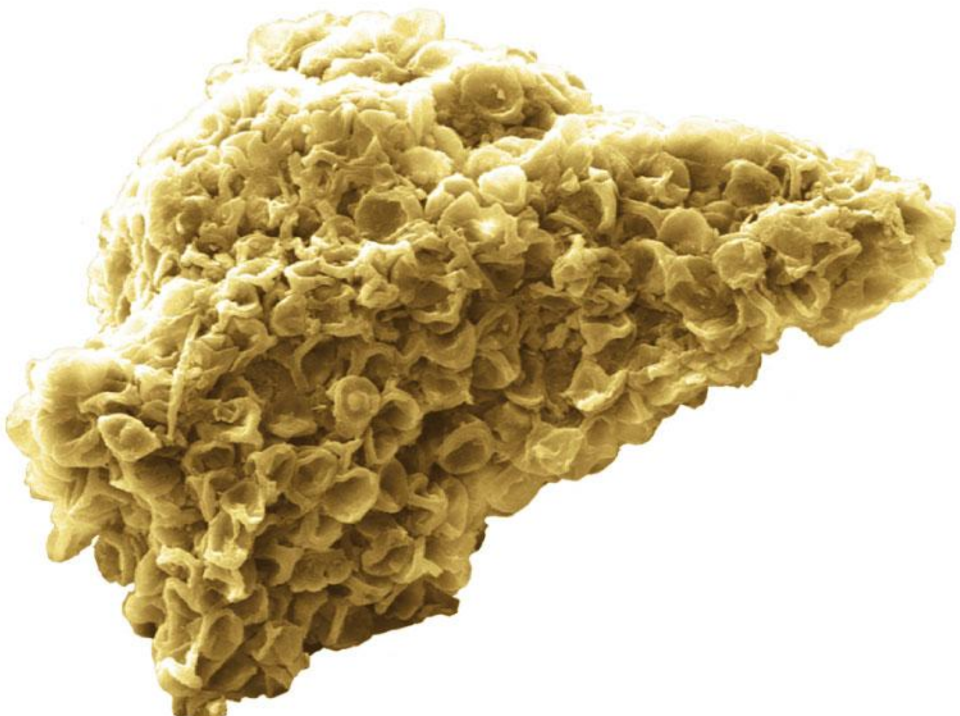
The Origin and Diversification of Plants



(a) Fossilized spores. Unlike the spores of most living plants, which are single grains, these spores found in Oman are in groups of four (left; one hidden) and two (right).



(b) Fossilized sporophyte tissue. The spores were embedded in tissue that appears to be from plants.

Land plants can be informally grouped based on the presence or absence of vascular tissue

Table 29.1 Ten Phyla of Extant Plants

	Common Name	Approximate Number of Extant Species
Bryophytes (nonvascular plants)		
Phylum Hepatophyta	Liverworts	9,000
Phylum Anthocerophyta	Hornworts	100
Phylum Bryophyta	Mosses	15,000
Vascular Plants		
Seedless Vascular Plants		
Phylum Lycophyta	Lycophytes (club mosses, spike mosses, and quillworts)	1,200
Phylum Pterophyta	Pterophytes (ferns, horsetails, and whisk ferns)	12,000
Seed Plants		
Gymnosperms		
Phylum Ginkgophyta	Ginkgo	1
Phylum Cycadophyta	Cycads	130
Phylum Gnetophyta	Gnetophytes (*Gnetum*, *Ephedra*, and *Welwitschia*)	75
Phylum Coniferophyta	Conifers	600
Angiosperms		
Phylum Anthophyta	Flowering plants	250,000

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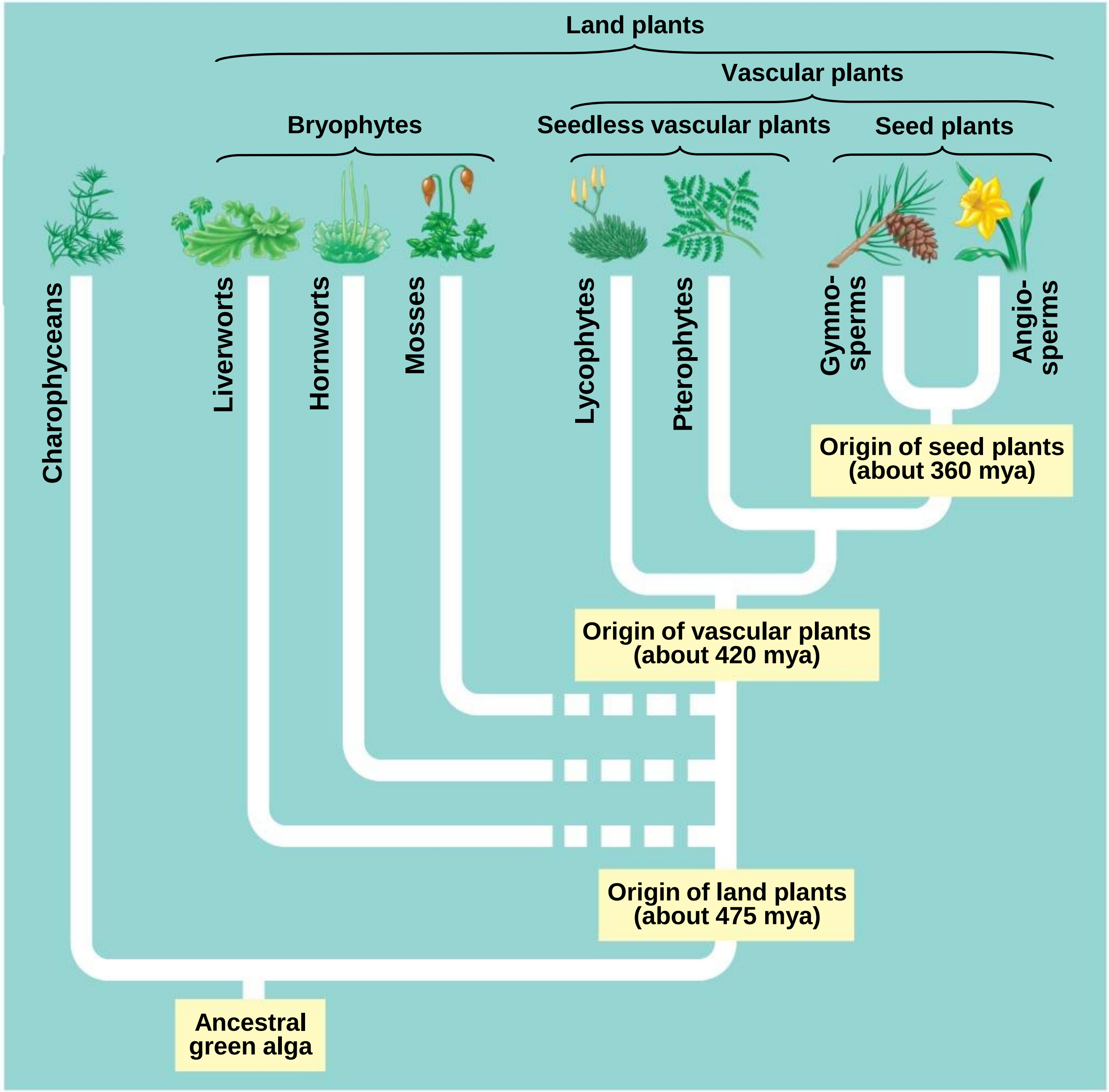
The origin of plants



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The life cycles of mosses and other bryophytes are dominated by the gametophyte stage

- **Bryophytes** are represented today by three phyla of small herbaceous (nonwoody) plants:
  - Liverworts, phylum Hepatophyta
  - Hornworts, phylum Anthocerophyta
  - Mosses, phylum Bryophyta
- Debate continues over the sequence of bryophyte evolution
- Mosses are most closely related to vascular plants
- In all three bryophyte phyla, gametophytes are larger and longer-living than sporophytes
- Sporophytes are typically present only part of the time

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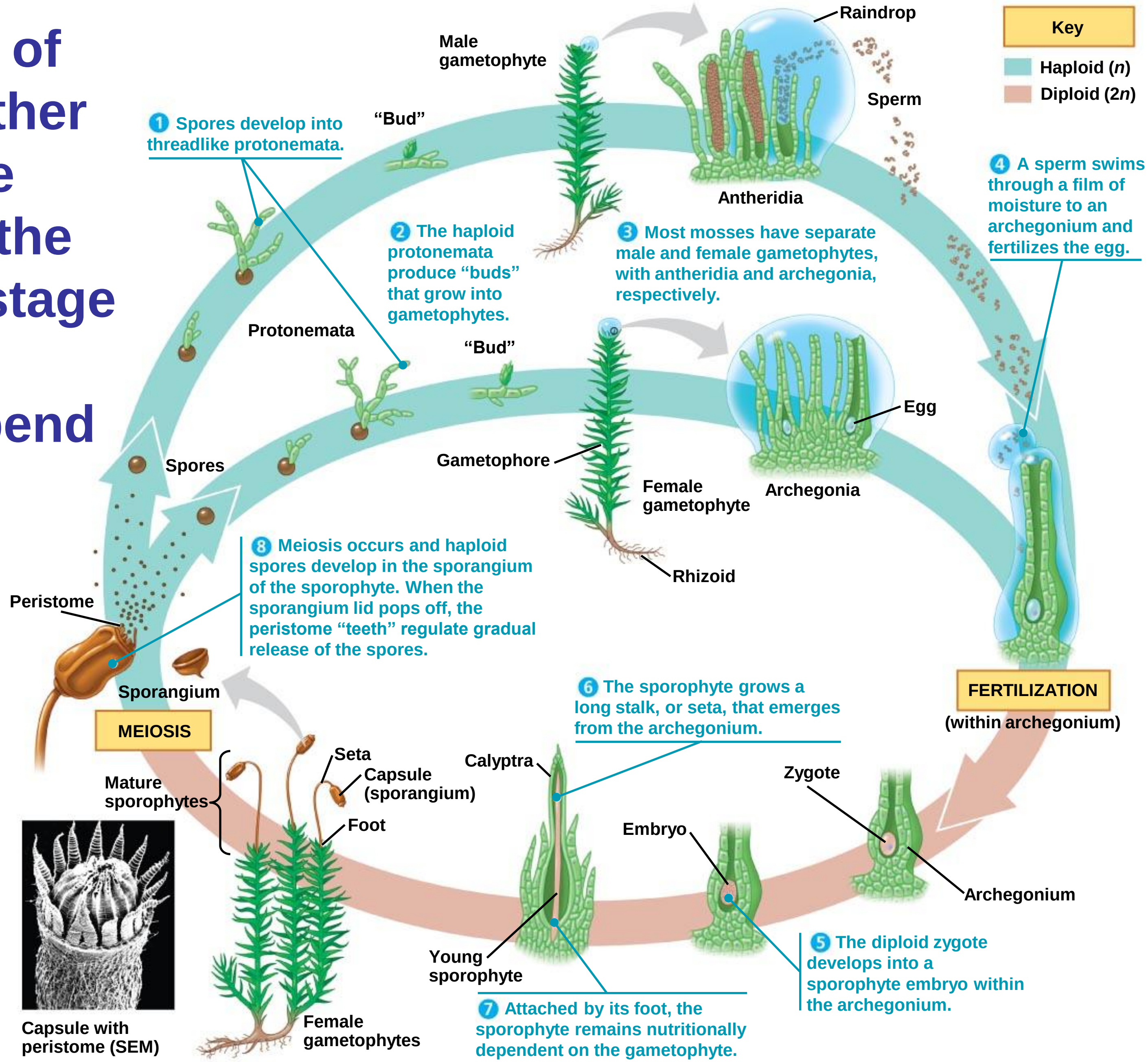
The life cycles of mosses and other bryophytes are dominated by the gametophyte stage

Bryophytes spend most of their life cycles in the haploid stage



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Bryophyte gametophytes vs. sporophytes

- Bryophyte gametophytes
  - Produce flagellated sperm in antheridia
  - Produce ova in archegonia
  - Generally form ground-hugging carpets and are at most only a few cells thick
- Some mosses have conducting tissues in the center of their “stems” and may grow vertically
- Bryophyte sporophytes
  - Grow out of archegonia
  - Are the smallest and simplest of all extant plant groups
  - Consist of a foot, a seta, and a sporangium
- Hornwort and moss sporophytes have stomata

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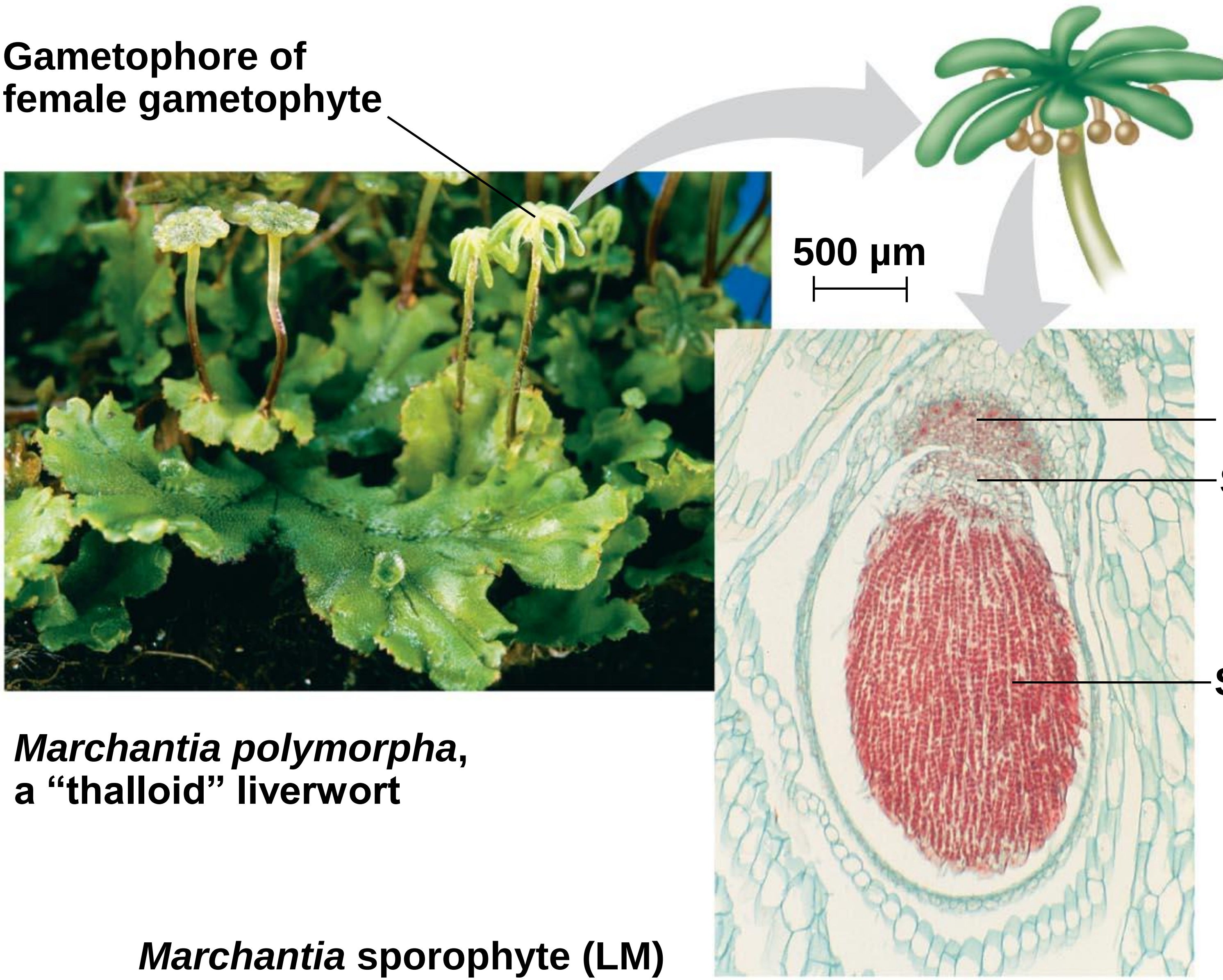
Bryophyte gametophytes vs. sporophytes



***Marchantia polymorpha*, a “thalloid” liverwort**

***Marchantia* sporophyte (LM)**

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Bryophytes: Liverworts and Hornworts

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***Plagiochila deltoidea,* a "leafy" liverwort**

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An *Anthroceros* hornwort species

Bryophytes: Mosses

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

Sporophyte

Gametophyte

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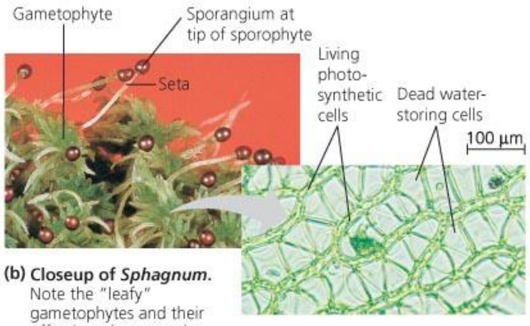
Ecological and Economic Importance of Mosses

- Sphagnum, or “peat moss,” forms extensive deposits of partially decayed organic material known as peat
- Sphagnum plays an important role in the Earth’s carbon cycle

(a) Peat being harvested from a peat bog



(b) Closeup of *Sphagnum*. Note the “leafy” gametophytes and their offspring, the sporophytes.

(c) *Sphagnum* "leaf" (LM). The combination of living photosynthetic cells and dead water-storing cells gives the moss its spongy quality.

(d) “Tolland Man,” a bog mummy dating from 405–100 B.C. The acidic, oxygen-poor conditions produced by *Sphagnum* can preserve human or other animal bodies for thousands of years.

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Ferns and other seedless vascular plants formed the first forests

- 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 Carboniferous period
- Vascular plants dominate most landscapes today
- Fossils of the forerunners of vascular plants date back about 420 million years
- These early tiny plants had independent, branching sporophytes
- They lacked other derived traits of vascular plants

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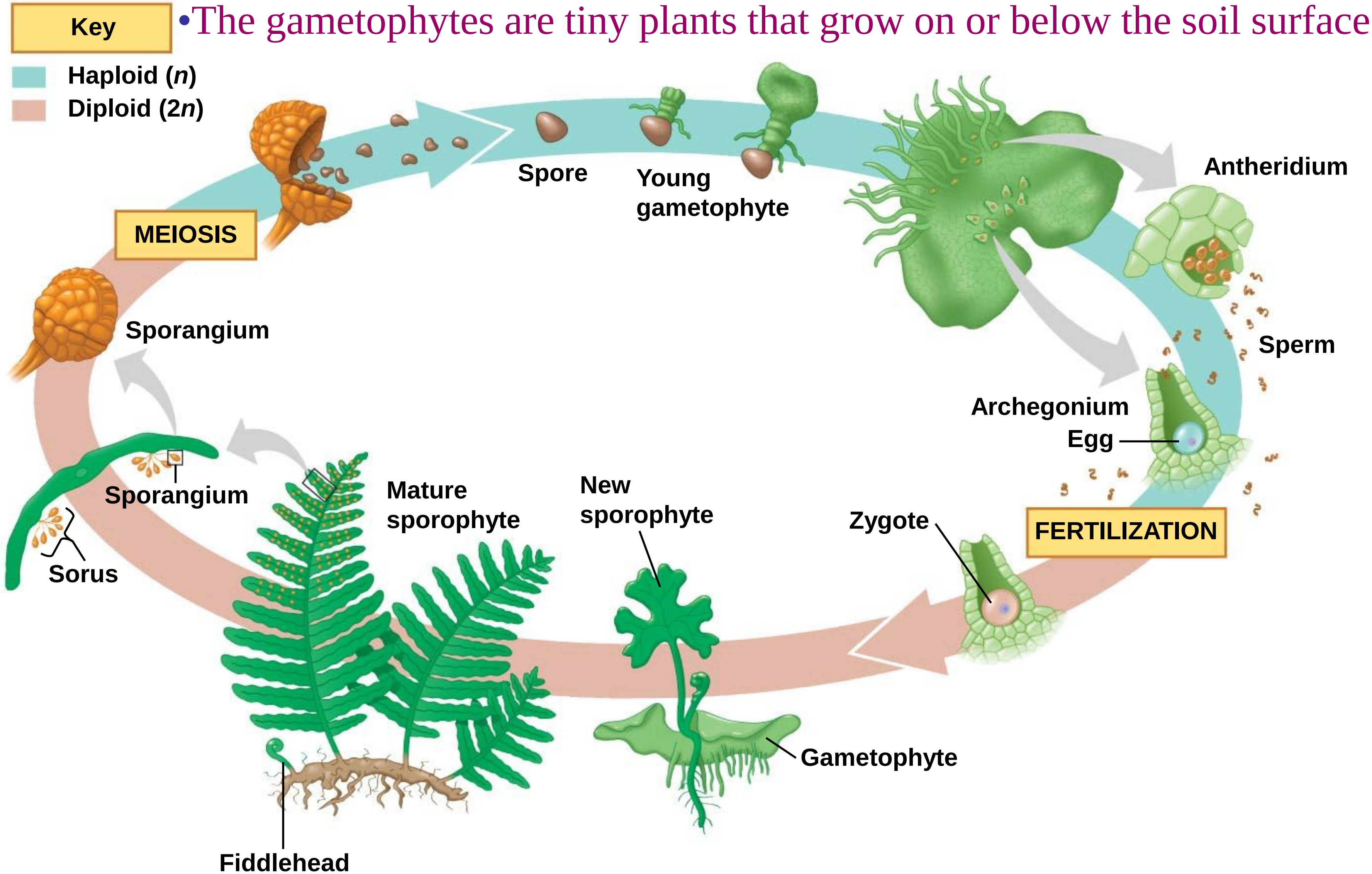
Life Cycles with Dominant Sporophytes

- 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



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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 food such as sugars, amino acids, and other organic products

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Evolution of Roots and Leaves

- **Roots** are organs that anchor vascular plants
- **Root hairs** increase the surface area of roots to help absorb water
- They enable vascular plants to absorb water and nutrients from the soil
- Roots may have evolved from subterranean stems
- **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

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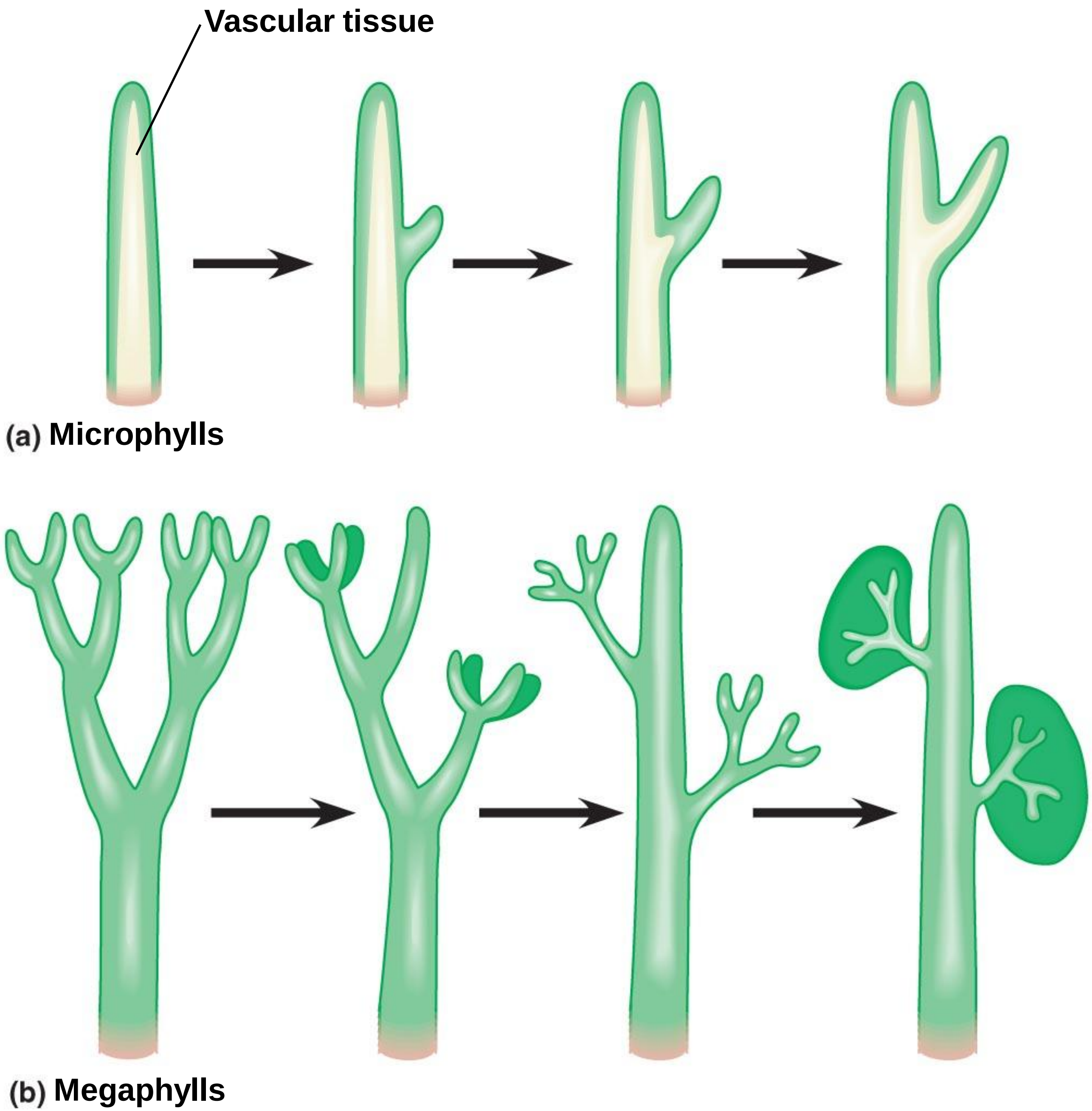
Microphylls vs. Megaphylls



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Sporophylls and Spore Variations

- **Sporophylls** are modified leaves with sporangia
- 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**, having two types of spores that give rise to male and female gametophytes

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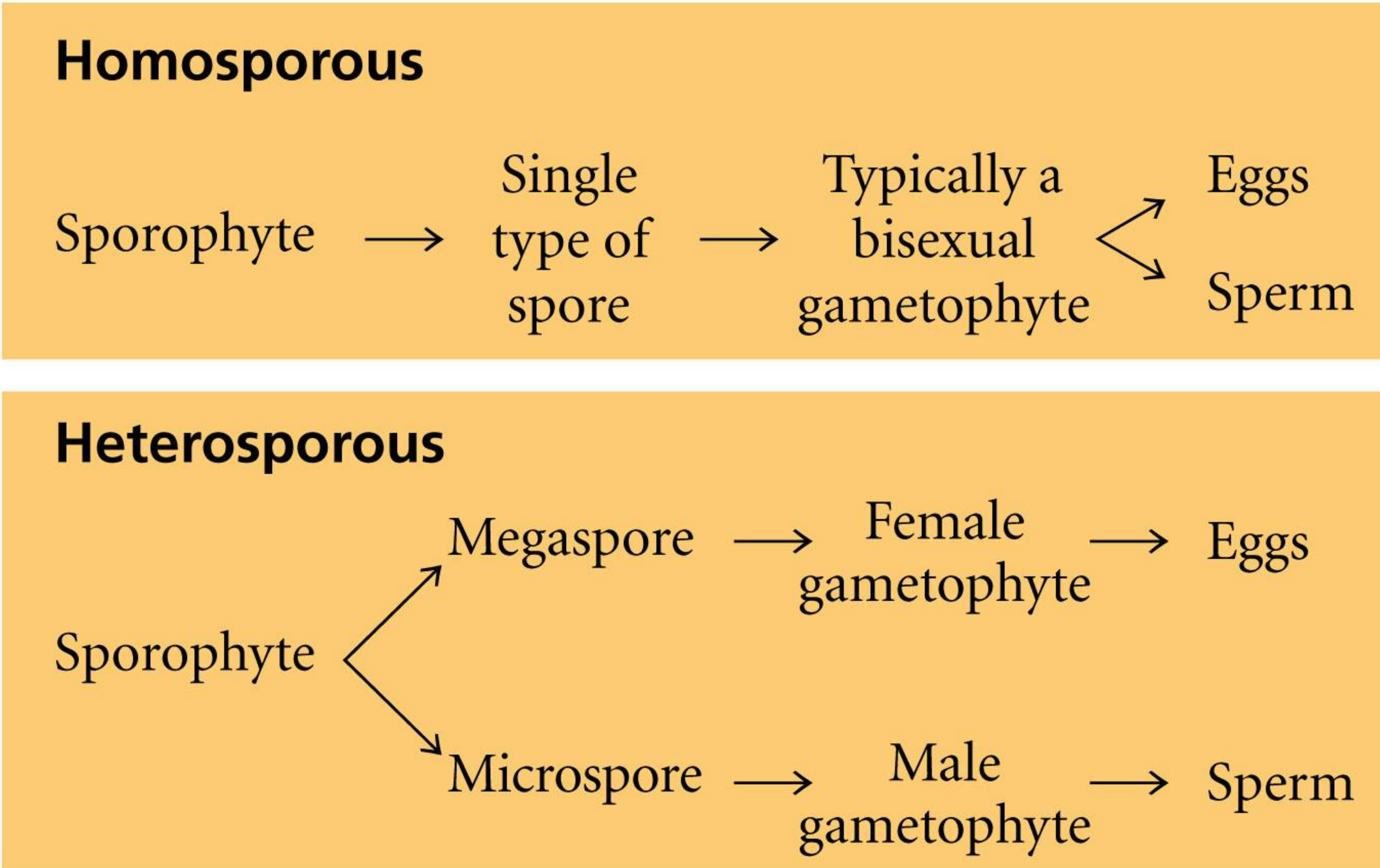
Homosporous vs. Heterosporous reproductive life cycles



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Classification of Seedless Vascular Plants

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

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Lycophyta

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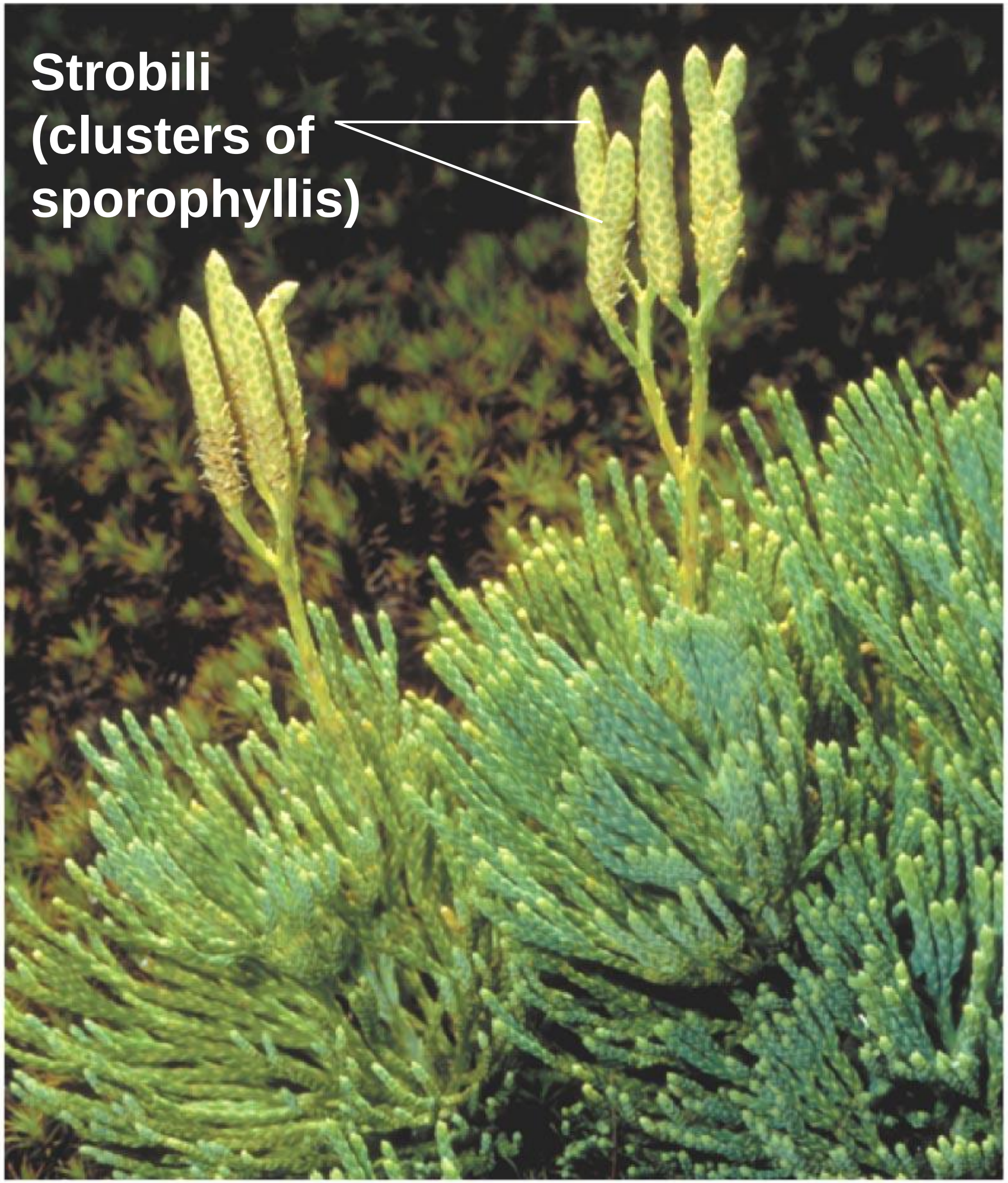
Lycophyta: *Selaginella apoda*, a spike moss

Lycophyta: *Isoetes gunnii*, a quillwort

Lycophyta



***Diphasiastrum tristachyum*, a club moss**

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Pterophyta

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***Psilotum nudum*, a whisk fern**

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***Equisetum arvense*, field horsetail**

Pterophyta

***Athyrium filix-femina*, lady fern**

Phylum Lycophyta and Phylum Pterophyta

- Giant lycophytes thrived for millions of years in moist swamps
  - Surviving species are small herbaceous plants
- Pterophyta: 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
  - Some species are even adapted to arid climates

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The Significance of Seedless Vascular Plants

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

C

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