Kingdom Plantae, Part I - Bryophytes and Ferns

I. Introduction
Plants are multicellular eukaryotic organisms that are autotrophic (produce their own food by photosynthesis), and possess: apical cell division, chlorophyll, a waxy cuticle, and have cell walls containing cellulose. Furthermore, all members of the plant kingdom have variations of a life cycle described as alternation of generations.

In the alternation of generations life cycle there are two mature stages known as the sporophyte and gametophyte. The sporophyte, which is always diploid (2n), produces haploid (n) spores by the process of meiosis in structures called sporangia. Spores germinate and develop into gametophytes, which are always haploid. The haploid gametophyte produces gametes (sperm or eggs) which later fuse to form a diploid zygote. The zygote develops into the mature sporophyte, thus completing the life cycle.

The major groups of plants that you will examine in this week's lab exercises are bryophytes (hornworts, liverworts, and mosses) and ferns. Next week we will examine the Gymnosperms ("naked seed" producing plants) and Angiosperms (flowering plants), which are the "most advanced" plants alive today. The bryophytes within the Kingdom Plantae include: the mosses (Phylum Bryophyta; ~9500 spp), liverworts (Phylum Hepatophyta; ~6,000 spp) and hornworts (Phylum Anthocerophyta; ~100 spp). Bryophytes are thought to be similar to the most primitive of terrestrial plants (see Figure 1). Thus bryophytes give us an idea of what the first land plants to evolve looked like.

Figure 1. Cladogram illustrating the evolutionary relationships of land plants.
Bryophytes (and thus, all land plants) share a common ancestor with green algae. Green Algae are multicellular, photosynthetic protists, but lack many of the adaptations that plants have for living on dry land.

Using the cladogram in **Figure 1** as a guide, we see 5 traits that bryophytes possess, but green algae lack. These include, an alternation of generations lifecycle, apical cell division, a waxy cuticle, and multicellular gamete producing structures (antheridia and archegonia).

What advantage does a waxy cuticle give to a land plant that a green algae lacks?

What advantage(s) does multicellular gametangia give to a land plant that a green algae lacks?

Using the cladogram in **Figure 1** as a guide, which structures do bryophytes lack that all other plants (ferns and seed plants) possess? *List at least three.*

The photosynthetic portion of a bryophyte is called a **thallus**. Remember, bryophytes lack vascular tissue, so they do not possess true leaves, roots, or stems like vascular plants. The life cycle of bryophytes is characterized by distinct alternation of generations in which the **gametophyte** is the dominant stage of the life cycle. The **gametophyte** stage is dominant because it is larger and longer lasting than the **sporophyte** stage, and the sporophyte is nutritionally dependent on the gametophyte. The gametophytes are either male or female. Male gametophytes develop male sex organs called **antheridia**, which produce flagellated, swimming sperm. Female gametophytes develop female sex organs called **archegonia**, which produce eggs. Bryophytes require water for sexual reproduction because the antheridia and archegonia are on separate individual gametophytes, so sperm must swim to the archegonia in drops of water. The fertilized egg is called a **zygote** (2n), which eventually develops into a mature sporophyte (2n). The mature sporophyte produces haploid **spores** (via meiosis), each of which can develop into a gametophyte, thus completing the alternation of generations life cycle.

As you look at the different groups of plants over the next two labs, pay attention to the difference in life cycles, tissue types, and their structure. These are the characteristics that taxonomists use to classify plants. More importantly, they reflect the traits that plants acquired as they evolved from an ancestral green algae, to bryophytes, to ferns, then ultimately the seed plants (Gymnosperms and Angiosperms).
II. Objectives:
Upon completion of this lab, students should be able to:
1) Identify the gametophyte and sporophyte generation of all plants studied.
2) Identify the basic structural characteristics of each plant group studied.
3) Describe the structure, function, and chromosome number (n or 2n) for the gametophyte and sporophyte generations of all plants studied.
4) Describe the life history and reproductive structures of bryophytes and ferns
5) Describe the relationship between green algae, the bryophytes, and vascular plants (ferns, Gymnosperms, and Angiosperms)

III. Part I - Bryophytes

REVIEW: Hornworts, liverworts, and mosses are non-vascular plants more commonly known as bryophytes. Bryophytes include the groups of terrestrial plants that do not possess vascular tissue (xylem and phloem). Without vascular tissue to conduct food and water efficiently, their growth is somewhat limited. Their distribution is typically restricted to moist habitats because their rhizoids (root-like structures) neither penetrate the soil very deeply nor absorb many nutrients. Despite their small size, however, bryophytes occur throughout the world in habitats ranging from the tropics to Antarctica.

KEY FACTS:
- Bryophytes are non-vascular plants.
- Antheridia are sex organs found on male gametophytes, which produce sperm.
- Archegonia are sex organs found on female gametophytes, which produce eggs.
- The bryophyte sporophyte is nutritionally dependent upon the gametophyte and usually non-photosynthetic.
- The gametophyte generation is dominant.

A. Mosses
Today, we will examine various mosses as our representative bryophytes.

**Examination of living/preserved *Polytrichum*:**

Obtain a living *Polytrichum* specimen and return it to your desk for examination. The "leafy" green portions of the plant are the **gametophytes**, which often grow in dense mats that are highly adapted to absorb and retain water. Again, the leafy portion is called the thallus. Note the **rhizoids** branching out from the lower portion of the thallus. Although absent in liverworts, mosses and hornworts possess **stomata**. Stomata are openings in the epidermis that allow gas exchange (O$_2$ and H$_2$O out; CO$_2$ in). Stomata are surrounded by two cells called guard cells that open and close according to the amount of turgor pressure within the cells.

How does the structure of the *Polytrichum* thallus aid in reproduction?
What is the ecological significance of mosses being able to hold and retain water in poor soils? HINT: *Think about how this may benefit OTHER plants* ...

What is the ploidy of the *Polytrichum* thallus?

Why do bryophytes need to take in CO₂ and let out O₂ and H₂O?

Examine a leaflet under a dissecting and compound microscopes. Can you see how many cell layers thick the leaf is?

Why do you think a moss "leaflet" is not many cell layers thick?

Examine closely an individual moss and note that they are composed of an upright stem-like structure bearing small spirally arranged leaf-like structures. Each stalk represents a haploid (n) *gametophyte*, which is either male or female. The gamete producing structures (antheridia and archegonia) are located at the top of the thallus, however, they are difficult to see. To see the gametangia, you will need to observe prepared slides of moss gametophytes under your microscope (we will do that next). Remember that male and female structures are not present on the same gametophyte.

Why do you think the gametangia are located on the upper part of a moss thallus?

Why do you think mosses possess separate sexes on different individual plants?

Although the archegonia and antheridia are difficult to distinguish, it is possible to identify male and female gametophytes by the presence or absence of sporophytes. The slender stalks extending from the tops of some of the gametophytes are *sporophytes*. 


What is the ploidy of the sporophyte?

What does the sporophyte grow out of? *Be specific.*

What sex is a gametophyte bearing a sporophyte?

Examine the sporophyte closely and note the capsule at the top; this is where meiosis occurs to produce the haploid spores. The capsule eventually breaks open, releasing its spores into the environment.

**Examination of prepared moss slides:**

Examine the following moss structures. For each, draw and label all of the listed structures.

- **antheridia**, including the sterile jacket, stalk and spermatogenous tissue
- **archegonium**, including the neck, egg, and stalk
- **mature capsule**, including the calyptra and operculum
- **protonema**

SAMPLE __________
MAGNIFICATION _______

SAMPLE __________
MAGNIFICATION _______
IV. Part II - Ferns

The traits that distinguish ferns and seed plants from bryophytes are: 1) vascular tissue (xylem and phloem), 2) independent sporophyte, 3) roots, and 4) megaphylls (leaves with branching or many veins).

Using the cladogram in Figure 1 as a guide, which structure does a fern lack that a seed plant possesses?

Ferns are non-flowering plants having a vascular system of xylem and phloem, independent branched sporophyte, root and shoot system. The vascular system connects the leaves, roots, and stems. The alternation of generation life cycle is similar to that of the bryophytes, however, the sporophyte generation is the dominant generation in ferns. The gametophytes are relatively small and short-lived. The sporophyte, which is what most people recognize as a fern, is relatively long-lived and is not dependent on the gametophyte for protection or nutrition. Another difference between bryophytes and ferns is that individual fern gametophytes possess both archegonia and antheridia. Recall that in bryophytes, the sex organs were located on separate gametophytes.

Ferns inhabit many different environments, but they are usually limited to habitats that are fairly moist during at least part of the year. This is because fern gametophytes require a moist environment to germinate and develop to the point where they can produce sperm and eggs. Also, flagellated sperm produced in antheridia require water drops to swim through to reach the eggs, which are produced in archegonia found on the same gametophyte.

Examination of fern sporophyte and section of sorus:

Examine the demonstration of a mature sporophyte. Ferns have underground horizontal stems called rhizomes. The roots and leaves (fronds) arise from the rhizome. Note the large fronds of the sporophyte. Some of the fronds possess small brown dots on their underside called sori. The sori are where, by the process of meiosis, spores are produced. Each sorus has many sporangia that house the spores until conditions are right for release. An indusium protects the sporangia.

Make a drawing of the underside of one of the fronds showing sori in the space below:
Obtain a prepared slide showing a cross-section of a fern sorus. Sketch what you see below.

Notes:

SAMPLE __________________
MAGNIFICATION ________

Observation of a fern gametophyte:

First examine the slide of a fern gametophyte against a white sheet of paper or other light background and note the small size of the gametophyte. Each haploid spore released from sori is capable of growing into a flat, heart shaped gametophyte like the one on your slide. The gametophyte will eventually form antheridia and archegonia. Sperm produced in the antheridia are released and swim through a film of water to the archegonia. The zygote formed by the union of a sperm and an egg develops into a young sporophyte, which remains attached to the gametophyte for a short period of time.

Examine the gametophyte on your slide under scanning power and note its characteristic heart shape. The gametophyte is mounted upside-down on the slide, so you are actually viewing the underside of the gametophyte. Note the rhizoids present on the underside of the gametophyte. The archegonia and antheridia also develop on the under side of the gametophyte. The archegonia can be identified as the dark spots near the "notch of the heart," however, the antheridia, which develop near the point of the heart, may not be identifiable. A single egg is present in each archegonium but many sperm develop in each antheridium. Make a drawing of a fern gametophyte below.
Fern gametophyte with attached sporophyte:

Examine the slide showing the young sporophyte attached to the gametophyte. Make a sketch of the gametophyte and sporophyte, and label them. Indicate the ploidy (n or 2n) of each stage below.
V. Review Questions

After you are done with this lab you should be able to answer these questions easily.

Fill in the blank questions with **bryophytes and/or ferns**:

1. ________________ have chlorophyll and carry out photosynthesis.
2. ________________ are vascular plants.
3. ________________ are nonvascular plants.
4. ________________ have two stages to their life cycle - a haploid gametophyte stage and a diploid sporophyte stage.
5. Individual gametophytes of ________________ are either male or female, but not both.
6. Individual gametophytes of ________________ are both male and female.
7. ________________ produce haploid spores which grow into gametophytes.
8. The gametophyte is the dominant stage of the life cycle in ________________.
9. The sporophyte is the dominant stage of the life cycle in ________________.
10. In the sporophyte stage of the life cycle ________________ are dependent on the gametophyte for nutrition.
11. Mosses, Hornworts, and Liverworts belong to a group of plants known as ________________

**Other:**

12. What is the name of the "leafy" photosynthetic portion of a moss?
13. What is the name of the "rootlike" structures found on gametophytes of mosses?
14. What do the archegonia produce?
15. What do the antheridia produce?
16. Where does fertilization take place in mosses and ferns?
17. Where does the sporophyte develop in mosses? Ferns?
18. What does the sporophyte produce in non seed plants?

19. Are both male and female reproductive structures located on the same individual in Bryophytes? Ferns?

20. Is the sporophyte diploid or haploid?

21. Does the sporophyte produce diploid or haploid spores?

22. How does the sporophyte produce spores (type of cell division)?

23. What is the function of the spores released by the sporophyte?

24. Which gametophytes (male or female) support the sporophytes? How do you know this?

25. If the sperm are produced in the antheridia of a male gametophyte and eggs are produced within the archegonia of female gametophytes, how does fertilization take place?

26. Are the cells that make up the sporophyte haploid or diploid?

27. In what part of the sporophyte does meiosis occur?

28. Are the spores produced by the sori haploid or diploid?

29. Are the cells of fern gametophytes haploid or diploid?

30. How does the gametophyte produce gametes (type of cell division)?