

NAME: \_\_\_\_\_

## Diversity in the Plant Kingdom

( refer to your Levine & Miller text: pgs. 596-601 of Chapter 30 and pgs 542-550 of Chapter 27)

All modern terrestrial plants are the descendants of algae that adapted to a terrestrial habitat roughly 500 million years ago. Compared to water, land is an erratic habitat where temperature and moisture availability may change abruptly and dramatically.

For a plant to exist on land, it has to have solved a variety of problems not faced by aquatic algae:

- Surrounded by air, the land plant is in constant threat of death by desiccation and must have **waterproofing** features to hold in the moisture.
- No longer surrounded by water with dissolved nutrients, the land plant must have structures to absorb the water and minerals from the soil and **transport** them to the rest of the plant body.
- Without the buoyant support of water, the land plant's body must have structures to **support** itself.
- Not being immersed in water, the land plant's **reproduction** is a challenge: the plant needs special methods for getting its sperm over to the egg, and also to keep the developing embryo from drying out.
- The land plant **disperses** its next generation with various strategies that do not involve water currents.

In today's lab, you will become familiar with the major groups of plants and how they have solved these problems in different ways. You will also look at microscopic structural details that promote the success of land plants.

### OBJECTIVES OF EXERCISE

1. You should be able to describe the characteristics of the plant groups:  
the non-vascular plants [bryophytes (=the mosses & liverworts)],  
the vascular seedless plants [ferns, lycopods, horsetails, etc], and  
the vascular seed plants [the gymnosperms (conifers, cycads, Ginkgo) & angiosperms (flowering plants) ].
2. You should be able to correctly place plants into one of these three main groups as well as in their subgroup; you should also be able to list the types of plants found in each group.
3. You should understand the evolutionary relationships among the plant groups and the evolutionary innovations arising in each.
4. You should learn to use a microscope and become aware of some of the microscopic structures that enable plants to survive on land.

**Use a Pencil--no ink--when answering questions and drawing diagrams. This allows corrections to be made. Neatness counts toward the grade.**

**✿ ✿ Bring your textbook to the lab! ✿ ✿**

## PLANTS DO IT DIFFERENTLY

In **animals**, the body grows to adulthood; in the adult body there are specialized locations where Reduction Division (Meiosis) occurs to produce special cells with half the normal amount of genetic material (chromosomes). These special cells are called gametes (sperm or egg cells) because they can directly engage in fertilization. Fertilization involves pooling the chromosomes of the egg and the sperm to produce a fertilized egg having once again the normal chromosome content, and thus a normal new individual results.

**Plants** are different! A multicellular plant body does have specialized locations where Reduction Division produces special cells containing half the chromosomes, but these special cells are unable to engage in fertilization themselves. Thus these special cells are called SPORES. These spores must first grow into another multicellular structure, which then produces the sperm or egg cells that can undergo fertilization.

Thus, in a complete **plant life cycle** there are **TWO different multicellular structures**:

- the fertilized egg grows into one structure called the **sporophyte** which produces spores;
- the spores grow into another structure called the **gametophyte** which produces the gametes (sperm or egg).

The plant life cycle thus has two different alternating multicellular structures, and is therefore referred to as "Alternation of Generations".

As you go up the plant evolutionary scale, the sporophytic stage becomes more dominant and elaborate, while the gametophytic stage becomes reduced to the point of being microscopic in the seed plants (see **Fig. 27.9 of your text** (Levine and Miller, 1994, 547)). Thus the plant life cycle approaches the animal life cycle which totally lacks the "gametophytic" stage.

## **I. NON-VASCULAR PLANTS: The Bryophytes = mosses and liverworts**

Bryophytes are sometimes called the "amphibians of the plant kingdom" because of their need for moist habitats; bryophytes are also typically not very tall. Why is this so?

One distinguishing feature of bryophytes is the **absence of a vascular system**. The vascular system is the internal plumbing (analogous to the circulatory system of animals) that transports water and nutrients through the plant. Because bryophytes lack a true vascular system, fluids can travel only short distances within their bodies. There are no tree-size bryophytes because water could never travel adequately from the rootlets to the very top.

There are three classes of bryophytes, two of which you will study.

### **Division Bryophyta (Bryophytes)**

Class Musci (**Mosses**)

Class Hepaticae (**Liverworts**)

### **Moss life cycle**

Mosses and other bryophytes are primitive plants. The spores produced by reduction division get wind dispersed and then grow into the major structure of its life cycle, the leafy moss plant (the gametophyte). At the top of the gametophyte, certain cells mature into gametes (sperm or egg cells). The sperm swims through a puddle of dew or rainwater to get to the egg. The fertilized egg remains in place and grows into the minor structure of the life cycle, the sporophyte which consists of the thin stalk with a capsule on top. Inside the capsule is reduction division that produces spores for dispersal. Note: **no seeds** are produced at any time.

(**Note** that the name “moss” is often misused; Spanish moss is a flowering plant, Irish moss is a marine Red Alga, Reindeer moss is a lichen, and Club mosses are the vascular Lycopods).

● **Lab Activities**

1. ➦ Obtain a mature moss plant that also possesses a sporophyte stage. Draw this plant, labeling the gametophyte, sporophyte, and capsule.

**Mature moss plant:**

**Young gametophyte (protonema)  
under the microscope:**

2. ➦ Obtain a very young developing moss gametophyte (“moss protonema”) which looks at this point like filaments of green algae rather than the ultimate leafy gametophyte. Place it in a drop of water on a microscope slide, cover with a cover glass, examine it under a compound microscope; draw it above and label your drawing. Has your young gametophyte reached the stage yet where you can find growing from the green filaments a leafy bud-like structure--the beginnings of the familiar leafy gametophyte?
3. ➦ Draw a diagram showing the life cycle of a moss. Label all of the stages and plant structures.

## More about mosses...

Peat moss, or "peat," is often added to garden soils to increase the organic content. Peat consists of partially decomposed *Sphagnum* moss, which accumulates to great depths in wetlands known as bogs from which the peat is "mined." *Sphagnum* itself is ecologically interesting in the way that it contributes to the bog habitat. The moss secretes acids that lower the pH of the bog water; the low pH discourages growth of decomposers as well as many plants, and causes nutrients such as nitrogen to be leached away. While most plants cannot grow in such a nutrient poor habitat, CARNIVOROUS PLANTS (which are angiosperms) occurring in bogs have evolved an interesting way to supplement their meager diet.

### ●Lab Activities:

1. ☛Examine the Carnivorous plant bog present in the hallway terrarium.

The terrarium contains a variety of different carnivorous plants, with different insect-capturing mechanisms. List the three different insect-capturing mechanisms that you see there:

- 1.
- 2.
- 3.

2. ☛Examine a *Sphagnum* leaf

*Sphagnum* is known for its ability to hold large amounts of water--four times as much water as cotton can hold. (That's why natives used *Sphagnum* in diapers, and why bogs are good natural flood-control areas.) There is something special about the leaf structure that enables it to hold so much water.

From the front desk, get some of the tiny leaves of *Sphagnum*, spread them out in a drop of water on a microscope slide, and cover with a cover glass. Examine the leaf with a compound microscope. Look for (1) the lack of any leaf veins of vascular tissue; and (2) the small living green cells surrounding the giant clear-looking empty dead cells that have openings that admit water. Draw the microscopic view of the leaf below:

***Sphagnum* leaf under a microscope:**

## Liverworts

Liverworts are also non-vascular, non-seed plants (Bryophytes). There are two main groups of liverworts: the leafy liverworts that look from a distance very much like mosses, and the easy-to-spot thallose liverworts that look like green ribbons growing along the ground. Liverworts and mosses are commonly found together along craggy riverbanks.

**●Lab Activities: Examine the examples of thallose liverworts provided in the lab.**

1. ☞ Is your liverwort just in a vegetative phase, or is it in a sexually reproducing or in an asexually reproducing phase?

A **vegetatively** growing thallose liverwort looks just like a flat, branching green ribbon; this is the gametophytic stage.

A **sexually** reproducing thallose liverwort has little umbrella-like structures growing up out of the ribbon (see Fig. 30.6 bottom, in your text (Levine and Miller, 1994, 600)); eggs and sperm are produced in the little umbrella tops; later, tiny bag-like sporophytic structures grow underneath the female umbrellas. (Note again that the sporophytic generation is the minor one in this primitive plant.)

An **asexually** reproducing thallose liverwort has tiny cups scattered on the upper surface of the green ribbon; each tiny cup (gemma cup) contains several tiny green balls (gemmae; singular is gemma), each of which is simply a cluster of vegetative cells. Rain drops splash out these gemmae that then lodge somewhere and resume growth, developing into another green ribbon gametophytic structure.

2. ☞ **Draw your liverwort:** Is it in vegetative, sexual, or asexual phase? \_\_\_\_\_

## **II. THE SEEDLESS VASCULAR PLANTS: Ferns, Lycopods, Horsetails**

The Vascular Plants are believed to have evolved from moss-like plants 300-400 million years ago. They were the first plants to grow to large size and away from open water. These capabilities were made possible by the **presence of a vascular system** which allowed these plants to form the first forests on earth. The vascular system extends from the roots, through the stem and branches, and into the leaves, allowing efficient transport of water and nutrients throughout the plant.

While the bryophyte's life cycle has the gametophyte as the dominant stage, **all vascular plants** have the **sporophyte generation** as the **dominant stage**.

The vascular plants include the more primitive vascular seedless plants (ferns, lycopods, horsetails, etc.) and the more advanced seed vascular plants (gymnosperms and angiosperms).

You will examine the following three of the four Divisions of seedless vascular plants.

**Division Pterophyta (Ferns)**

**Division Lycopphyta (Lycopods)**

**Division Sphenophyta (Horsetails)**

## Fern Life Cycle

The fern "**plants**" with which you are familiar as well as the lycopod and horsetail "plants" are the dominant **sporophyte** stage which, like the small sporophyte of moss, produces spores. Ferns also have a **gametophyte** stage which develops from the germinating spores, but the fern gametophyte is a very small and thin independent structure, about the size of a child's fingernail.

The fern frond (leaf) may have on its underside some small brownish spots. Sometimes people scrape off these brownish spots or even throw away the whole fern, thinking the spots are a disease or insect pest. In reality, the plant is trying to reproduce! The brownish spots are called **sori** (plural of sorus), and consist of clusters of lollipop-shaped **sporangia** producing spores.

### ●Lab Activities: look at several fern fronds

1. ➡ Draw a fern leaflet of two different fern species, showing precisely the arrangement of sori on the under side of each leaflet.

	<u>Fern leaflet</u>
Species A	Species B

Do the two species have the same arrangement of sori on their leaflets? \_\_\_\_\_

2. ➡ Next examine one of the sori under a dissecting microscope. Notice the cluster of rounded "sporangia", inside each of which the spores are produced. Draw the microscopic appearance of a sorus (singular of sori) in the space to the right. Label the sorus and sporangia.

Sorus under microscope

3. ➡ Using forceps, carefully remove some of the sporangia and mount them in a drop of water on a microscope slide with a cover slide. Draw a sporangium as it appears under the 10x objective of a compound microscope. Notice the row of thick-walled cells on one side of the sporangium; upon drying, these thick-walled cells contract, causing the sporangium to tear open and then violently fling the spores away from the plant, catapult-style.

Fern Sporangium

## Other seedless vascular plants: Lycopods and Horsetails

A number of other common plants in temperate deciduous forests are similar to the ferns in that they possess a vascular system but do not produce seeds. These include the lycopods (Division Lycopphyta) and horsetails (Division Sphenophyta) among others; examples of these are **on display in the lab**.

The fossil record indicates that these plants were dominant during the Carboniferous period (300 mya) and grew to the size of trees. The partially decomposed bodies of these plants along with tree ferns eventually created the coal deposits that we now use as an energy source. Because of their long evolutionary lineage, the

lycophods and horsetails are often called "living fossils." All of the *tree-like* lycophods and horsetails are now extinct.

These lycopod and horsetail specimens that you are looking at are the sporophytic generation of their life cycle. Spores are typically produced in small cone-like structures (strobili) at the shoot tips. The life cycle also includes a tiny independent gametophytic stage that can be up to a few centimeters long.

●**Lab Activity: Examine the lycopod and horsetail specimens on display.**

☛What similarities exist among lycophods, horsetails and ferns? What are some of the differences?

**Similarities:**

**Differences:**

### **III. THE SEED PLANTS: GYMNOSPERMS & ANGIOSPERMS**

So far in this lab, we have looked only at non-seed plants, both nonvascular as well as vascular; these non-seed plants disperse via spores (single cells with protective coating), and the gametophyte's sperm require the presence of external water through which to swim to get over to the egg.

A great advance in the plant kingdom was the evolutionary appearance in the vascular plants of the **SEED**. The seed is a rugged package for dispersal; within the tough seed coat is a dormant plant embryo as well as stored food for the embryo to use in resuming growth and getting established.

**SEED PLANTS** all have pollen grains containing sperm, ovules containing egg cells, and seeds that develop from the ovules after fertilization. Note that seed plants also have broken the dependence on external water in reproduction; the sperm do not swim through external water but rather are within the pollen grains that travel through the air.

As a result of these major advances in reproductive efficiency, the seed plants eventually supplanted the seedless vascular plants as the dominant plant forms on Earth.

### **GYMNOSPERMS (the naked-seed plants): Conifers, Cycads, Ginkgo**

Those Gymnosperms with which you are most familiar are probably the common evergreen conifers of the northern coniferous forests and mixed temperate forests—the pines, firs, spruces, hemlocks, etc. There are also several “deciduous” conifers which drop all their needles at once in the autumn—the baldcypress of the Southeast and larches of the North woods. And there are other Gymnosperms that do not bear cones and are not conifers at all. Today you will study three of the four Divisions of Gymnosperms:

**Division Coniferophyta (Conifers)**

**Division Cycadophyta (Cycads)** –in the tropics and subtropics

**Division Ginkgophyta (Ginkgo)** –native to China

The name Gymnosperm means ‘**naked seed**,’ referring to the seed being naked at the end of a stalk or lying naked on a cone scale, rather than being enclosed in a fruit as in the Angiosperms (flowering plants).

## Reproduction of Conifers

Conifers produced cones in the spring—male cones and female cones. In the small non-woody **male cone**, reduction divisions occurs on each cone scale, producing many spores, each of which grows into a microscopic gametophyte—the **pollen grain** that contains only 3 cells, one of which is a **sperm**. In the **female cone**, reduction division occurs inside an **ovule** on each cone scale, producing a spore inside each ovule. This spore grows into a microscopic gametophyte within the ovule, and contains an **egg**. Pollen grains borne on wind currents are deposited on the ovules in the female cones. A pollen grain grows a tube into an ovule, allowing the pollen grain's sperm cell to get to the egg and fertilize it. An ovule then matures into a seed.

Firs, spruces, hemlocks and redwoods require one summer for the little female cone to grow to its mature woody form and to mature its two seeds per cone scale. Pines on the other hand generally require two summers to grow their much harder tougher woody cones and to mature the two seeds on each cone scale. Conifer seeds are usually **winged**—have a papery extension of the seed coat to aid in wind dispersal.

### ●Lab Activities

- ☛Examine the assortment of cones and seeds on display in the lab. Which are male or female cones?
- ☛How many seed per cone scale in a cone? \_\_\_\_\_ **Conifer seed:**  
Draw a seed at the right; label its wing:
- ☛Why do you think male cones are rather soft and non-woody while female cones are so well reinforced and armed with ferocious looking spikes?
- ☛Examine the conifer branches provided in the lab. Most conifers are “evergreen” and do not drop their leaves in the winter when it's cold and a lot of the water is tied up in snow and ice. Notice that the surface area of conifer leaves is much smaller than of broadleaf trees; notice the thick waxy covering on the needles. How might these adaptations help a conifer survive the winter season?

## Other Gymnosperms: Ginkgo and Cycad

The **GINKGO** tree is the sole surviving member of an evolutionary line that extends back to the Paleozoic; it also was a dominant tree during the Carboniferous period. Known from fossils, it was thought extinct until western explorers discovered it in the 1800's, growing in temple gardens in the mountains of China, where it was considered to be a sacred tree.

The apricot-like balls hanging on the female Ginkgoes along Fayerweather in the autumn are actually **fleshy-coated seeds**, not fruits. At maturity the seeds stink like rancid butter, because the flesh produces butanoic and hexanoic acids as does rancid butter. (M.C.'s Physical Plant tries to keep the seeds swept up.)

● **Lab Activities:**

1. ☛ **Look at** the primitive branching pattern of the leaf veins: the **veins fork into two**, as in fern leaves.
2. ☛ Look at the picture on display (Moore *et al.*, 1998, 522) of a Ginkgo leaf fossil and a live Ginkgo leaf.

The **CYCADS** are non-flowering seed plants that look like very short-stemmed palms. Some cycads have the common name of “Sago Palm” which is a misnomer; it’s not a palm; palms are flowering seed plants. (Sago is the name of the starch derived from the center of certain cycads.)

Cycads were particularly abundant during the Mesozoic (“Age of Cycads and Dinosaurs”), and probably were a major food source for herbivorous dinosaurs.

Cycads produce **cones** at the top of the stem.

● **Lab Activities:**

1. ☛ Go look at the large female cycad in the rock garden of the greenhouse’s tropical room. A few years ago it produced leafy cones bearing ovules.
2. ☛ Is it (she) currently bearing any leafy ovulate cones at the top of its (her) stem? \_\_\_\_\_

## THE ANGIOSPERMS (the flowering seed plants)

**Division: Anthophyta** -all flowering plants are in this one Division

Angiosperms are believed to be the plant group that arose most recently (within last 100 million years) and became the dominant plant life form by virtue of their efficient means of reproduction. Of greatest significance was the **evolution of flowers and fruits**. You’ve already become familiar with flower and fruit structure in a previous lab.

Angiosperms are subdivided into two Classes: Monocotyledones and Dicotyledones. The “**Monocots**”, such as the grasses and lilies, have one cotyledon in the seed, have leaves with parallel leaf veins, and have flower parts in threes or multiples thereof (such as a flower with 3 sepals, 3 petals, six stamens). The “**Dicots**”, such as lilac, waterlily, peanut, apple and oak, have two cotyledons in the seed, have net-veined leaves where veins branch and rebranch, and have flower parts in fours or fives or multiples thereof (such as a flower with 4 sepals, 4 petals, 8 stamens, or a flower with 5 sepals, 5 petals, 5 stamens for example).

**Woody trees** are found in the Gymnosperms and in the Dicots. The woody dicots are often called “hardwood trees” or “broadleaf trees”, while the gymnosperm trees are often called “softwood trees” by the general public.

● **Lab Activity:**

1. ☛ Brainstorm within your lab group: what is it about flowers and fruits that permit the Angiosperms to become dominant over the other seed plants, the Gymnosperms? What do flowers and fruits make possible that Gymnosperms don’t have the benefit of? Come up with several things:

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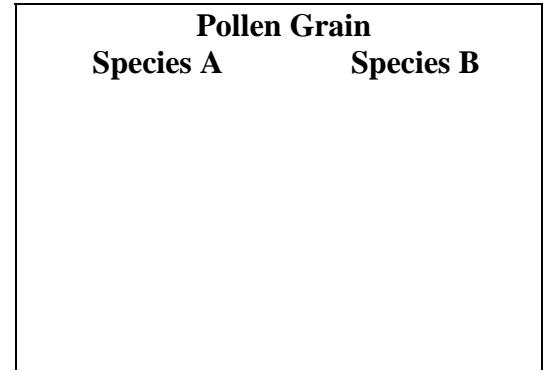
A flowering plant is the sporophyte, undergoing reduction division inside the anthers and inside the ovules that are enclosed in the ovary. Within the anther, many microspores are produced, each of which matures into a pollen grain (microscopic gametophyte containing the sperm). Within each ovule, a single megaspore survives and develops into a microscopic gametophyte including an egg cell.

### ●Lab Activities

1. ☛**Pollen.** Pollen is produced by all seed plants: that means all gymnosperms and all angiosperms.

Place a drop of water on a microscope. Swirl an anther in the droplet to release some pollen. Add a coverslip and examine the pollen on a microscope under high power. Make a drawing of a typical grain in the space to the right.

☛Repeat with the pollen of a different species. Do the pollen grains of these two species look the same or different?



Forensic labs have been able to solve crimes by examining such “insignificant” microscopic structures as pollen grains, fibers and leaf fragments on the victim and accused.

2. **Xylem.** The vascular tissue consists of the xylem (conducts water) and the phloem (conducts sugars).

☛**Blocks of wood (xylem) under a dissecting microscope:** look at the longitudinal surfaces wood:

--White Pine and Engelmann Spruce (Gymnosperms)

Can you see the uniform array of elongated cells? The wood (xylem) of gymnosperms has one kind of long conducting cells for conducting water up the plant; thus, the uniformity seen in the wood.

--White Oak and Chestnut (woody Dicots)

These two “hardwoods” have especially prominent wood grain. What does such “grain” look like under the microscope? \_\_\_\_\_

The wood (xylem) of woody dicots has two kinds of conducting cells:

-the large diameter cells (“vessels”) that produce the visible wood grain, are absent in gymnosperms

-the more abundant smaller-diameter cells (“tracheids”) are much like those in the gymnosperms.

☛**Wood sections under a compound microscope:** look at the prepared microscope slides of wood:

--White Pine (*Pinus strobus*) --a gymnosperm

-cross section: look at the uniformity of the cell diameters. The scattered huge holes are the resin ducts that are lined with small cells secreting resin. Resin protects the tree. (How?)

-longitudinal section: again look at the rather uniform array of very long conducting cells; they get gradually narrower in diameter towards the end of each summer’s growing season.

--Basswood (*Tilia*) --a dicot

-In both the cross section and the longitudinal section, note the scattered, large-diameter vessels.

3. ☛**Give yourself a ☛plant☛!** Plant some of the seeds in the soil provided; keep the soil moist, and watch your own personal little oxygen generator growing on your windowsill!

### Literature Cited

- Levine, J. and Miller, K. (1994) Biology: Discovering Life, Second Edition. D. C. Heath and Company, Lexington, MA.
- Moore, R., Clark, W. D., and Vodopich, D. (1998) Botany, Second Edition. WCB/McGraw-Hill, (no city or state given).