

Biology 3B Laboratory

Vascular Seed Plants – Gymnosperm & Angiosperm

Objectives

- To understand the general systematic relationships of gymnosperms and angiosperms
- To describe the general features of gymnosperms and angiosperms
- To understand the life cycles of gymnosperms and angiosperms
- To compare the significant features of life cycles for various gymnosperms and angiosperms and state the particular evolutionary importance
- To be able to differentiate between representative organisms in each group: pine, cycad, ginkgo, *Ephedra* and *Welwitschia*.

Introduction

In the last laboratory you studied nonvascular and seedless vascular plants. If you recall, there are four natural extant groupings for plants: the Bryophytes, Pteridophytes, Gymnosperms and Angiosperms. In this laboratory, you will study seed plants: the Gymnosperms and the Angiosperms.

Both seed plant groups are thought to have risen from a group of extinct phylum Progymnospermophyta. These progymnosperms had intermediate characteristics between ancestral ferns (an extinct seedless vascular group) and seed plants. Progymnosperms reproduce via spores like seedless vascular plants. However, progymnosperms also possess secondary vascular structures (secondary xylem and phloem) that are characteristic of seed plants. Therefore, it is thought that this secondary vascularity evolved first in progymnosperms.

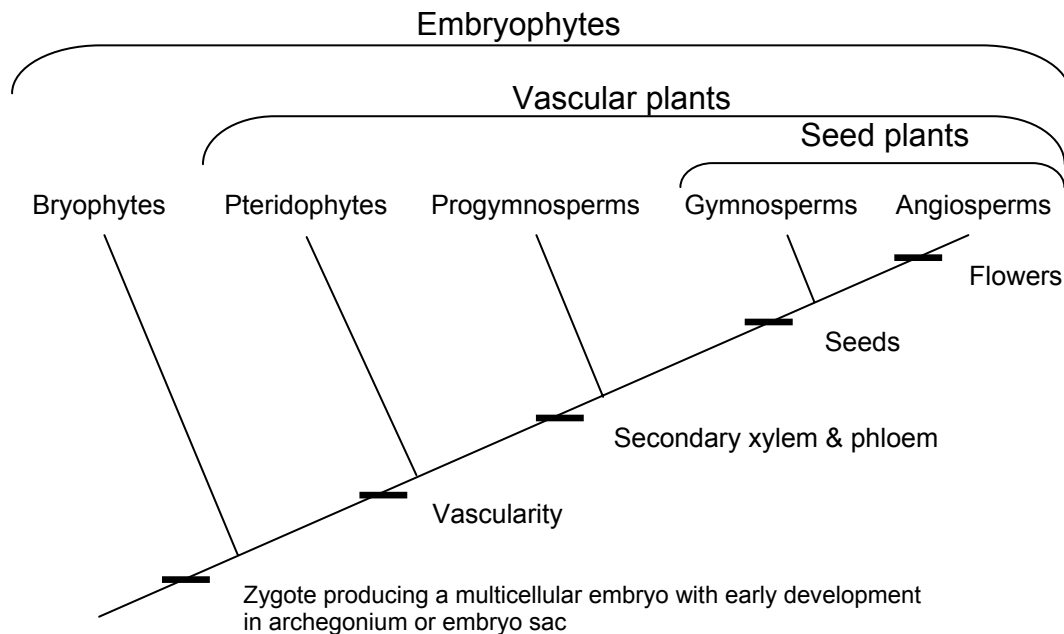


Figure 1: A simplified summary showing the phylogenetic relationship between the major groups of Embryophytes, vascular plants and seed plants.

Currently, taxonomists have seed plants grouped into one of five phyla. Four phyla are commonly grouped together as the gymnosperms (naked seeds – 720 living species). These four phyla all

include living representatives: Cycadophyta (cycads), Ginkgophyta (ginkgo), Gnetophyta (gnetophytes) and Coniferophyta (conifers). The most successful plants now are angiosperms in the phylum Anthophyta (flowering plants – 235,000 living species). Both groups have adaptations which allowed members in these groups to survive in a drier environment, thus they are not restricted to damp habitats like the plants studied in the last lab. In addition, angiosperms have unique set of characteristics that distinguishes them from gymnosperms that have contributed to their success.

Both gymnosperms and angiosperms exhibit alternation of generations like the “lower plants.” However, the gametophyte generation is reduced further than what you examined with the seedless vascular plants. The gametophyte generation of seed plants is dependent on the sporophyte generation to support them.

Gymnosperms

Gymnosperms have been around since the Carboniferous period (362 MYA). During this time, vascular seedless plants dominated the swamp forest landscape. As the environment became warmer and drier, gymnosperms began to diversify. One of the reasons for this diversification was the reduced (microscopic) gametophyte stage. Gymnosperms are **heterosporous**, producing two different types of spores. Male cones (**microsporophyll**) produce the male gametophyte (**pollen** or **microspore**) that is resistant to desiccation and often wind dispersed due to its microscopic size. As a result, this eliminated the need for water as the dispersal mechanism. **Pollination** occurs when the pollen arrives at a female cone (**megasporophyll**) that contains the female gametophyte (**ovule** or **megaspore**). A pollen tube develops so that the pollen grain can reach the microscopic ovule. At this point, fertilization occurs and the developing embryo is dependent on the mature sporophyte in becoming the seed. The evolution of seeds is one of the most significant events for the plant kingdom. A seed typically consists of an embryo, seed coat, and stored food. The seed coat and stored food is what enables seeds (small sporophyte) to remain dormant until conditions are more favorable for growth.

Phylum Cycadophyta – Cycads

The once widely diverse Cycadophyte has been reduced to ten genera and approximately 100 species. Cycads may look like miniature palms due to their unbranched leaves and are found in tropical and subtropical regions. However, cycads produced flagellated sperm in the conelike structure near the apex of the plant. Ovulate cones produce ovules on separate plants. Organisms that have separate male and female reproductive parts are referred to as **dioecious** (two house).

- Examine demonstration examples of cycads and be able to recognize the representatives.

Phylum Ginkgophyta – Ginkgo or maidenhair tree

The only living representative in this phylum is the *Ginkgo biloba*. The last wild stands of ginkgos were most-likely in China. Today, ginkgos can be found worldwide as it has been introduced as a landscape tree due its resilience to air pollution. Present day ginkgos have change very little over the past 150 million years.

- Examine the leaves from *G. biloba*. Notice the bi-lobed leaves with branching venation. Between the two doors outside SM 202 is a living ginkgo. Unlike other gymnosperms, ginkgos are deciduous (loses its leaves).

Phylum Coniferophyta

The phylum Coniferophyta has the most numerous (550 species), widespread and ecologically important gymnosperms. Coniferophyta also has the oldest living individual organism, a 5,000 year old bristlecone pine and the tallest vascular plant, the redwoods with heights up to 117 meters. This group includes pine trees, junipers, cedars, firs, spruces, etc.; which are of economic value.

As mentioned before, gymnosperms are heterosporous. Male cones (microsporophyll) have specialized tissues (microsporangium) that produce pollen via meiosis resulting in four microspores. Each of these microspores develops into a winged pollen grain which consists of two prothallial cells, a generative cell and a tube cell. The smaller male cones are typically located on the lower branches of the tree where as the female cones (megasporephyll) are on the upper branches, reducing the chances of self pollination.

Female cones are typically larger and more complex than male cones (Figure 2). The ovules are contained within a seed-scale complex of the female cone. The megasporangium (multinucleated nucellus) of each ovule contains the megaspore mother cell that undergoes meiosis producing a linear series of four megaspores after pollen enters through the **micropyle**. Only one of the four megaspores survives, the remaining three megaspores nearest the micropyle disintegrate. As the pollen reaches an egg, fertilization occurs and the embryo begins to develop within the seed. Seed development usually occurs some 13 – 15 months after pollination. Upon dispersal,

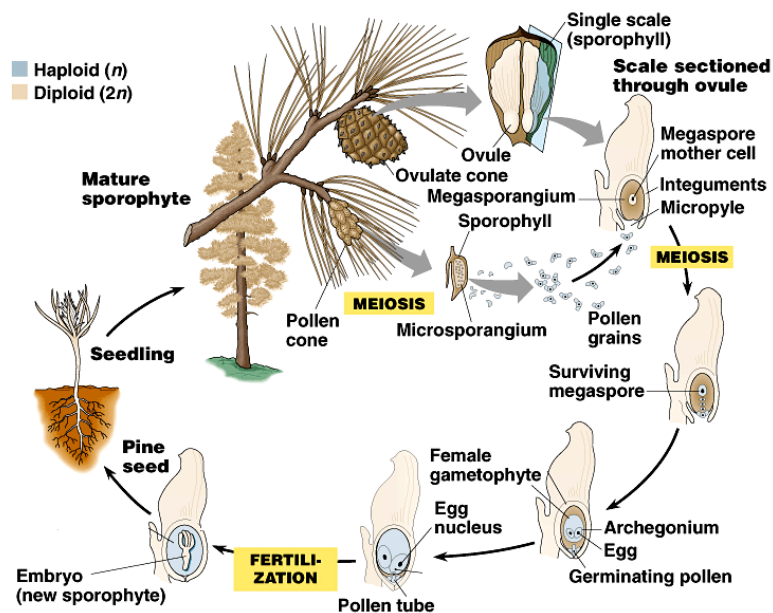


Figure 2: Pine life cycle

the seed develops into a seedling that matures into the sporophyte beginning the process again.

- Examine a female and male cone. The male cone is elongated where as the female cone is more rounded. The seeds are ready for dispersal in two years.

- Examine a prepared slide (longitudinal view) of a male (staminate) cone using a dissecting scope and then the microscope. Notice the pollen grains in various stages of development within the microsporangia. On a pollen grain, identify the **wing**, **tube cell** and **generative cell**.

- Examine a prepared slide (longitudinal view) of a mature female (ovulate) cone using a dissecting scope and then the microscope. Identify the following structures: **megasporophyll**, **integument**, **egg cell**, **nucellus** and **micropyle**.

Phylum Gnetophyta – Gnetophytes

There are three species in the phylum Gnetophyta: *Ephedra*, *Welwitschia* and *Gnetum*. Current molecular data support the idea that this group is a gymnosperm that is most closely related to angiosperms. One reason for this is that, members in this phylum have **double fertilization** like angiosperms. A difference here is that gnetophytes such as *Ephedra* and *Gnetum* double fertilization results in more embryos as opposed to nutritive material in angiosperms.

- Examine photographic examples of *Ephedra* (Mormon Tea – US name). Most species are restricted to arid environments. What you will primarily notice is the photosynthetic stems without any leaves. Notice the difference between male (round and clustered into a whorled

arrangement) and female (elliptical and opposite arrangement) cones in *E. nevadensis*. Those that go to the CSU Desert Studies Center will have the opportunity to see two species (*E. nevadensis* and *E. viridus*). There is considerable economic value to *Ephedra* species worldwide as many are used medicinally for various ailments. Most of you are probably familiar with extract pseudoephedrine that is used to manufacture nasal decongestants and methamphetamine.

Angiosperms

Of all the plants, angiosperms (phylum Anthophyta) probably have the greatest impact on our lives. We depend upon angiosperms for many of our food and clothing items. Where ever we go, angiosperms are bound to be there. Their success can be attributed to several factors: structural diversity, more efficient vascular system, mutualistic associations and relatively short generation times. The most obvious characteristic of angiosperms are the flowers, which is essentially the sexual reproductive part of the plant. Flowers that have both male and female reproductive parts on the same are often referred to as perfect flowers. Imperfect flowers are those that are missing either male or female parts. Staminate flowers have only male parts while carpellate flowers have only female parts.

The sporophyte stage is the dominant for angiosperms like gymnosperms. However, angiosperms have ovules that have tissues enclosed by the ovary. After fertilization, the ovary matures into a fruit with a seed(s) to begin sexual reproductive process again. However, many angiosperms can reproduce asexually (vegetative reproduction) in the form of “cuttings” that can be taken from one plant to start another. The growth of a cutting represents a new plant that is an exact genetic replica of the original plant. No fertilization is required. In nature, however, reproduction often takes place via sexual reproduction with external fertilization between male and female gametes via pollination.

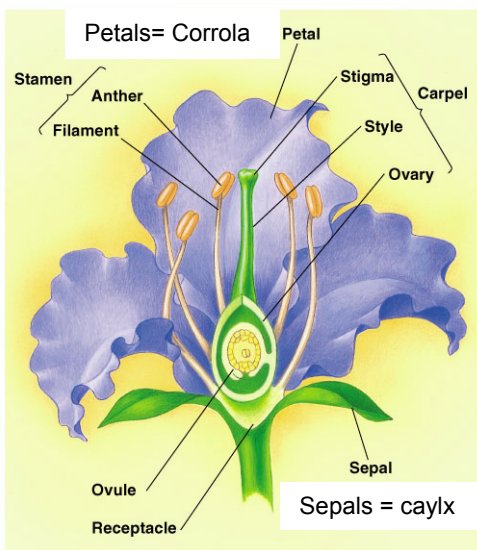


Figure 3: Parts of a flower

The female reproductive parts of a flower are collectively referred to as the **carpel** consisting of the stigma, style and ovary (Figure 3). The **stigma** is at the top of the pistil and secretes a sticky substance that traps the pollen. The stigma is supported by the **style**. At the base of the style is the **ovary** containing the ovules. The ovules undergo meiosis forming four megaspores, three of which desintigrates. The fourth develops into the female gametophyte, which at maturity is an **embryo sac**. Within the embryo sac, there are cells that will eventually form the **endosperm**, a nutrient material for the developing embryo after fertilization.

The male reproductive structure called the **stamen** consists of the **anther** and the **filament** (Figure 3). The anther is a sac in which the microspore mother cell (2N) in which meiosis occurs and

pollen grains develop. The pollen grains house the cells that develop into haploid sperm. The anther is supported by the stalk-like structure called the filament.

Once the pollen grain leaves the anther, it is bound for the stigma (whether on another flower or plant or the same flower or plant). The pollen can be transferred in one of several ways: by wind or carried by an animal. The pollen grains “fit” the stigmas of the same species, similar to a lock and key analogy. When it lands on the stigma (Figure 4), the pollen grain will germinate on the stigma (divide mitotically) and form a **pollen tube** that grows downward through the style toward the ovary. Each pollen grain contains two sperm. In angiosperms, these two sperm will travel through the pollen tube to the base of the style and to the ovary. In gymnosperms, only one sperm enters the micropyle. However, the reproductive process in angiosperms involves **double fertilization**. This is where one sperm will join with the female egg while the other sperm moves down along with the first, but joins with the other cells in the embryo sac to form the nutrient endosperm. The endosperm rapidly divides and surrounds the fertilized egg (zygote) and will protect it and provide nutrients for its growth. A protective coating will enclose the zygote and the endosperm and this entire structure is now collectively called the **seed**. Remember that this takes place in the ovary, so the seed is now developing in the ovary of the plant. Mature seeds

dispersed by wind or animals to suitable habitats will begin to germinate, developing into the mature sporophyte.

Pollination occurs with pollen being carried by wind or by animals from the anther to the stigma. Flowers and pollinators have different adaptations that allow them to be more successful at one form of pollination or another, or with one flower or another. Some pollinators are better adapted to certain flowers and can more efficiently obtain food from the plants they frequent, and are thus better suited to aid in pollination of that species. **Coevolution** is the interdependent evolution of two or more species. We see with flowering plants and

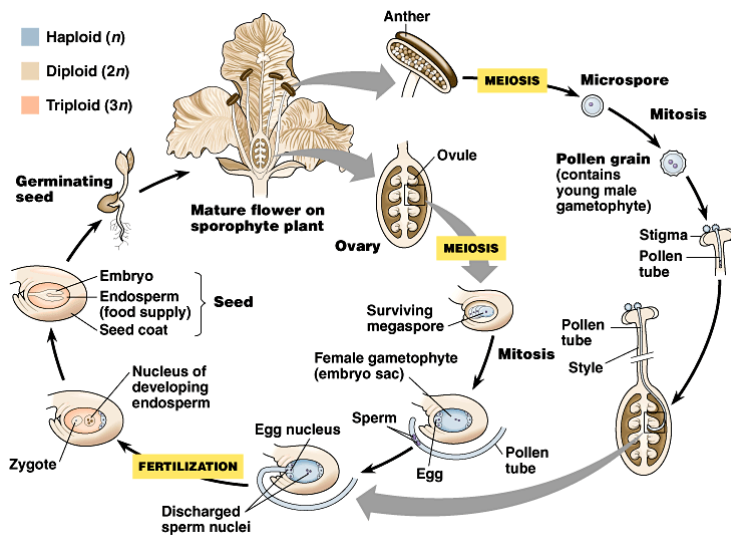


Figure 4: A typical angiosperm life cycle

their animal pollinators, that coevolution can benefit both species and that this relationship is often **species specific**, to ensure that the pollen is delivered to the right stigma. We will examine this relationship when we examine flowers in greater detail in a later laboratory.

The first leaves that appear on a plant embryo are called **cotyledons**. The number of cotyledons on a plant embryo can differ. If there is one cotyledon, the plant is in the class Monocotyledones (monocots) that includes grasses, lilies, bamboos, palms, bromeliads and orchids. If there are two cotyledons, the plant is in the class Eudicotyledon (eudicots) include most nonwoody plants, broad leaf shrubs and tree, vines and cacti. You will see remnants of the cotyledons when we examine fruits and nuts in a later laboratory. We will also examine monocot and eudicot difference in the plant structure laboratories.

- Obtain a flower. Notice the rosette arrangement of the calyx, corolla stamen and carpel as you carefully peel back each layer. Examine other types of flowers available in the lab.

- Observe the dissected flower that has been cut longitudinally. There may be one or more fused carpels, each containing ovules.

- Examine the prepared cross-section slide of a lily (*Lilium*) anther. Identify the mature microsporangia with pollen grains. Do you see the pollen tetrads of microspores? Mature pollen will contain two or more nuclei. Observe any of the fresh specimens. Note the differences between the pollen of gymnosperms and angiosperms.

- Examine the prepared cross-section slide of a lily ovary. Look at the various stages of development of an ovule and embryo sac. In early development, you should be able to identify: **megaspore mother cell, integument, micropyle** and **nucellus**. The embryo sac will appear in later development.