Vascular Plants

There is still debate as to whether mosses, liverworts and hornworts led directly to the evolution of vascular plants (plants with specialized tissue for conduction of food and water). In any case, the oldest known vascular plants date to the late Silurian and early Devonian periods of the Paleozoic era (Campbell 1993). Three genera for which we have a fossil record are *Rhynia, Cooksonia* and *Zosterophyllum*.

Rhynia is named from the location first discovered; the Rhynie chert beds of Aberdeenshire, Scotland. *Rhynia* formed fairly small plants (15-20 cm in height) with dichotomous branching of the stem. There were no leaves or roots so the stem was photosynthetic. Sporangia were found on the terminal axes of the plant (Bold 1973).

Figure 1. Rhynia. *From Bold HC. 1973. Page 456* in *Morphology of plants, 3rd ed. New York: Harper & Row.*

Cooksonia was named after the paleobotanist Isabel C. Cookson of Australia. It was similar in appearance to *Rhynia*.

Zosterophyllum has an eerie resemblance to a living plant called eel-grass, a marine vascular plant found in Florida. The sporangia were kidney shaped and the fossilized basil portions of the stem showed branches in the shape of an "H". There is debate as to whether the stem actually was "H" shaped or this was simply the way it fossilized.

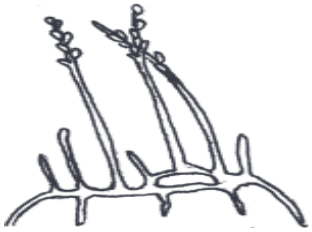
Figure 2. Cooksonia. *From Bold HC. 1973. Page 455* in *Morphology of plants, 3rd ed. New York: Harper & Row.*

We divide vascular plants into two major categories: those which do *not* produce seeds and those that do. Of those that do, the seeds are either "naked" (or exposed) or they are covered as in a fruit.

Seedless Vascular Plants

The earliest vascular plants did not produce seeds; instead, they produced spores. Spores germinate to form the gametophyte plant which may be relatively long-lived. Spores are born is spore containing structures called **sporangia**. These sporangia often protect and nourish the spores by a nutritive layer called the **tapetum.**

Figure 3. Zosterophyllum. *From Bold HC. 1973. Page 458* in *Morphology of plants, 3rd ed. New York: Harper & Row.*



There are four divisions of seedless plants: Psilophyta, the whiskferns; Lycophyta, the clubmosses; Sphenophyta, the horsetails; and Pterophyta, the ferns.

Division Psilophyta - the Whiskferns

There are only two genera within this division: *Psilotum* and *Tmesipteris*. *Tmesipteris* is found only in Australia and New Zealand. *Psilotum* may be found in any tropical or subtropical region, including Florida. There are three species of *Psilotum* worldwide; the species found in Florida, Louisiana, Texas, and Arizona is *Psilotum nudum* (L.) Beauv. Our species may grow in soil or **epiphytically**.

☐ Observe the living or preserved *Psilotum* sporophyte and note its resemblance to many of the extinct early forms of vascular plants like *Rhynia*, *Cooksonia*, and *Zosterophyllum*. *Psilotum* does not have true roots or true leaves. Instead, the only photosynthetic part of the plant is the stem. The very primitive "leaves" are called **prophylls**, and are much reduced and nonphotosynthetic. Prophylls lack vascular tissue but do have vascular **traces** which lead from the stem up to the prophyll. The di-

chotomously branching stem contains **stomata**, just as you found them in the sporophyte of the hornwort. The plant anchors itself to the soil by an underground stem called a **rhizome**. There is a major problem in obtaining nutrients just through a rhizome, so *Psilotum* establishes an obligatory mutualistic relationship with a fungus that penetrates the rhizome. The fungus derives some photosynthetic products from *Psilotum* and *Psilotum* is benefited by the increased surface area provided by the fungal hyphae. This allows more water and nutrients in the soil to enter *Psilotum*. This relationship is called a **mycorrhizal** relationship and since the fungus penetrates the cells of *Psilotum* it is considered to be **endomycorrhizal**.

☐ Look for the three-lobed **sporangium** located on short, lateral branches. Each sporangium is subtended by bracts.

☐ Observe a prepared slide through the sporangium of *Psilotum*. Many botanists feel the sporangium is a fusion of three. Note the **sporangial** wall, usually one to two cells thick. Only part of the **sporogenous** tissue becomes **sporocytes**. Sporocytes undergo meiosis to produce a **tetrad of spores**. Part of the sporogenous tissue degenerates to from a slimy mass of material around the developing sporocytes. This is called a **plasmodial tapetum**. The tapetum serves as nourishment tissue for the sporocytes and later, spore tetrads.

The tetrad of spores breaks apart and individual spores are released when the sporangium ruptures. If spores land on a suitable substrate, they germinate to produce a gametophyte plant (n). The gametophyte is tiny and nondescript. The gametophyte is saprophytic. On the surface of the gametophyte may arise either archegonia (n) or antheridia (n). Sperm are multiflagellate and when released, swim to fertilize the egg in the archegonium. An embryo develops which then matures into the adult plant. Note that in the case of *Psilotum*, most of the life cycle of the plant is spent in the sporophyte stage as opposed to the mosses, liverworts, and hornworts.

Figure 4. Psilotum nudum *(L.) Beauv. Sporophyte plant, sporangium. From Bold HC. 1973. Page 342* in *Morphology of plants, 3rd ed. New York: Harper & Row. Section through sporangium. From* camera lucida Psilotum *sporangium l.s. Carolina Biological Slide # B398.*

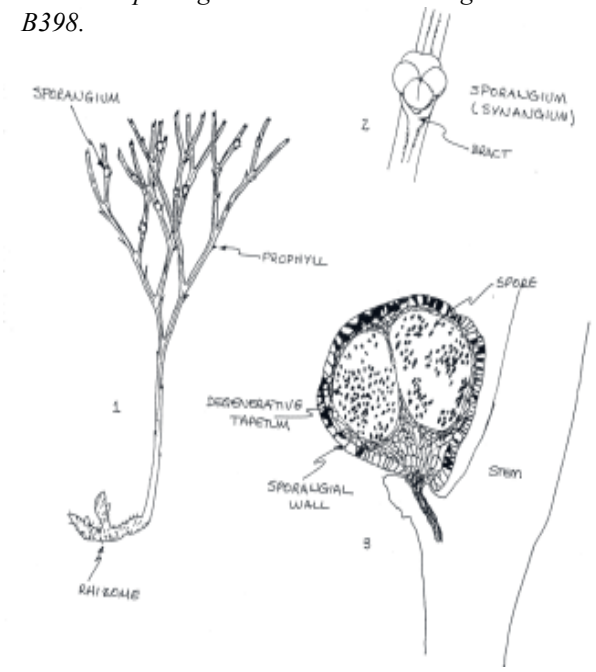
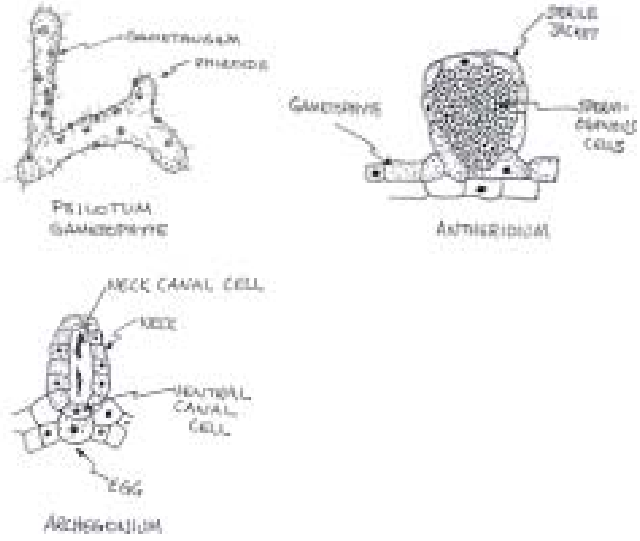


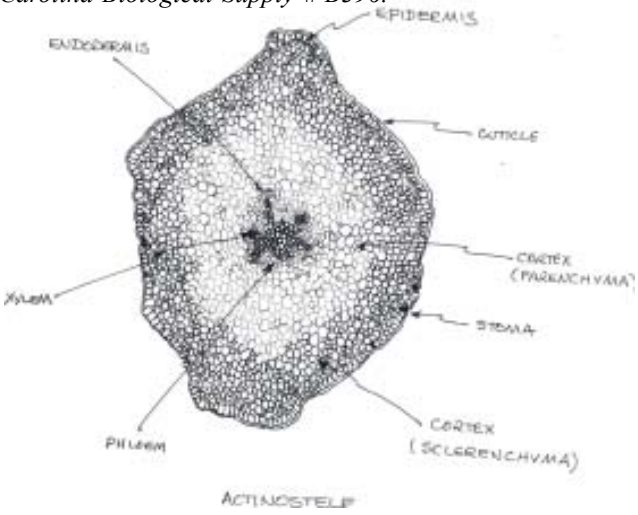
Figure 5. Psilotum nudum *(L.) Beauv. gametophyte, antheridium. From Bold HC. 1973. Page 347* in *Morphology of plants, 3rd ed. New York: Harper & Row. Archegonium. From Adriance S, Gifford EM. 1974. Page 130* in *Comparative morphology of vascular plants, 2nd ed. San Francisco: W.H. Freeman.*



Obtain a prepared slide of a cross section of the aerial stem of *Psilotum*. The slide has been

stained to show xylem and phloem of the vascular bundle. Xylem typically stains red and phloem typically stains blue. Note the pattern of xylem and phloem. This type of pattern is called an **actinostele**. How many lobes of xylem do you see? _____ The number of lobes can be designated as monarch (1 lobe), diarch (2 lobes), triarch (3 lobes), tetrarch, etc. Also note the extensive **cortex** that surrounds the vascular bundle and extends outward to the epidermis. Cortex is storage tissue composed primarily of a cell type called **parenchyma.** Look at the epidermis and try to find openings called **stomata**. The opening should be flanked by a pair of cells called **guard cells.** Stomata, of course, are used for gas exchange.

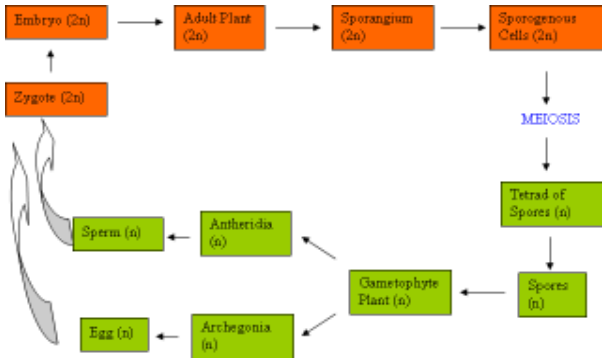
Figure 6. Psilotum nudum *(L.) Beauv. Cross section through the stem.* Camera lucida Psilotum *aerial stem, Carolina Biological Supply # B396.*



Division Lycophyta - Club Mosses, Spike Mosses

The Lycophyta differ from the Psilophyta mainly by the vascularized prophylls, true roots, and sporangia very closely associated with the prophylls (called **sporophylls**). There are three genera considered evolutionarily significant: *Lycopodium, Selaginella*, and *Isoëtes*. *Selaginella* and *Isoëtes* differ from *Lycopodium* by the presence of a leaf-like structure at the base of each sporophyll, called a **ligule.**

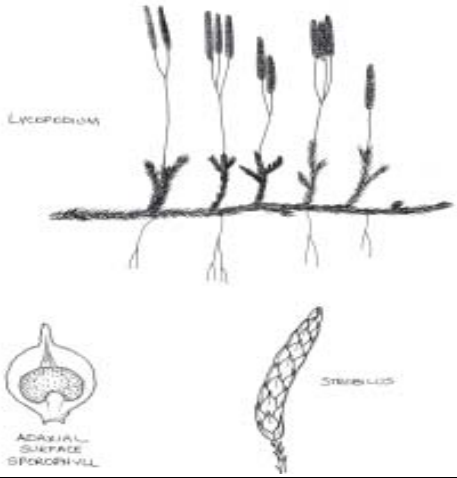
Figure 7. Psilotum *life cycle.*



The Genus Lycopodium (Gr. *lukos,* wolf + *podus*, foot) Clubmoss

Apparently, at one time, someone once thought these looked somewhat like the foot of a wolf. Today, they are commonly known as ground pine (due to its resemblance to pine boughs) or clubmosses (from the appearance of the sporangia on the plant). Most are temperate species but some are tropical in nature. They are often sold in plant nurseries as a ground cover. The sporophyte plant is often dichotomously branched, or one branch may overgrow the other to exhibit **pseudomonopodial** growth. The sessile "leaves" are termed **microphylls**. They are small and spirally arranged around the stem. The aerial portion of the plant rises up from rhizomes. Attached to the rhizomes are dichotomously branched roots. **Root hairs** cover the roots to provide increased surface area for absorption of

Figure 8. Lycopodium *whole plant. From Foster AS, Gifford EM. 1974. Page 138* in *Comparative morphology of vascular plants, 2nd ed. San Francisco: W.H. Freeman. Sporophyll and Strobilus.*



nutrients and water.

☐ Observe the herbarium specimen of *Lycopodium* showing the vegetative characteristics. Note the dichotomous branching, the spirally arranged microphylls, and the dichotomously branched roots.

Sexual reproduction involves the formation of sporangia which produce spores that germinate to produce the gametophyte plant. Microphylls that have sporangia attached are called **sporophylls.** The reason for the common name club moss immediately becomes evident because the sporophylls are arranged in a terminal club-like **strobilus**.

☐ Observe the club-like strobilus of *Lycopodium*. Note how the sporophylls are much smaller than the microphylls on the stems. Using a dissecting scope, pull back the sporophylls on the strobilus and locate the orange, kidney-shaped sporangia covered by each sporophyll.

☐ Obtain a prepared slide of *Lycopodium* strobilus. Note the basic pattern of development that you also saw in *Psilotum*: a **sporangial wall** (three layers thick in *Lycopodium*) the **sporogenous tissue** and/or **tetrads of spores**, and the nutritive layer, the **tapetum**. *Lycopodium* and *Psilotum* are said to be **homosporous**, meaning that produce only one type of spore which produces both male and female gametophytes from that one spore. Once the spore germinates, it produces a much reduced gametophytic plant which develops archegonia and antheridia. Fertilization results in a zygote which undergoes mitotic divisions to produce an embryo, and then an adult sporophytic plant.

☐ Observe the prepared slide of *Lycopodium* stem cross section. Note the **plectostele** with **endodermis.** Distinguish between **protoxylem** and **metaxylem.** Is this endarch, exarch, or mesarch development? _____ Identify the **cortex** and **epidermis** and try to find a **leaf trace.**

Figure 9. Lycopodium *strobilus cross section.* Camera lucida *from Carolina Biological Supply # B458.*

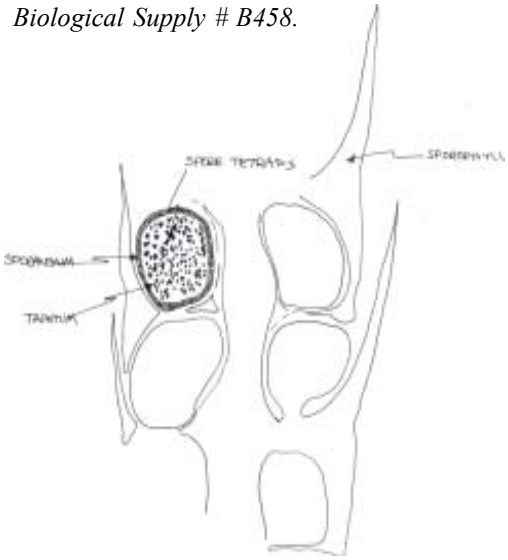
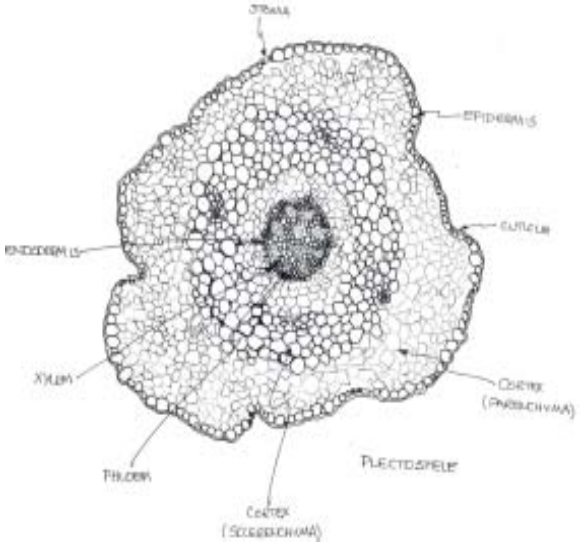


Figure 10. Lycopodium *stem cross section.* Camera lucida *from Carolina Biological Supply # B455.*



The Genus *Selaginella* (diminutive of L. *selago,* a name of a plant representing savin, a juniper + L. *ella*, diminutive) Spikemoss

Selaginella or spikemoss, is a heterosporous fern ally. These are found in temperate, tropical, and xeric habitats throughout the world. The plant body exhibits either dichotomous or pseudodichotomous branching. The plants are somewhat rare and unusual and as a result, are often used as a ground cover in landscaping.

☐ One interesting species found in the U.S. is *S. lepidophylla* (Hook. and Grev.) Spring. This is called Resurrection Plant. Note the dry form and also the one placed in water. Under dry conditions, it closes up to retard water loss. If abundant rain comes, they uncoil and immediately begin photosynthesis.

Each microphyll has a **ligule** or leaf-like piece of tissue attached to its axial surface. Microphyll arrangement may be spiral (a primitive condition) or in four rows flattened dorsoventrally. In this latter case, the leaves are unequal in size and the condition is referred to as **anisophylly.** The dorsal leaves are smaller than the ventral ones. In what other group of plants did you see anisophylly?

Since *Selaginella* is heterosporous, it produces either **microsporangia** or **megasporangia**. Microsporangia will eventually produce **microspores** which develop into male gametophytes bearing antheridia. Megasporangia will develop into **megaspores** which develop into female gametophytes bearing archegonia.

☐ Use the dissection scope and pull back the microsporophylls and megasporophylls to observe the sporangia. The microsporangia are located toward the apex of the strobilus and the megasporangia toward the base of the strobilus. To differentiate between these, look for the ones which have four lobes or swellings. These are the megasporangia. Microsporangia are single structures within the microphylls.

☐ Obtain a prepared slide of a longitudinal section through the strobilus of *Selaginella*. Note the **sporangial wall**, the **tapetum**, the **microsporocytes** and/or **tetrads of microspores** or **megaspores.** The tapetum should be well defined in early microsporogenesis and megasporogenesis. How many megaspores are produced on each megasporophyll? _____. The spores are discharged and each germinates to produce either a microgametophyte or megagametophyte plant. Microgametophytes produce antheridia and thus sperm; the megagametophytes produce archegonia and thus eggs. Fertilization results in the production of an embryo which grows into the adult sporophytic plant.

Obtain a prepared slide of a cross section of *Selaginella* stem. *Selaginella* has a vascular bundle known as a meristele. Another unusual feature is the appearance of thin strands of tissue which unite the meristele to spaces within the cortex. These thin strands are called **trabeculae** and their function is poorly understood.

Figure 11. Selaginella. *Whole plant and strobilus from Foster AS, Gifford EM. 1974. Pages 161-162* in *Comparative morphology of vascular plants, 2nd ed. San Francsico: W. H. Freeman. Longitudinal section from* camera lucida *of Carolina Biological Supply # B465A.*

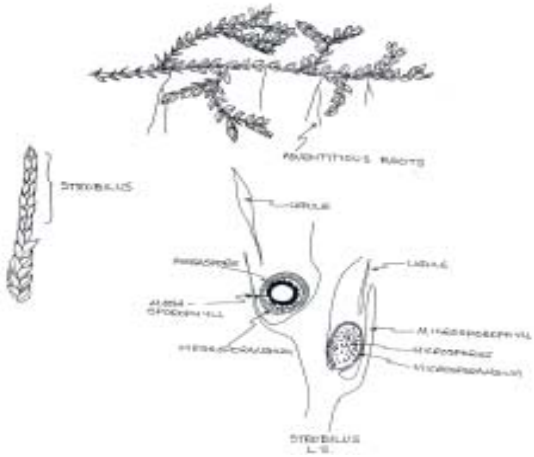
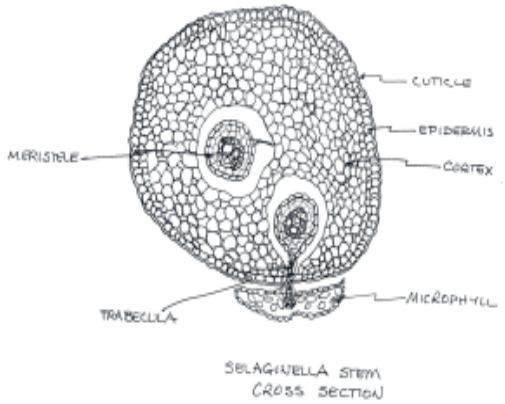


Figure 12. Selaginella *microsporophyll and megasporophyll from Bold HC. 1973. Pages 367 in Morphology of plants, 3rd ed. New York: Harper & Row.*

Figure 13. Selaginella *stem cross section. From Bold HC. 1973. Page* 364 *in Morphology of plants, 3rd ed. New York: Harper & Row.*



The Genus *Isoëtes* (L. houseleek; Gr. *isos*, equal + Gr. *etos*, year) Quillwort

These plants grow as partially submerged aquatics or amphibious plants although there are some

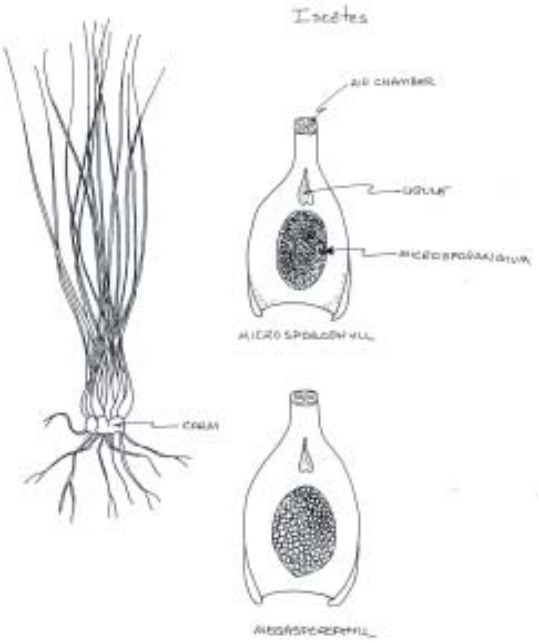
terrestrial forms. The common name is quillwort from the quill-like microphylls arising from a short, vertical, fleshy underground stem called a **corm.** Quillworts are heterosporous like *Selaginella*. The microphylls are hollow in they have four air spaces or **lacunae** per microphyll. Each microphyll has a ligule.

It's estimated some 150,000 to 1 million microspores are formed *per* microsporangium. Each megasporangium may have anywhere from 50 to 300 megaspores. The male and female gametophytes are similar to *Selaginella*.

☐ Observe the herbarium specimen of *Isoëtes.* Note the long "quills." Look closely at the base of the microphylls and see if you can detect any "grains" coming out of the microphylls. These are megaspores and can be seen with the unaided eye. Microspores, on the other hand, are much too small to be easily seen.

Note the dichotomously branching roots at the base of the corn. An unusual characteristic of *Isoëtes* is there is a mathematical formula you can use to determine the number of roots arising from the base of the corm.

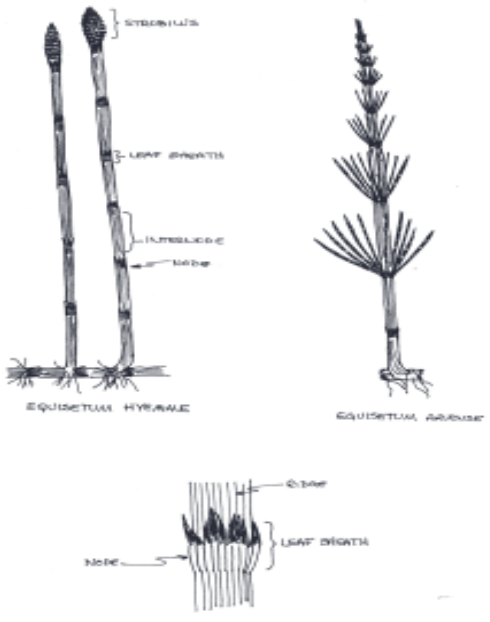
Figure 14. Isoëtes *or quillwort. From Foster AS, Gifford EM. 1974. Page 186* in *Comparative morphology of vascular plants, 2nd ed. San Francsico: W.H. Freeman.*



Division Sphenophyta - the Horsetails

This division is represented by a single extant genus *Equisetum* (L. *equus*, horse + L. *saeta*, bristle). These date from the Devonian period of the Paleozoic. *Equisetum* is sometimes commonly referred to as scouring rush because pioneers would sometimes use the plant as the original scouring pad. The plants grow in xeric, mesic, or hydric habitats, often in the presence of silicon dioxide or sand. Sand is absorbed by the stem and you can feel a rough texture. The abrasive nature of the stem allowed early settlers to use it to scour pots and pans - much like a Brillo© pad. These are temperate and tropical plants and are often used in landscaping. Most temperate species are small and the maximum height rarely exceed 4 feet. The tropical species, *E. giganteum*, is appropriately named, and may reach 5 meters in height and have a stem diameter of 2.4 cm. *E. giganteum* is abundant in Costa Rica. An infusion may be made from the stems and it is used as a local remedy for kidney ailments. Some species are reported poisonous to livestock.

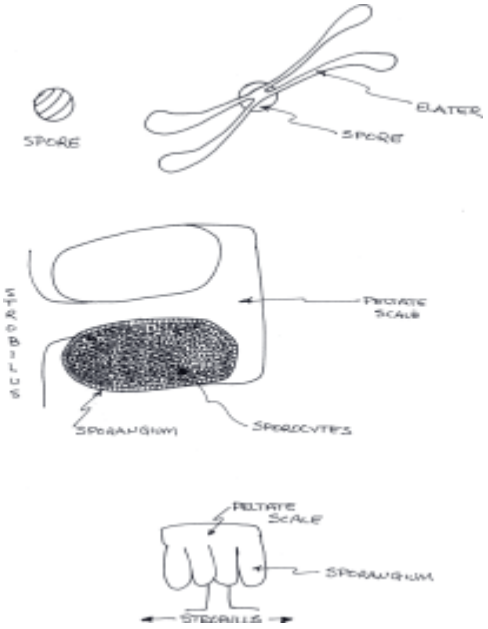
Figure 15. Equisetum. *From Bold HC. 1973. Pages 380-381* in *Morphology of plants, 3rd ed. New York: Harper & Row.*



The microphylls are photosynthetic for a short period of time then become dry and scale-like. Photosynthesis takes place primarily in the stem. The rhizome has **adventitious roots.** At first, the common name horsetail can be misleading if you look only at the species *E. hyemale*. This

particular species simply grows as long columns. However, more typical of the growth pattern is that of *E. arvense* which produces lateral branches at the axils of all the leaves of the stem. The stems are jointed and at each joint you find axillary buds which can each produce a lateral stem. The numbers of these lateral stems give somewhat the appearance of a horse's tail.

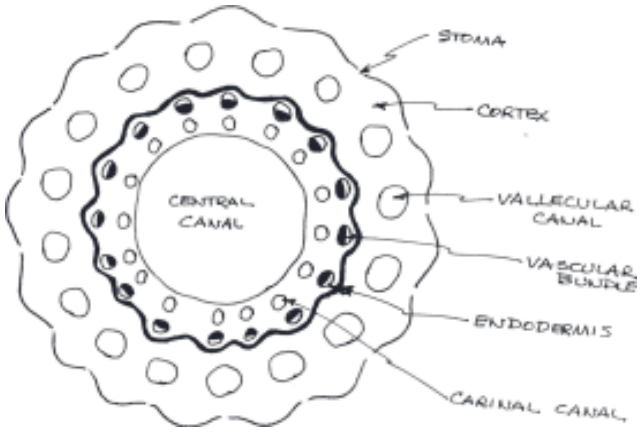
Figure 16. Equisetum *strobilus and spores. From Foster AS, Gifford EM. 1974. Pages 221, 224* in *Comparative morphology of vascular plants, 2nd ed. San Francisco: WH Freeman.*



☐ Observe the herbarium specimen of *E. hyemale*. Note the dry, scale-like microphylls at joints on the stems. These microphylls, when first produced, are photosynthetic but quickly degenerate. In the axil of each microphyll is found a bud that may give rise to a new stem and adventitious roots. Note the rhizome and roots at the base of the plant. Some species have been reported to have rhizomes 6 feet below the surface and extend over a 100 square feet from the plant.

☐ Obtain a prepared slide of a cross section of *Equisetum* stem. Note the large **central canal** or airspace. Surrounding the central canal are two additional canals: the **carinal canal** and **vallecular canal**. The carinal canals are directly opposite to the ridges in the stem and closest to the central canal. Adjacent to the carinal canal are the vascular bundles of xylem and phloem, one each for each canal. The vallecular canals are opposite the grooves in the stem and are located in the cortex. The function of these are unclear. Also note the stomata sunken within the epidermis of the stem.

Figure 17. Equisetum *stem cross section. From Foster AS, Gifford EM. 1974. Page 216* in *Comparative morphology of vascular plants, 2nd ed. San Francsico: WH Feeman.*



☐ Obtain a preserved sample of *Equisetum* strobilus and place under a dissecting scope. The strobilus is composed of a series of **peltate scales** which are modified sporophylls. Each scale has hanging from it eight sac-like sporangia. Remove one of these and place on a slide. Do not add water. Crush the sporangia on the slide and notice the spores inside. Place the *dry* slide with no coverslip on your microscope and observe. Leave it for a period of time until the spores begin to dry out. Notice as they dry, **elaters** around the spores begin to uncoil. Each spore has an elater with four branches with each branch terminating in a paddle-shaped structure. These uncoil and float the spore on air currents. Now fog the slide with your breath and note the elaters recoiling around the spores. l When the spore passes over moist areas, the elater recoils and falls to the ground.

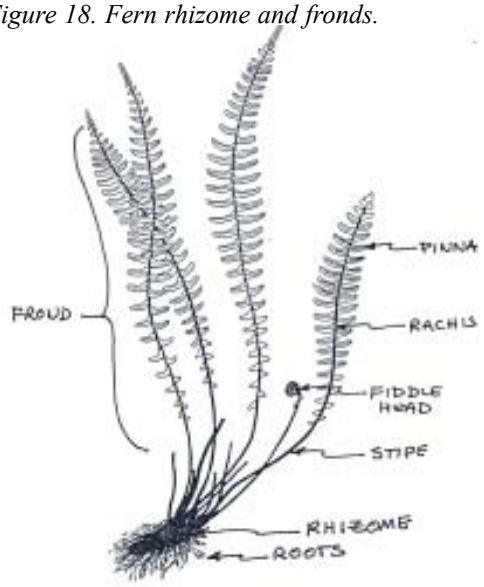
☐ Observe the prepared slide of a longitudinal section through *Equisetum* strobilus. Try to find the **sporangial wall,** the **tapetum**, the **spores**, **elaters**, and **peltate scales.** *Equisetum* is homosporous, like *Lycopodium*, with production of gametophytes with both antheridia and archegonia.

Division Pterophyta - the Ferns

Ferns began their rise to dominance during the middle Devonian of the Paleozoic era, therefore, they are a very ancient group of plants. At one time in our earth's history, the ferns and fern allies were the dominant form of vegetation. Ferns grew to the sizes of some modern day trees. Today, ferns are no longer the dominant vegetation and their sizes have been considerably reduced. Fern are of major interest to plant lovers who enjoy their delicate beauty.

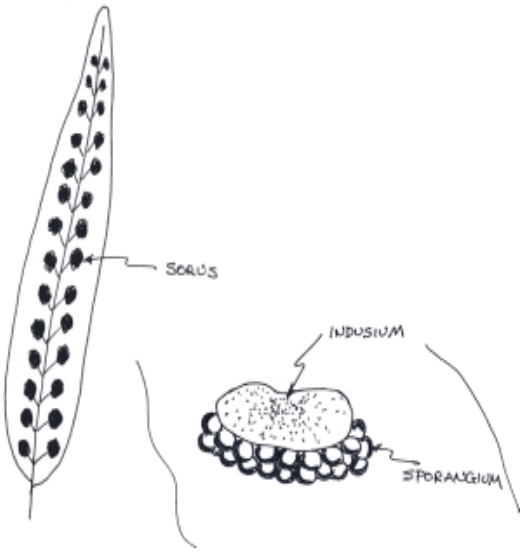
Ferns show great variation in size, shape, form, texture, and reproduction. The leafy segments of a fern "leaf" are called the **pinnae**. The pinnae are united along an axis called the **rachis** and the pinnae and rachis attach to the base of the fern **rhizome** by the **stipe.** The stipe, rachis and pinnae form the fern **frond. Adventitious roots** grow from the rhizome.

Figure 18. Fern rhizome and fronds.



They do not produce seed, instead they reproduce by spores, like the fern allies just covered in lab. Spores develop in cases called sporangia located in various places on the leaf or frond. The sporangia are produced in clusters called **sori** which are seen as a group of dark spots underneath some fronds. The sporangium is made up of many cells formed into a stalked capsule. An area or zone of thick cells called the **annulus** is responsive to changes in moisture. At the proper time, the sporangium breaks along a weakened line between two cells, the **lip cells**, and the annulus arches backward similar to loading of a catapult. The annulus springs closed and the spores are thrown from the sporangium. The spores discharged from the sporangia may germinate producing a gametophyte called the **prothallus**. The prothallus resembles a small heart and produces on its surface either archegonia, antheridia, or, depending upon the species, both. Fertilization results in an embryo which grows into the adult sporophytic plant.

Figure 19. Fern pinna with sorus. Fern pinna with indusium and sorus. From Foster AS, Gifford EM. 1974. Page 288, 290 in *Comparative morphology of vascular plants, 2nd ed. San Francisco: WH Freeman.*



☐ Observe the herbarium specimen of a fern and identify **rhizome, stipe, rachis, pinnae, frond,** and **roots.** Fronds can be either simple or compound. If the rachis branches, the smaller units are called the **rachillae**. Pinnae may be subdivided into **pinnules**. Is your fern frond simple or compound? _____

☐ Obtain a fern frond from the supply table and look at the under surface of the frond. Look for clusters of dot-like structures called **sori**. Sori are clusters of sporangia. Using a sharp tipped probe, scrape a few of the sporangia from the sorus and place them on a clean, dry, blank slide. Add a drop of distilled water and cover with a coverslip. Press down on the cover slip to break open the sporangia. Try to identify the **lip cells**, the **annulus**, **sporangium**, **stalk**, and **spores.**

☐ Some ferns protect the sori by a little flap of tissue called the **indusium**. If available, obtain a fern frond with indusiate sori. Observe under a dissection scope.

☐ Obtain a prepared slide of a cross section of a fern pinna. Note the upper and lower **epidermis**, the **mesophyll,** the **indusium** with **sporangia.** You may need to use high power but search the epidermis for **stomata.**

☐ Obtain a prepared slide of a cross section of *Polypodium* rhizome. Remember, a rhizome is an underground stem. Identify the **epidermis, cortex,** and **vascular bundles.** What type of stele is present?

_____

☐ Observe the various herbarium specimens of fern species. Try to determine if their fronds are simple or compound; once, twice, or thrice pinnate, etc.

Figure 20. Fern gametophyte with emerging sporophyte. Fern sporangium.

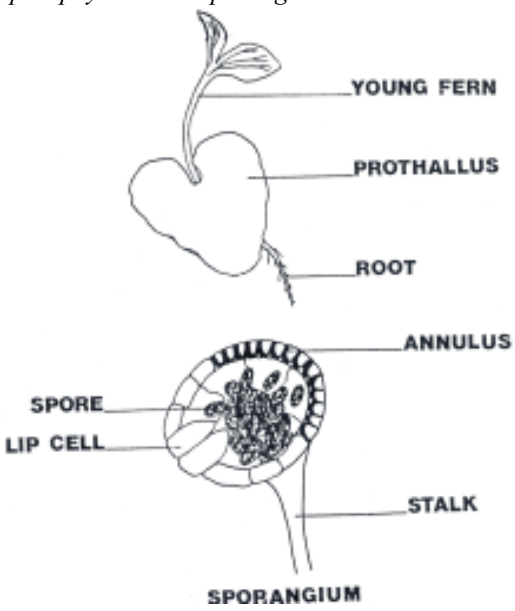
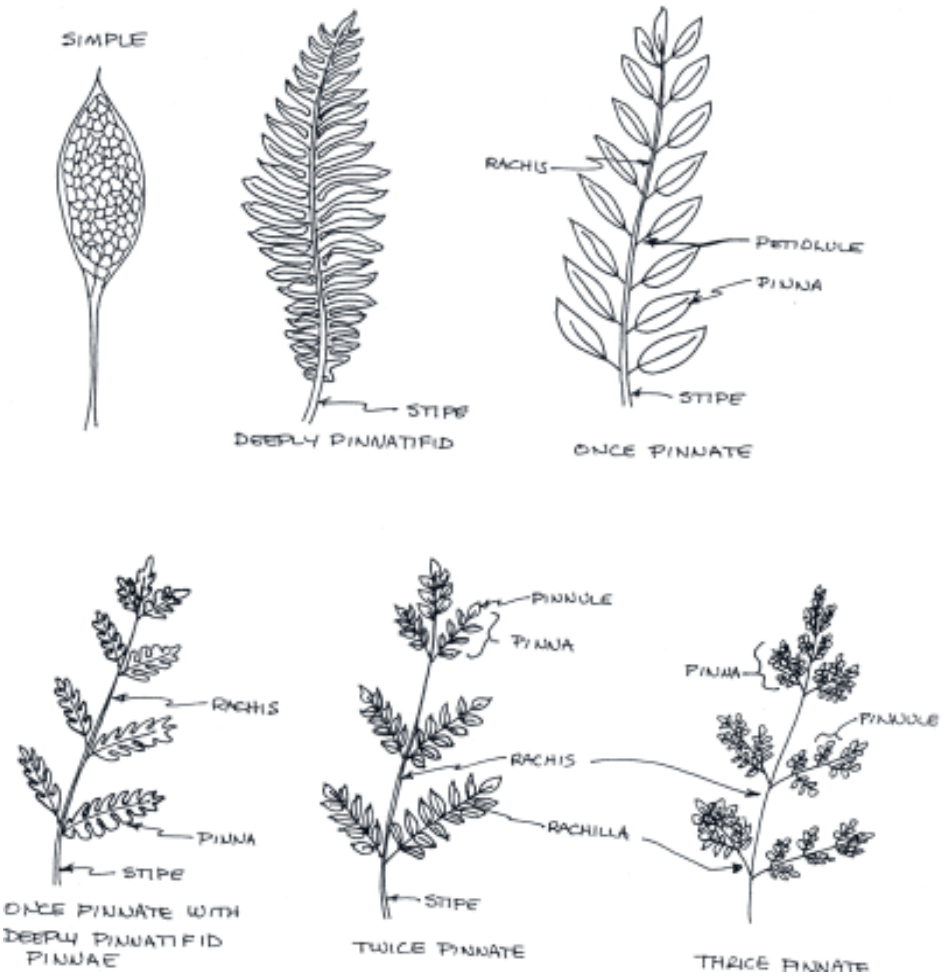


Figure 21. Types of fronds. From Foster AS, Gifford EM. 1974. Page 279 in *Comparative morphology of vascular plants, 2nd ed. San Francisco: WH Freeman.*



The Gymnospermous Seed Plants

These plants produce true seed, not spores. Seeds are mature ovules which contain an embryo. Remember spores need to germinate and produce antheridia and archegonia on gametophytes before fertilization and the production of an embryo. Seed plants produce eggs and sperm on the sporophyte plant. The egg is fertilized and develops into an embryo protected by a seed coat and nourishment tissue.

Gymnosperms produce "naked" seeds. Their seeds (along with the seed coats) are exposed to the environment and are simply held in place by bracts. Angiospermous seed plants, on the other hand, protect their seed by the production of a fruit covering.

Gymnospermous seed plants are represented by four divisions: Cycadophyta, Ginkgophyta, Gnetophyta and Coniferophyta.

Division Cycadophyta - the Cycads

These plants resemble ferns in their foliage but produce true seeds instead of spores. Today, all but one class and order are extinct. Cycads belong to the Class Cycadophyta and the Order Cycadales. There are three families with 10 genera and approximately 100 extant species. At one time, botanists thought these plants were on their way to extinction, but evidence indicates they are still evolving; however, their habitat is significantly on the decline. Most species today are used in landscaping and many cycad species can be found in lawns and gardens of South Florida. For example, the cardboard palm is not really a palm, but a cycad of the genus *Zamia*. Sago palm is a cycad of the genus *Cycas*. Fairchild Tropical Garden in Miami is considered to have one of the largest collections of cycads in the world. A breakdown of the families and genera are found below.

Family Cycadaceae
- Genus: *Cycas* (native to Australia, Japan, Madagascar)

Family Strangeriaceae
- Genus: *Strangeria* (South Africa)

Family Zamiaceae
- Genus: *Zamia* (U.S., Mexico, West Indies)
  - *Microcycas* (Cuba, Mexico, West Indies)
  - *Macrozamia* (Australia)
  - *Lepidozamia* (Australia)
  - *Encephalartos* (South Africa)
  - *Bowenia* (Australia)
  - *Ceratozamia* (Mexico, West Indies)
  - *Dioon* (Mexico, West Indies).

The Genus *Zamia*

Two species of *Zamia* are native to Florida: *Z. integrifolia* and *Z. umbrosa*. The common name is coontie and the starchy roots were cooked and used as a food source by Seminoles. The plant is generally less than four feet tall; the fern-like leaves arise from a short stubby stem. Fleshy roots support the plant and leaves often remain several seasons on the plant. They are dark green and spirally arranged around the stem.

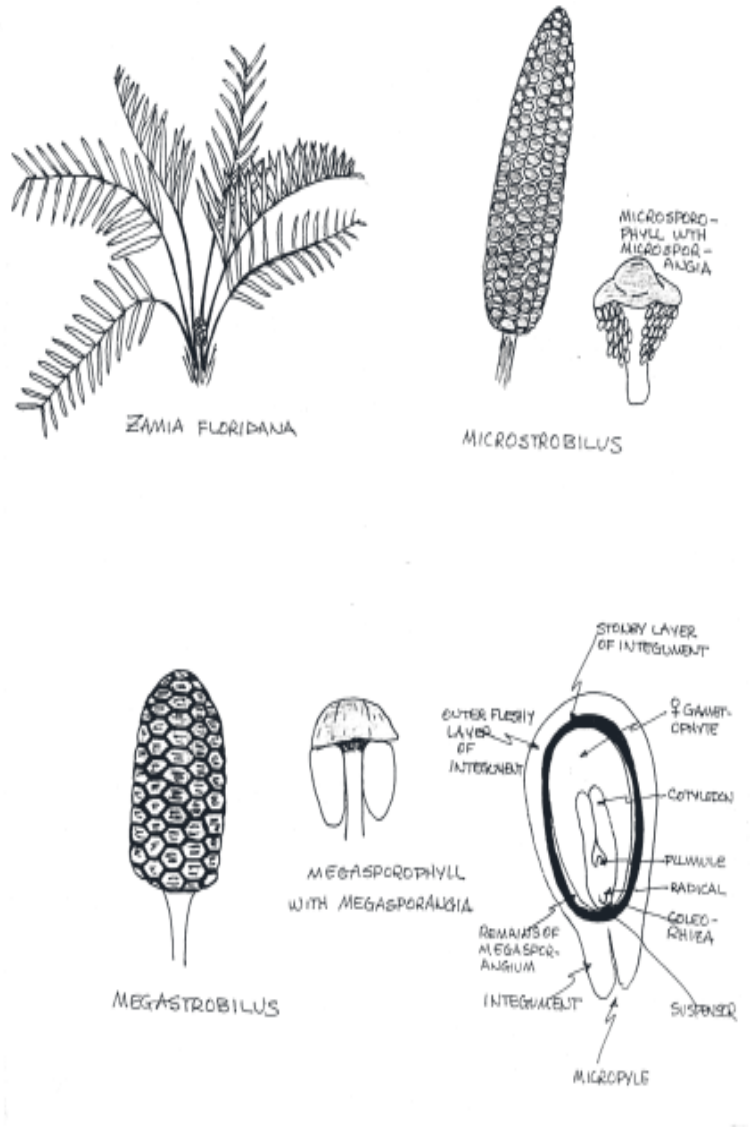
☐ If a living specimen is provided, observe the above characteristics of the plant. *Zamia* has the ability to withstand long periods of drought. Part of this is due to the presence of sunken stomata on the abaxial surface so that any water vapor that does escape actually condenses on the sunken stomata and not lost directly to the air. In addition, there is a **hypodermis** immediately underneath the epidermis which holds water.

Some of the roots of *Zamia* are **apogeotrophic** which means they grow up instead of down. These roots may contain the cyanobacterium *Nostoc* in a mutualistic relationship.

Zamia is dioecious. Male plants produce a male cone or **microstrobilus.** Microstrobilli arise from the base during summer and eventually may reach a length of 10 cm. It is composed of a central axis surrounded by **microsporophylls**, each bearing numerous **microsporangia**.

☐ Remove a single microsporangium from a microsporophyll and crush on a slide. Add water and cover slip and try to find mature pollen grains. Pollen is shed in South Florida from December to February and some pollination may occur by wind but the main method of pollination is by a species of beetle. Fairchild Tropical Garden was instrumental in discovering this method of insect pollination of *Zamia* and it revolutionized thinking about fertilization in cycads. There is a five month interval between pollination of the female cone and fertilization of the egg.

Figure 22. Zamia floridana. *From Bold HC. 1973. Pages 487, 492, 500* in *Morphology of plants, 3rd ed. New York: Harper & Row.*



In *Zamia*, the microsporocyte undergoes meiosis to produce a tetrad of spores. This tetrad breaks apart to release individual microspores. Microspores undergo mitosis to produce a two cell stage. One cell is called the **prothallial cell** and the other is called the **antheridial cell.** The antheridial cell undergoes mitosis to produce a **generative cell** and a **tube nucleus.** A mature pollen grain ready to be shed for fertilization is composed of a prothallial cell, a generative cell and a tube nucleus. Look for mature pollen grains in your slide and see if you can identify the two types of cells and tube nucleus.

The generative cell next undergoes mitosis to produce a **stalk cell** and a **body cell**. The tube nucleus stimulates the production of a pollen tube. The pollen tube begins to grow and search out the unfertilized egg cell on the female plant. The body cell next undergoes mitosis to produce two multiflagellate **sperm.** The prothallial cell and stalk cell degenerate.

The **megastrobilus** or female cone arises on a separate plant. The megastrobilus is composed of numerous **peltate scales** (or megasporophylls). Each megasporophyll has two **ovules** underneath. The ones you have been provided have already undergone fertilization.

Make sure you have on gloves and remove a single ovule from the megastrobilus. Carefully cut longitudinally through the seed, through the **micropyle** (where the pollen tube enters). View the

embryo embedded within the seed coat. Try to find the following structures in the ovule: **coleorhiza, radicle, plumule, cotyledons, female gametophyte, megasporangium,** and **stony layer of integuments.**

The radical will form the root of the embryo. The coleorhiza protects the root as it emerges from the seed. The plumule is the area where the leaves and stem will emerge. Cotyledons are seed leaves that nourish the embryo temporarily after germination until true leaves emerge and begin photosynthesis. The female gametophyte nourishes the embryo while in the seed and for a short period after germination. The megasporangium is a remnant structure which held the egg. The stony layer of the integuments simply protect the seed from environmental forces.

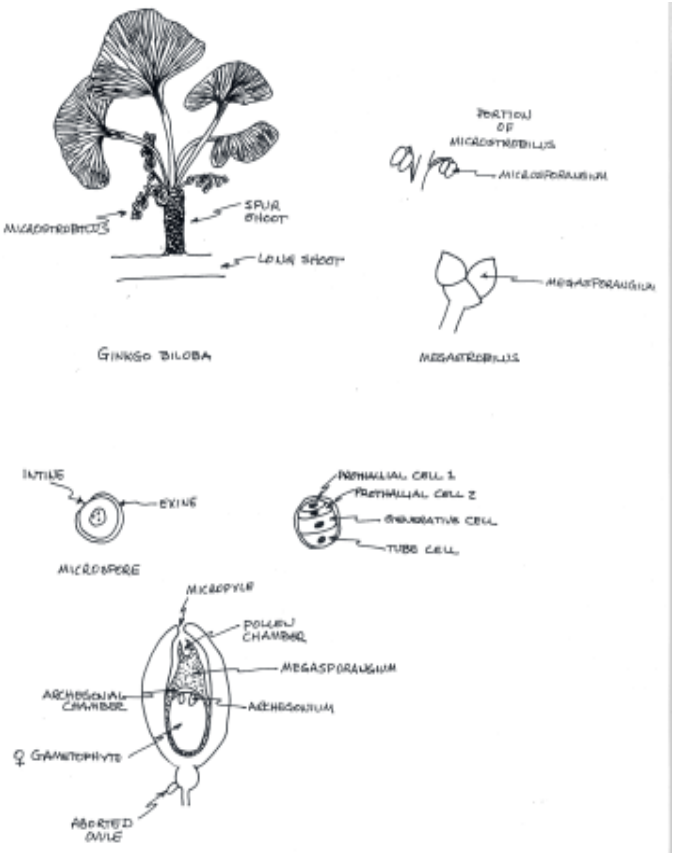
Division Ginkgophyta

There is only one extant species: *Gingko biloba* L., one extant order: Gingkoales, and one extant class Gingkopsida, to this division. *Gingko* is considered to be a "living fossil." It is native to China and was first discovered by the botanical explorer Myer, south of the Yangtze River in Anwei, Iangsu, and Chekiang provinces (Bold 1973. Fossil records date the tree to the Permian period of the Paleozoic era.

The common name for *Gingko* is maidenhair tree. It gets this name from the superficial appearance of the leaves of *Gingko* and that of the maidenhair fern.

☐ Note the pinnae of *Adiantum pedatum* L. (maidenhair fern with that of the leaves of *Gingko biloba* L. (maidenhair tree). Note each is dichotomously veined. The *Gingko* tree may grow quite large, up to a height of 100 feet. The leaves are deciduous even though *Gingko* is considered to be a gymnosperm-like plant. The leaves turn a brilliant golden yellow in the fall and are shed for the winter. The tree is somewhat resistant to fire.

Figure 23. Gingko biloba *L. From Bold HC. 1973, Pages 506-507, 509-510* in *Morphology of plants, 3rd ed. New York: Harper & Row.*



Gingko exhibits **dimorphism** in branching. The main axes of the plant are called **long** shoots. From these long shoots buds arise to form short, lateral branches called **spur** shoots. From these spur choots arise terminal clusters of spirally arranged leaves (as many as 16 per cluster).

☐ Observe the long shoot and spur shoot of *Gingko*.

The leaves of *Gingko* are very distinctive. The leaves of long shoots are deeply bilobed. Those of the spur shoots are either entire or obscurely lobed.

Sexual reproduction in *Gingko* is by the production of either microstrobilili or megastrobili (*Gingko* has male and female plants and is thus, dioecious). The microstrobili arise from spur shoots and form a pendulous structure composed of microsporophylls. Each microsporophyll develops two microsporangia.

☐ Remove a microsporangium from a microsporophyll and crush on a slide. Add a drop of

distilled water and a cove slip. Look for the pollen grains. The mature pollen grain has an inner coat, the **intine**, and an outer coat, the **exine.** The exine does not completely surround the microspore. Try to observe the two **prothallial cells**, the **generative cell**, and the **tube cell** found in mature pollen grains.

The female part of the plant, the megastrobilus, is also found on spur shoots. Two developing ovules are found at the ends of a dichotomously branched stalk.

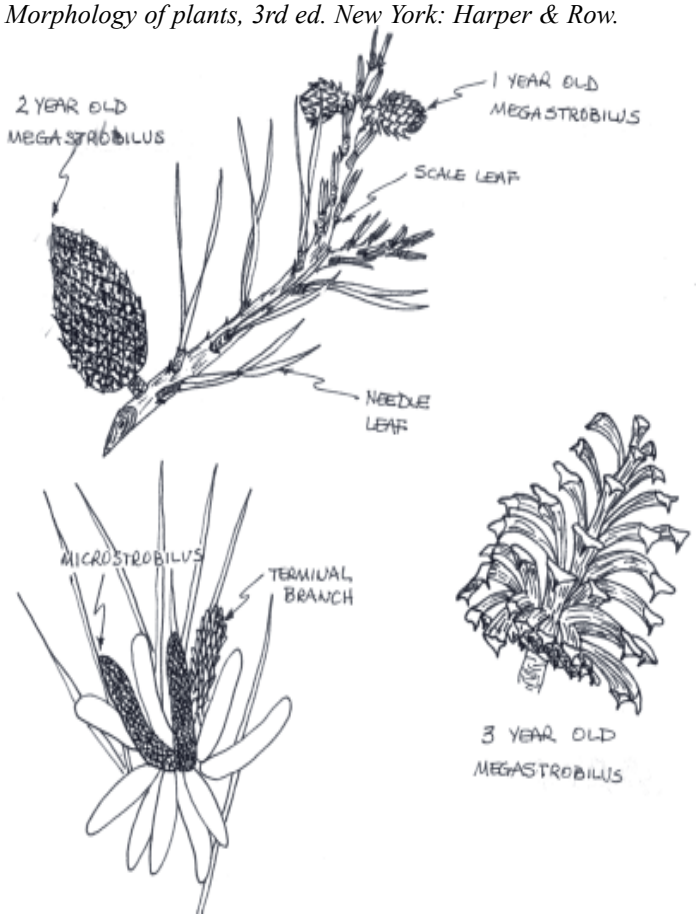
☐ Observe the developing ovules. After fertilization, the ovules enlarge and become fleshy. Observe the fertilized ovules and note the resemblance to very small plums. The female plant produces large numbers of these; unfortunately, they have an extremely disagreeable odor.

Division Coniferophyta - the Conifers

Perhaps the most familiar characteristic of this division is the production of seed bearing cones on trees with needle-like leaves. However, that's only for certain species. Bold (1973) suggests there are some 50 genera and 550 species in this division and it includes some of the most familiar of plants such as pines (*Pinus*), Fir (*Abies*), Spruce (*Picea*), junipers and red cedar (*Juniperus*), hemlock (*Tsuga*) and redwoods (*Sequoiadendron*). Junipers produce fleshy cones, the giant redwoods produce some of the smallest of cones, and not all conifers have needle-like leaves. In this lab we will concentrate on the genus *Pinus* with a brief overview of other species.

There are numerous species of pines in the United States and they are some of the most well researched plants on earth due to the commercial value of the genus *Pinus*. Pines are utilized for lumber, pulp for making paper, furniture, naval stores, and many other uses. Pines include some of the longest living organisms on earth with one bristlecone pine, *Pinus aristata* Engelm, documented to be over 4,600 years old.

Figure 24. Pinus. *From Bold HC. 1973. Pages 517, 519* in *Morphology of plants, 3rd ed. New York: Harper & Row.*



Pines are typically temperate species. There are approximately 100 species o the genus *Pinus*; 36 of these in the United States. Trees, in general, exhibit one of three types of growth: **columnar, excurrent**, and **deliquescent.** Palm trees are an example of columnar growth. If you have ever seen a Christmas tree, that's excurrent growth, and deliquescent growth is characterized by the spreading crown of oaks. Pines, thus, exhibit excurrent growth.

Pines also have periodic or seasonal growth in temperate zones. The young shoots on branches are protected from cold and drought by **bud scales**. Seasonal growth is more evident in stem tissue. Seasonal growth results in the production of **spring** and **summer wood.** Spring wood is xylem tissue in which the growth rate is fast due to plenty of moisture, nutrients, and sunshine. This type of xylem is large and not heavily **lignified.**

Summer wood is xylem tissue that is slower growing due to dry periods in the summer and it is heavily lignified or water proofed. The overall result is a pattern of growth rings which are **annular**. The age of pine trees can, thus, be determined by counting the number of intersections of spring and summer xylem.

☐ Observe the prepared slide of a cross section of pine stem. Note the central core of pith. Pith is composed of parenchyma cells and is used primarily for storage. In older stems, the pith is eventually crushed out by xylem growth.

Also note the large **resin canals** in the stem. These canals produce and transport pine **resin**. Resin is biochemically classified as a terpene and is considered an excretory by-product of normal cellular metabolism in pines. It has no known use in plants but is used in the production of turpentine, rosin, and many other products.

To the outside of xylem is phloem tissue and **cortex**. It may also have resin canals. Cortex is used for storage and in very young stems it may be photosynthetic. The phloem and cortex are eventually crushed by the growing xylem. Only a small amount of phloem remains in any mature stem. This is easily damaged when someone cuts into a tree. To the outside of the cortex is the epidermis. This later converts to **phellem** or **cork cells.**

Try to identify the following in your cross section: **cork** or **epidermis, cortex, resin canals, spring xylem, summer xylem, phloem, pith, growth rings, cambium** and **xylem rays**. What do you think are the functions of cambium and xylem rays?

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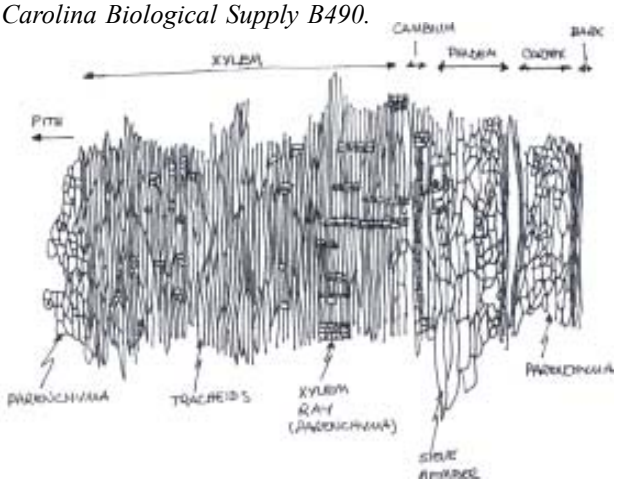
Figure 25. Pinus *stem cross section.* Camera lucida *pine older stem Carolina Biological B484.*

Figure 26. Pinus *stem radial section.* Camera lucida *Carolina Biological Supply B490.*

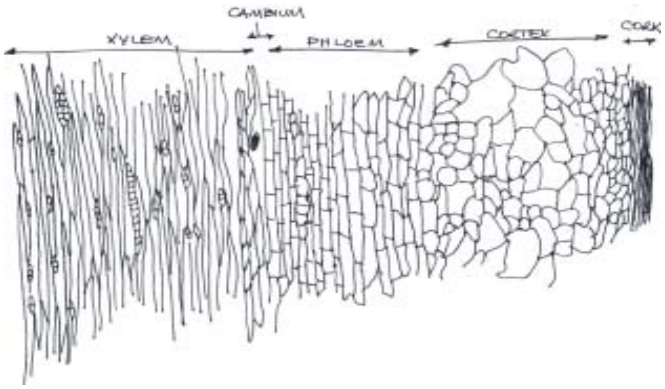


There are three methods of sectioning a stem: **cross, radial** and **tangential**. Cross sections are made perpendicular to the axis of the stem. Radial sections are made through the center of the stem, outward, like a radius drawn through the stem and cut longitudinally. A tangential section is also a longitudinal cut but does *not* pass through the center of the stem.

☐ Observe the three different sections on the wood block. Next, count the growth rings on the block provided to determine the age of the stem. Age in years _____

☐ Obtain a prepared slide of a radial section of *Pinus*. Keep in mind the cross

Figure 27. Pinus *stem tangential section.* Camera lucida *Carolina Biological Supply B 490.*



section you just viewed and try to identify the following: cork, cortex, phloem, resin canals, cambium, xylem, xylem rays, and pith. Note how the xylem rays run perpendicular to the xylem and appear as stacked bricks. What type of cell composes the xylem ray?

_____

☐ Obtain a prepared slide of a tangential section of *Pinus*. Try to identify the following: **cork, cortex, phloem, resin canals, xylem, xylem rays, cambium**, and **pith**. Note the appearance of the vascular rays in this slide and compare it to those seen in the cross section and radial section.

Conifers have xylem composed of **fibers, tracheids**, and **parenchyma**. Angiosperms and some members of the Gnetophyta have an additional xylem element called the **vessel**. *Conifers do not have vessels.*

Obtain a prepared slide of macerated xylem showing fibers and tracheids. Fibers are tapered, spindle-shaped structures and tracheids are longer and more blunt on the ends. Both contain openings in their cell walls called **pits.** Pits allow lateral movement of water between tracheids and fibers. There are two types of pits: **simple** and **bordered.** The bordered pit differs from the simple in that the secondary cell wall provides a border around the opening of the pit.

☐ Observe the pits in tracheids and fibers. Can you detect both simple and bordered?

Pine needles (leaves) are specially designed to prevent water loss. The number of needles in a fascicle varies with the species and can be as few as two.

☐ Obtain a prepared slide of a cross section of *Pinus* needle. Locate the following: **epidermis, hypodermis, mesophyll, endodermis, transfusion tissue, resin canals**, and **stomata**. What are the functions of the hypodermis?

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What are the functions of endodermis?

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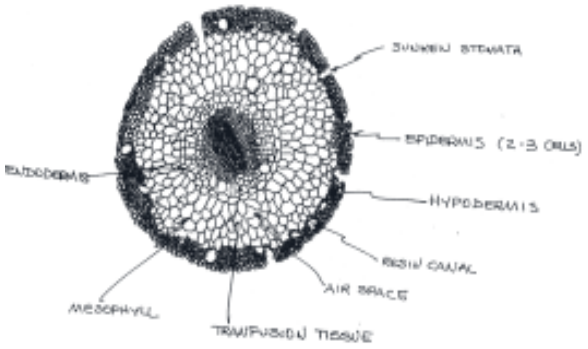
Figure 28. Pinus *needle cross section.* Camera lucida *Carolina Biological Supply B478A.*



Sexual reproduction in *Pinus* involves the production of male cones (microstrobili) and female cones (megastrobili). Male cones are composed of aggregations of sporophylls, each of which has two microsporangia attached to the underside of the microsporophyll. These pollen sacs are composed of a microsporangial wall, a tapetum, and sporogenous tissue. The sporogenous tissue undergoes meiosis to produce microspore tetrads. These in turn mature into pollen grains.

☐ Obtain a prepared slide of a longitudinal section of a male cone and observe the following: microsporophyll, microsporangial wall, tapetum, and mature pollen grains.

☐ Observe the preserved female megastrobilus. The female strobilus is called the cone. This si a first-year cone that has been pollinated. Fertilization is a year away.

☐ Observe some of the preserved cones of various members of the division Coniferophyta. We will reserve detailed study of the female cone until a later lab.

Division Gnetophyta

This division is represented by some 71 species. Some botanists consider the Gnetophyta to be a bridge to the angiosperms. Members produce tracheid-like **vessel elements** (or vessel-like tracheids). Also, like the angiosperms, the sperm are nonmotile. Three genera are commonly studied in botany courses: *Gnetum, Welwitschia*, and *Ephedra*. We'll concentrate on *Ephedra*, but first, a word about

Gnetum and *Welwitschia*. *Gnetum* is represented mostly by vine-like plants with broad leaves, similar in nature to the broad leaves seen in dicotyledonous angiosperms. It grows in northeastern South America, especially Brazil, tropical West Africa, India, and Southeast Asia. *Welwitschia* can best be described as otherworldly. It has an rather large stems which may have a diameter of over 4 feet which may extend below the soil, much in the way a tap root penetrates the soil. There are only two mature leaves in the adult plant which remain throughout the life of the plant (although they may be beaten and battered). It pretty much looks like a plant that may lie in wait for an animal to step into it and be eaten, but it's strictly photosynthetic. It's found in the coastal region of Angola and the Republic of Namibia in extreme desert conditions. The stem serves to store water over prolonged periods of time (Bold 1973)

Figure 29. Gnetum. *From Foster AS, Gifford EM. 1974. Page 524* in *Comparative morphology of vascular plants, 2nd ed.*

The genus *Ephedra* may have some 40 species. At first, the plant may look like a gigantic version of *Psilotum*. Some species may reach 9 to 15 feet in height. Six species are found in the arid regions of the southwestern United States. The drug ephedrine, a vasodilator, is derived from the plant.

Branches may arise as whorls along the stem, but branching can be highly variable in some species. The minute leaves may be either opposite or whorled in **phyllotaxis**. Older stems are woody. *Ephedra* has **tracheids** in which the terminal walls are perforated. This suggests the structure known as a **vessel**, a cell type characteristics of true angiosperms.

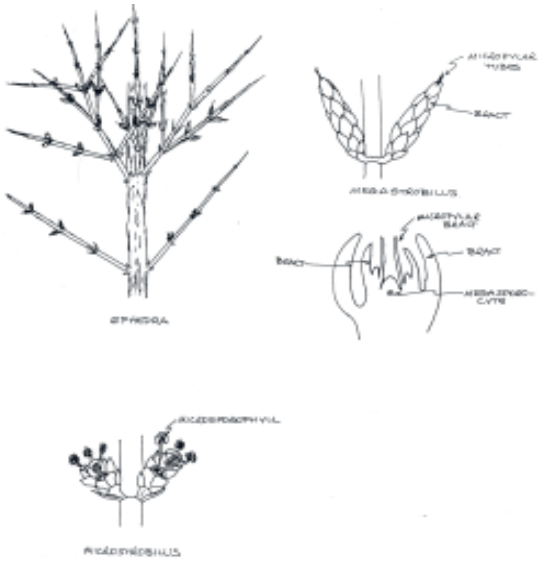
Figure 30. Welwitschia mirabilis. *From Foster AS, Gifford EM. 1974. Page 522* in *Comparative morphology of*

☐ Note the male strobilus. Male strobili are compound. They have around 7 bracts subtending each microsporangium.

Observe the megastrobili. The ovulate bracts enclose the megasporangium, but extensions of the integuments project over the bracts which enclose the developing ovule.

The Angiospermous Seed Plants

Figure 31. Epedra *From Bold HC. 1973. Pages 537, 540-541* in *Morphology of plants, 3rd ed. New York: Harper & Row.*



Depending upon whether you include certain algae in the kingdom known as plants, estimates for plant species may reach as high as 350,000. It's estimated that 250,000 of that number are members of the Division Anthophyta, sometimes commonly called the flowering plants.

Obviously this is a very successful group of plants. What makes these so successful? Among the traits are (1) flowers to attract pollinators to increase the chance of fertilization, (2) fruit to protect developing seeds, and, according to Raven and others (1986), (3) ability to resist drought and cold through the development of (a) tough, thick leaves (b) reduced size of plants (c) vessels - as opposed to tracheids, and (d) resistant seed coats.

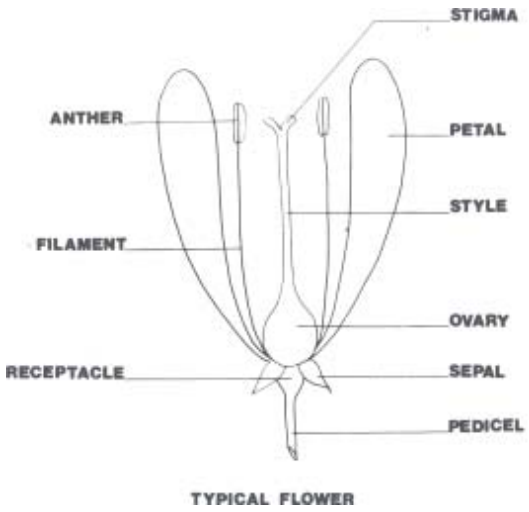
When one looks at the ancestry of angiosperms (Gr. *angion,* vessel + Gr. *sperma*, seed), they share

the same lines of evolution of ferns, cycads, and conifers. First, they are vascular plants. Second, they are divergent from the ferns in they produce true seeds, not spores. Third, they differ from cycads and other gymnosperms by having special xylem cells called **vessels**, and fourth, they produce their seed protected by a fruit.

Parts of A Typical Flower

☐ Observe the model of the flower provided. The obvious part of a flower is the **petals**. Petals are often the most showy portion of the plant the collective term for petals is the **corolla**. Stamens are the male portion of the flower composed of **anthers** that contain pollen, and the **filaments** that attach the anthers to the flower. The female portion of the flower is called the **pistil**. It is composed of an often sticky top called the **stigma**, the narrow, neck-like **style** and the swollen base called the **ovary.** It's in the ovary one finds the seeds. The small, often green, leaf-like structures on the flowers are **sepals**. They generally serve no major functions. Sepals are collectively called the **calyx.** All these parts are attached to the **receptacle** and the flower is often held above the plant by a **pedicel.**

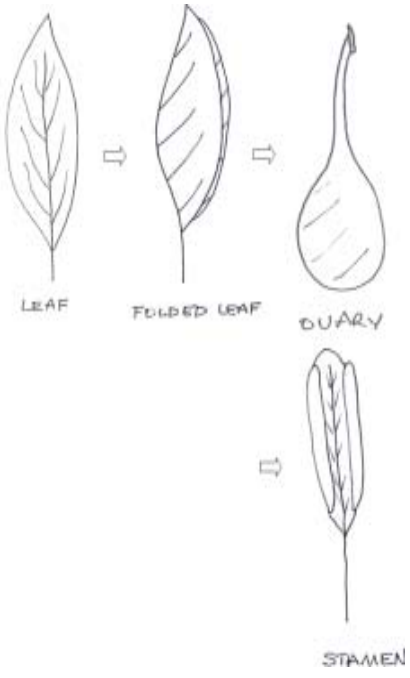
Figure 32. Parts of a typical flower.



Origins of Flower Parts

The flower produces the **fruit.** Flowers, therefore, separate angiosperms from gymnosperms by providing a more secure means of ensuring reproduction. Flowers are the sexual features of angiosperms. The German philosopher and botanist Goethe suggested flowers are modifications of leaves.

Figure 33. Origin of pistil and stamens.



☐ Look at the simple leave provided and fold the edges of the blade around to touch. This is pretty much the appearance of a primitive simple pistil (or **carpel**), the female portion of a flower. The most obvious correlation is the sepals. They even look leaf-like most of the time. Petals and stamens are also modified leaf parts.

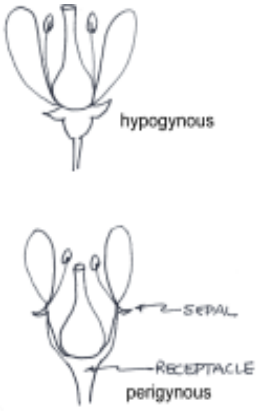
Location of the Ovary

The location of the ovary in the flower is an important feature in identification of the species. If the flower parts (sepals, petals, stamens) are found below the ovary, the ovary is said to be **superior**. If the flower parts are located above the ovary, the ovary is said to be **inferior**. However, sometimes plants try to fool you. Flowers of apples and their relatives appear to have inferior ovaries. This is not the case. The sepals, petals, and stamens are often attached to a **floral tube** held away from the ovary, yet the floral tube is connected below the ovary. This type of ovary is said to be **perigynous.** If the flower is truly superior, the ovary is said to be **hypogenous.** If the ovary is truly inferior, the ovary is said to be **epigynous**.

Monocots and Dicots

Angiosperms are divided into two major groupings: **monocotyledons** and **dicotyledons**. The terms indicate the number of seed leaves produced when the seed first germinates. Flower parts are also useful in determining whether or not the plant is a monocot or dicot. If flower parts (sepals, petals, stamens) are in three's or multiples of three's, it is an indication the plant is a monocot (there are exceptions to this rule). If the flower parts are in two's, four's, or five's, or multiples of these, the indication is the flower is a dicot.

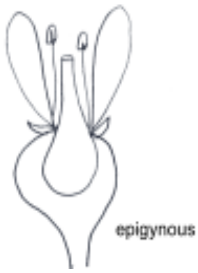
Figure 34. Types of ovaries.



☐ Observe the flowers provided and try to determine, based on floral characteristics alone, whether the plant is a monocot or dicot. Some of the flowers are rather small and you may need to place them under a dissection scope for closer observation.

Actinomorphic and Zygomorphic Flowers

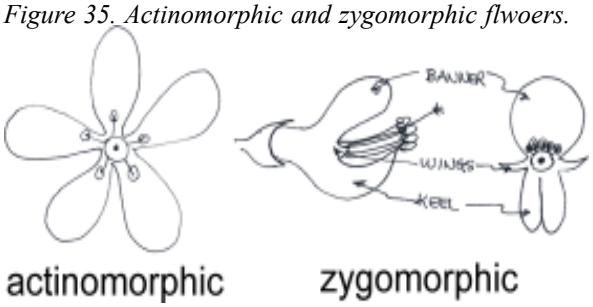
Flowers have symmetry. If flowers are said to be bilaterally symmetrical (also called irregular) they are referred to as **zygomorphic**. If flowers are regular or radially symmetrical, they are said to be **actinomorphic**. For example, *Hibiscus* flowers are actinomorphic while snap dragons and orchids are **zygomorphic.**



☐ Observe the flowers provided and determine whether they are actinomorphic or zygomorphic.

Modifications of Flowers

Figure 35. Actinomorphic and zygomorphic flwoers.



Flowers don't always follow the typical form shown by the flower model. There are numerous variations. Flowers do not necessarily contain all flower parts. Some flowers do not have sepals. Others may not have petals, and others may not have stamens. If a flower is missing one or more of its flower parts, it is said to be **incomplete**. If the flower has all the major parts, it is said to be **complete.** To further complicate matters, if a flower has all the flower parts except it is missing *either* stamens or pistil (the sexual parts), it is said to be **imperfect**. If it has stamens and pistils, it is said to be a **perfect** flower. Can you have an imperfect, complete flower? _____ Can you have an incomplete perfect flower?

_____

☐ Observe the flower provided and determine whether they are (1) complete or incomplete and (2) perfect or imperfect.

Modifications of *Hibiscus*

The common hibiscus flower has a modification to the basic flower plan.

Observe the hibiscus provided and note the major parts of the flower. The unusual feature of the hibiscus is the stamens are united into a tube which surrounds the ovary and style. Use a dissecting needle or probe to cut through the staminal tube of hibiscus and pull apart. Note the ovary is found inside the staminal tube. Also note hibiscus also has a series of bracts in additional to sepals. Bracts are modified leaves which may or may not be present on flowers.

Modifications of Bougainvillea

Speaking of bracts, *Bougainvillea* is an example of a highly modified flower where bracts play an important role. What most people consider to be the flowers of the bougainvillea is really showy bracts.

☐ Look closely at the flowers provided and notice the flowers of bougainvillea are tiny small flowers to the inside of the showy, colored bracts. The calyx is the tubular structure of each flower. Petals are not evident in the flowers.

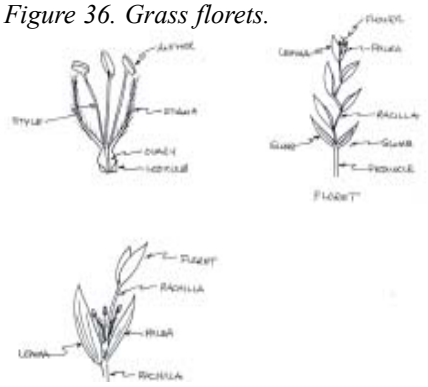
Modifications of Orchids

Orchids are zygomorphic flowers. Parts of the orchid you may thing are petals are really sepals. The flower is also **spurred**. The stamens are united to the ovary and pollen forms in waxy masses called **pollinia**. Orchids are typically epiphytes and constitute one of the largest groups of flowering plants with some 15,000 species. Is the orchid complete or incomplete? _____ Perfect or imperfect? _____ Is the orchid a monocot or dicot? _____

Grass Flowers

Grasses have reduced flower parts and their modifications don't look anything like what you have seen as a flower.

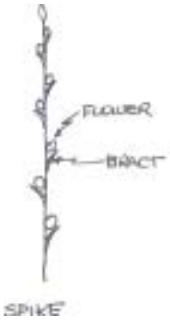
Figure 36. Grass florets.



☐ Observe the grass flowers provided and carefully dissect one spike of flowers. The grass flower has no petals. Instead, two bracts (the **lemma** and **palea**) enclose each flower. The lemma is typically the larger of the two bracts and the palea fits within the lemma. The flowers are perfect and you should see a single ovary (the stigma is often branched into a biramous fork) and three stamens. Is a grass flower monocot or dicot? _____ If you look carefully at the ovary, you may see a set of membranous structures at the base of the ovary. These are **lodicules** and they are thought to be remnants of the sepals.

The ovary, stamens, lodicules, lemma and palea constitute the glass **floret**. Sometimes florets are subtended by a pair of additional bracts called **glumes**. There may be a single floret per flume or numerous florets per glume. The flowers are arranged on the stem in the form or a spike.

Figure 37. Spike.



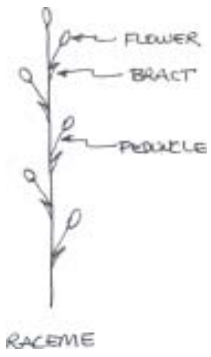
Inflorescences

Flowers are arranged on the plant in specific ways. In some plants, the flowers are found sessile or stalked in the axils of leaves and are thus said to be **axillary**. These may occur singly in the axils of leaves or in clusters. More commonly, flowers are arranged on a stem in one of several ways outlined below.

Spikes

The simplest arrangement of flowers on an elongated inflorescence is a spike. The flowers are sessile (no pedicel) and are subtended by bracts (not leaves). Don't confuse this with a long row of axillary flowers.

Figure 38. Raceme.



Racemes

Racemes are a form of inflorescence that the flowers are stalked (have a pedicel). It's a variation of a spike of flowers. Often the oldest flowers (the more mature) are found toward the base of the inflorescence and the young unopened flowers are found toward the tip. Each flower is often subtended by a bract as in the spike.

Figure 39. Panicle.

Panicles

Panicles are inflorescences where the flowers branch off the main axis of the spike. Again, bracts are present but they are found off the main spike axis. Each individual flower is not necessarily subtended by a bract.

Corymbs

Corymbs are flat-topped inflorescences where the point of origin on the pedicel is at different heights along the spike but where are the flowers are at the same level. Therefore, several of the pedicels are longer than others. Usually, in a corymb, the flowers on the periphery of the inflorescence are more mature than those towards the center.

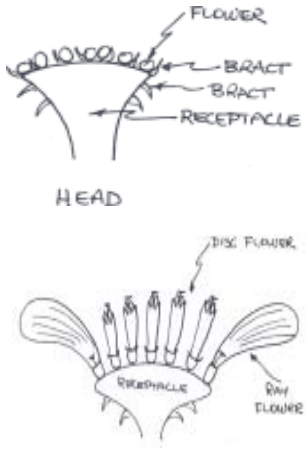
Figure 40. Corymb.

Heads

Heads are clusters of sessile flowers on a flat-topped receptacle. Look closely at the head or **composite** flower provided and notice it is an aggregation of flowers on one stalk. The flowers are often surrounded on the outside of the head by a group of bracts called the **involucre**. Heads often have two types of flowers associated with them: **ray** and **disk** flowers. Ray flowers form the petal-like structures you may have seen on sunflowers. They are the showy part of the head. Disk flowers are much less conspicuous but often make up most of the head. The disk flowers produce seed which you eat when you eat sunflower seeds. Some heads are composed exclusively of ray flowers and at other times, a head may only have disk flowers. The most common case is for their to be a mixture of both types.

Carefully dissect the head flower provided by cutting through the head longitudinally. Notice there are both ray and disk flowers. Many times, the ray flowers are sterile and do not produce fruit or seed. The disk flowers are most often fertile and produce the preponderance of seed.

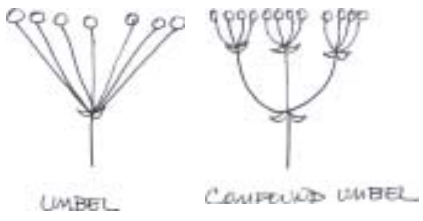
Figure 41. Types of heads.



Look at the base of disk flowers. Note the ovary. Is it superior or inferior? _____

Dissect a disk flower and notice the stamens are united by their anthers to form a tube around the style. How many branches are found on the stigma? _____ Observe the top of the ovary where the corolla tube meets the ovary. Many disk flowers have modified sepals at this point called a **pappus**. The pappus may be hairlike or hairy, scale or awn like or even absent. The pappus is often used to distribute the seed. If you have ever seen dandelion flowers, the pappus carries the seeds upon the wind. Another flower in South Florida is the Spanish Needle. The awns are barbed and needle-like and stick into your clothing. You pick them out and discard them, an excellent way of disbursing seeds.

Figure 42. Umbel and compound umbel.



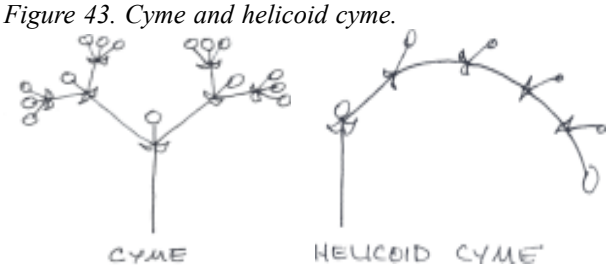
Umbels

Umbels have the pedicels arising from the same point. The umbel may be either simple or compound. Compound umbels are composed of a series of umbels.

☐ Note the inflorescence provided. Is it simple or com-

pound? _____

Figure 43. Cyme and helicoid cyme.



Cymes

Cymes are a strange type of inflorescence where clusters of flowers are found attached at several points along the stem and at same points. It's a modification of the umbel. Sometimes the cyme is modified by having the branches along a single axis. When this occurs, it is called a **helicoid cyme.**

Figure 44. Catkin.

Catkins

Catkins are modified spikes where the entire unit falls from the plant. Individual flowers do not mature and drop off, instead, the entire spike detaches from the plant. Oak trees produce catkins of male flowers.

☐ Observe the material provided. Determine whether or not the flower is perfect, imperfect, complete, or incomplete.

Spathe and Spadix

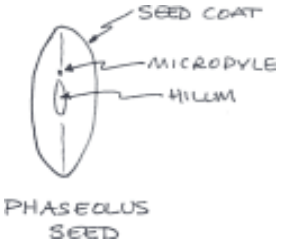
One of the more unusual inflorescences is the spathe and spadix. The spadix is a fleshy stem with sessile flowers attached. Often the spadix is surrounded by a leaf-like bract called the spathe. Often times, the flowers found at the top of the spadix are male and the flowers along the bottom are female.

☐ Try to identify as many different types of inflorescences as possible.

Fruits

A fruit is defined as a mature, ripened ovary with its accessory parts. The accessory parts may be petals, sepals, stamens, bracts, and floral tubes. Since the fruit is a mature ovary (with seeds) the ovary becomes the object of study. The ovary wall is three layered. The outer layer of the ovary wall is called the **exocarp**. The middle layer is the **mesocarp** and the inner layer is the **endocarp**. If you refer to all three layers, it is called the **pericarp.** These layers may be either **dry** or **fleshy**, depending upon the fruit.

Figure 45. Phaseolus seed showing hilum.



Fruits are also classified as to the type of flower from which they are produced and also the arrangement of the ovaries in the fruit. Remember the pistil is folded like a leaf. If the ovary was composed of a single leaf, we say it is **unicarpellate**. If more than one leaf formed the ovary, it is **multicarpellate**. Fruits are classified as **simple** if the ovary is composed of one (single) or more (compound) carpels. A fruit is said to be an **aggregate** fruit if it has numerous carpels (ovaries) on a single flower. If the fruit is composed of numerous flowers which fused together to produce the fruit, the fruit is said to be **multiple.** Examples of each type are

(1) simple: tomato
(2) aggregate: strawberry, and
(3) multiple: pineapple.

Figure 46. Funiculus and ovule.

If you cut an ovary in cross section and look within, the seeds are attached to the ovary by a **placenta**. Leading from the placenta to the seed (**ovule**) is a thin strand of tissue called the **funiculus,** analogous to the umbilical cord in hu-

mans. The funiculus attaches to the seed and often forms a scar called the **hilum**. How seeds are attached to the ovary is significant. Seeds found along the outside wall of the ovary (along the periphery) are said to exhibit **parietal placentation.** If the seeds are attached to the central core of tissue at the center of the ovary, the placentation is said to be **axile.** A third placentation is a modification of the axile. If the placenta extends only a short distance up the ovary and does not run the full length, the placentation is said to be **free-central.**

Figure 47. Types of placentation.

☐ Observe the fruit types presented and try to determine how each was placed in the specific category.

I. Simple Dry Fruits

1. Follicle. The follicle is a dry fruit composed of a single, simple ovary (thus one carpel) that **dehisces** (opens) along only one suture. An example is the milkweed pod shown. Examine the fruit and note the fruit opens along one point only (in this case, the point where the ends of the leaf fused to form the fruit). Notice on the opposite side of the opening there is a midvein, again showing evidence ovaries are simply modifications of leaves. Also note the seeds of the fruit have hairs to aid in their dispersal.

2. Legumes. Legumes are fruits that are like the follicle in that they arise from a single, simple ovary but the legume dehisces along *two* sutures. An example is the butter bean or lima bean. Notice the butter bean is opening along both the midvein of the ovary and at the point of fusion.

Peanuts are a special case in the legumes. It is an indehiscent fruit. Also, peanuts are peculiar in the way they are produced. Flowers of the peanut are found on long pedicels above the ground. When the flower is fertilized, the developing fruit is pushed under ground by an elongating pedicel and the fruit matures underground.

3. Capsule

The capsule is a fruit derived from several carpels (thus it's a compound fruit). It may dehisce by several methods. If the fruit opens along the midrib of the capsule, it is said to exhibit **loculicidal** dehiscence. If it opens along the partitions (or septa) of the capsule, it is said to exhibit **septicidal** dehiscence. Sometimes, capsules open via pores along the top of the capsule (water lilies are an example). This is called **poricidal** dehiscence.

4. Caryopsis (Grain)

A caryopsis is a fruit where the pericarp is adnate to the seed coat at all points. It is as if the ovary wall fuses to the seed. This is typical of the corn "seed" which is really a corn fruit. Corn grains are found in clusters called heads (what you call the ear of corn).

5. Achene

An achene is a fruit much like the caryopsis but the pericarp is attached to the seed only at one point. The seed actually rattles around in the expanded pericarp. The sunflower "seed" is thus really a sunflower fruit. The achenes are the ovaries of disk flowers produced on the head or composite inflorescence of sunflowers.

6. Samara

The samara is simply a winged achene. The wing of the samara is used in seed dispersal to ensure the seed finds a suitable place to germinate and grow. When samaras are released, they float to the ground in a helicopter action and float on air currents away from the parent.

7. Silique and Silicle

The silique is a modified capsule where the placenta is persistent. The walls of the ovary peel

away and expose the seeds still attached to the placenta. Many members of the mustard family produced siliques. A modification of the silique is the silicle. This is simply a shortened silique. An example is the money plant often sold in dried flower arrangements.

II. Simple Fleshy Fruits

1. Berry

The berry is a fruit where certain parts of the ovary wall (pericarp) become fleshy or succulent. In the case of a true berry like the tomato, the exocarp is skin-like, the mesocarp is fleshy, and the endocarp is fleshy or succulent.

a. Hesperidium

The hesperidium is a modified berry where the exocarp is leathery and often has oil glands. The mesocarp is spongy and the endocarp is composed of juice sacks (the part you like to eat in an orange). The spongy mesocarp is often referred to as the white part of an orange. All citrus fruits are hesperidia.

b. Pepo

The pepo is a modified berry where the exocarp is rind-like as in a watermelon. The mesocarp is also rind-like and the endocarp is the fleshy portion of the fruit. Often, this is obscured in some pepos as the gourd. The fleshy part of a gourd often dries out and leaves the center of the fruit empty except for seeds. Think of the pumpkin - a pepo.

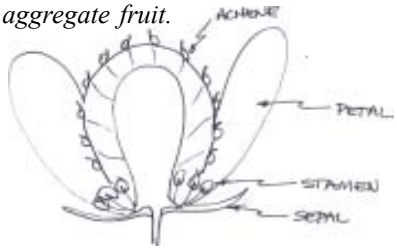
2. Drupe

A drupe is a fruit where the exocarp is skin-like, the mesocarp is fleshy and the endocarp is stony. The proverbial peach pit is not the seed but the endocarp. If you break open a peach pit you will find the seed within.

3. Pome

A pome is an accessory fruit. The exocarp is fleshy but much reduced along with the mesocarp. The endocarp is cartilaginous. It is the floral tube of the perigynous flower of the apple that forms the part you eat. What you throw away (the core) is actually mostly exo, meso, and endocarp.

Figure 48. Strawberry, an aggregate fruit.



III. Aggregate Fruits

Aggregate fruits are those fruits that are formed from a single flower but with numerous pistils and stamens. The strawberry is an aggregate fruit. The "berry" of the strawberry is really the fleshy receptacle (an accessory fruit). The so-called "seeds" of the strawberry are actually tiny achenes. Each represents an individual ovary. The stamens of the strawberry are found around the sepals and bracts.

Figure 49. Pineapple, a multiple fruit.

IV. Multiple Fruits

Multiple fruits are those fruits composed of a cluster of flowers that have fused together. Examine the pineapple and note there appear to be bracts on the surface of the pineapple. At every bract you find, there was at one time a flower. The flowers fused to form the fruit. The core of the pineapple is stem tissue used to support the flowers.

References Cited

Bold HC. 1973. Page 456 *in* Morphology of plants, 3rd ed. New York: Harper & Row.
_____. 456.
_____. 455.
_____. 458.
_____. 342.
_____. 347.
_____. 367.
_____. 364.
_____. 380-381.
_____. 487, 492, 500.
_____. 506-507, 509-510.
_____. 517, 519.
_____. 537, 540-541.

Foster AS, Gifford EM. 1974. Page 183. *in* Comparative morphology of vascular plants, 2nd ed. San Francisco: WH Freeman.
_____. 130.
_____. 161-162.
_____. 186.
_____. 221, 224.
_____. 216.
_____. 288, 290.
_____. 279.
_____. 524.
_____. 522.

Raven PH, Evert RF, Eichorn SE. 1986. Pages 353-369 *in* Biology of plants, 4th ed. New York: Worth Publishers.