Laboratory 2: Reproductive Morphology

A Review of the Plant Life Cycle

All plants have a very characteristic life cycle composed of two distinct phases or generations: a haploid (1N) gametophyte generation and a diploid (2N) sporophyte generation. The gametophyte generation produces gametes (by mitosis) which fuse in the process of fertilization to produce a diploid sporophyte. The sporophyte, in turn, produces haploid spores (by meiosis) which gives rise to new gametophytes. Because the two generations alternate with one another, this kind of life cycle is often referred to as alternation of generations (see FIGURE 1).

Some plants are homosporous, in that they produce only one type of spore, which gives rise to a bisexual gametophyte upon germination. Most plants, however, produce two morphologically different types of spores and are thus heterosporous. The larger of these spores is termed the megaspore and the smaller one the microspore. Upon germination megaspores will give rise to female gametophytes (megagametophytes) and microspores will germinate to form male gametophytes (microgametophytes). One important consequence of heterospory is that gametophytes are now rendered unisexual. Heterospory has evolved at least four times in the history of plants, yet, although it is regarded as a key evolutionary step, the advantages (if any) of heterospory have proven difficult to assess.

FIGURE 1: Generalized plant life cycle. Note that the spores are haploid because they are the products of meiosis. These spores germinate to form a haploid gametophyte. The gametophyte then produces gametes (eggs or sperm) by mitosis. Fusion of the gametes (i.e. syngamy) produces a diploid zygote that will develop into a mature sporophyte, and when this spore germinates it gives rise to a gametophyte, in this case with both male and female reproductive organs. See p. 54-58 of Simpson for further information.
For all of the plants we will study during the course of the semester the sporophyte is considered the "dominant" generation because it is larger than the gametophyte and persists (generally) from year to year. The gametophyte, on the other hand, is typically very reduced in size, especially in flowering plants. The gametophyte is independent of the sporophyte in lycophytes (Club mosses, Quillworts, etc.) and pteridophytes (Ferns, Horsetails, etc.), but in gymnosperms and angiosperms it is completely dependent on the sporophyte for its nutrition.

Reproductive Morphology

A second and perhaps more important source of characters for classifying plants utilized by systematists relates to reproduction. In fact, plant classification systems have historically focused on the structure of the reproductive organs. See pages 364-388 in Simpson for further information relevant to this lab.

Units of Dispersal

• **Spores** - For some groups of vascular plants (i.e. seedless vascular plants), such as the pteridophytes, the haploid spores that are produced are the unit of dispersal. Most of these same plants are homosporous as well, so when the spores are released from the parent sporophyte they germinate to form free-living **bisexual** gametophytes. When mature these gametophytes form both male and female gametangia, called antheridia and archegonia, respectively. Since the sperm of these plants are flagellated, free water is required for fertilization to occur. When the egg(s) is/are fertilized a diploid zygote is formed and the new sporophyte begins to develop.

• **Seeds** – Angiosperms (the flowering plants) and gymnosperms (conifers, cycads, etc.), on the other hand, use the seed as their unit of dispersal, and are thus collectively known as the seed plants. The mature female gametophyte and some additional layers of sporophytic tissue (i.e. the integuments) constitute the ovule. A seed is simply a matured ovule containing the embryo and nutritive tissue to support the embryo, which will grow into the new sporophyte. One important distinction between gymnosperms and angiosperms is that the ovules of the former are exposed ("gymno" = naked) on the cone scales, while the ovules in flowering plants are completely enclosed within a carpel. In both groups, however, if the ovule is pollinated and fertilized it will eventually develop into a seed which may then be dispersed to new habitats. Another development of the flowering plants is the fruit, which is discussed below.

The Flower

A unique innovation that angiosperms possess that other land plants do not is the flower itself. The flower is the center of reproductive activity on the plant, and also serves to attract pollinators in many cases. Pollination is a complex issue, which will be discussed in detail in a later lecture.
• **Parts of the flower** – The flower is in essence a determinate reproductive shoot that is composed of both sterile appendages (sepal and petals) and fertile appendages (stamen and carpel). All of the sepals are collectively referred to as the calyx while all of the petals are called the corolla; both the calyx and corolla together constitute the perianth.

The male reproductive structures are the stamen and they are composed of a filament and a terminal anther. The anther, or microsporangium, is where the pollen grains are made that will eventually pollinate an egg (if successful). All of the stamens are collectively referred to as the androecium.

The female reproductive structure is the carpel (=megasporophyll). It generally is composed of three distinct regions: a terminal stigma, an elongate style and at the base, the ovary (see FIGURE 2). The term pistil is often used interchangeably with carpel, and when all of the carpels in a flower are distinct (i.e. not fused together) the terms are in fact synonymous. However, if the carpels are fused, the pistil then refers to the structure as a whole, composed of several fused carpels.

It is important to mention here that not all flowers will have all of the parts mentioned above. If a flower lacks sepals, petals, stamens or carpels, the flower is said to be incomplete. Correspondingly, a complete flower has all of these appendages. Additionally, flowers may have both stamens and carpels and are called perfect or bisexual. If a flower lacks either stamens or carpels then it is imperfect or unisexual. Note that all imperfect flowers are also incomplete but an incomplete may not necessarily be imperfect. If a plant has imperfect flowers and the male and female flowers are on separate individuals then the plant is dioecious. If the male and female flowers are on the same individual then the plant is monoecious.

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**FIGURE 2**: Diagram of a complete flower.
• **Floral Symmetry** – Flowers display various degrees of symmetry, the three basic types of which are described below:
  
  **Radial** – Two or more planes of symmetry; also called “regular”
  
  **Bilateral** – One plane of symmetry; also called “irregular”
  
  **Asymmetrical** – No plane of symmetry; uncommon

• **Fusion of Floral Parts** – Floral parts are not necessarily distinct, in fact most flowers display fusion of parts to one degree or another. Fusion of like parts, such as petals united with other petals) is known as **connation**. Fusion of different parts (such as a petal and a stamen) is known as **adnation**. The process and degree of fusion differs widely among plant groups. **Note:** Adjectives describing fusion that begin with the prefix “apo-“, such as “apopetalous”, or “syn-“, such as “syncarpy”, indicate that the structures are distinct or fused respectively.

• **Insertion of Floral Parts** – **Insertion** refers to the position of attachment of floral parts. Most importantly for our concerns, this applies to the position of the ovary relative to the attachment of the perianth, corolla, and androecium. A **superior** ovary is inserted above the **receptacle**, to which the perianth, corolla, and androecium are attached. An **inferior** ovary is inserted below the attachment point of the perianth, corolla, and androecium. In some flowers with superior ovaries, and in all flowers with inferior ovaries (although not necessarily obvious), the perianth, corolla, and androecium are attached to a structure known as the **hypanthium** or floral cup. In the case of inferior ovaries, the hypanthium is adnate (fused) to the ovary to some degree.

• **Placentation** – Ovaries are divided into ovules in varying patterns or types **placenta**. This is often an important feature for distinguishing fruit types and frequently has phylogenetic implications.

• **Inflorescence Types** – An inflorescence is simply a cluster of flowers and their arrangement on a plant can be useful in identification. The main stalk of an inflorescence is known as a **peduncle**, whereas an individual flower stalk is known as a **pedicel**. A few of the more common types are listed below:
  
  **Cyme**: determinate growth, peduncle present, various flower types.
  
  **Spike**: indeterminate growth, peduncle present, flowers sessile.
  
  **Raceme**: indeterminate growth, peduncle present, flowers pedicellate.
  
  **Panicle**: a compound raceme.
  
  **Umbel**: flowers pedicellate, all originating from single point.
  
  **Head/Capitulum**: indeterminate growth, peduncle absent, flowers sessile.

**Fruits and Seeds**

Seeds develop from fertilized ovules. Note that not all vascular plants produce seeds because not all vascular plants have ovules. As mentioned above pteridophytes and lycophytes disperse to new environments through the dissemination of spores, whereas gymnosperms and angiosperms disperse seeds. The seed is composed of a seed coat (=integuments), nutritive...
tissue (haploid megagametophyte tissue in gymnosperms and triploid endosperm in angiosperms) and the embryo. In angiosperms, the ovary surrounds the seeds and the two together, when ripe, constitute the fruit of a flowering plant. Gymnosperms, although they produce seeds, are not said to produce fruits because the seeds are not contained within a carpel (remember that the ovary is that part of the carpel that contains the ovules).

The fruit is a matured ovary, the seeds it contains, and any fused parts derived from hypanthium, perianth, or receptacle tissue. Cucumbers, avocados, squash, and tomatoes, all of which are considered vegetables by many people, are all fruits because they contain seeds. Fruits that derive from one flower are called simple, and these include aggregate fruits that derive from separate carpels in the same flower (such as Rubus, the genus that includes blackberries and raspberries). A multiple fruit is derived from several tightly clustered flowers (such as Ananas, the genus that includes pineapples). A fruit that opens or breaks in some fashion is called dehiscent, whereas those that remain closed are called indehiscent.

There are many names for the specific types of fruits, and certain groups have fruit types unique to that group; a few of the more common types of fruits are listed below:

- **Berry**: indehiscent, fleshy, 1-many seeds (e.g. grapes, melons, citrus fruits)
- **Drupe**: indehiscent, fleshy, 1 or more hard pits (or “stones”) containing seeds (e.g. peaches, coconuts, walnuts)
- **Pome**: indehiscent, fleshy, seeds enclosed by cartilaginous structures (e.g. apples, and most of the remainder of the Ros family)
- **Nut**: indehiscent, dry, with a hard wall surrounding 1 seed, usually large (e.g. hazelnuts)
- **Achene**: indehiscent, dry, with a thin wall surrounding 1 seed, usually small (e.g. sunflowers)
- **Capsule**: dehiscent, usually dry, derived from multiple carpels, opening in multiple ways (e.g. poppies, morning glories)
- **Follicle**: dehiscent, usually dry, derived from 1 carpel, opening along a single suture (e.g. oleander, milkweed)

**Exercises:**

- Look at the fruits on display. Can you see and identify any other floral appendages that are still adhering to the fruit?

- Examine and dissect several different kinds of flowers on display and be sure that you can identify each of the flower parts discussed above. Are they perfect or imperfect? Complete or incomplete? What plant organ do you suppose these floral structures are derived from? Why do you think so?

- Examine the different inflorescence types on display. Are the flowers sessile or stalked? How are they arranged on the stem? Are there any examples of flowers occurring singly (i.e. solitary)?