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.

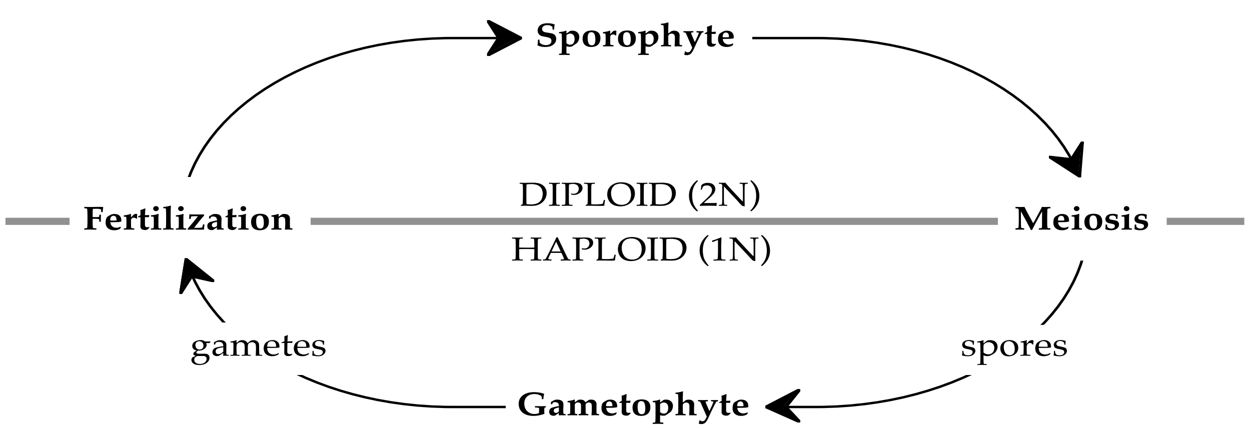


FIGURE 1: Generalized plant life cycle. Note that the spores are haploid because they are the products of meiosis. These spores germinate to form a haploid gametophyte. The gametophyte then produces gametes (eggs or sperm) by mitosis. Fusion of the gametes (*i.e.* syngamy) produces a diploid zygote that 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

In the last lab, we looked at vegetative 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 lycophytes and pteridophytes, the haploid spores that are produced are the unit of dispersal. Most of these plants are homosporous, 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 an egg is 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

An 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 (**sepals** and **petals**) and fertile appendages (**stamens** and **carpels**). 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 **stamens** 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; they are then 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 flower 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**.

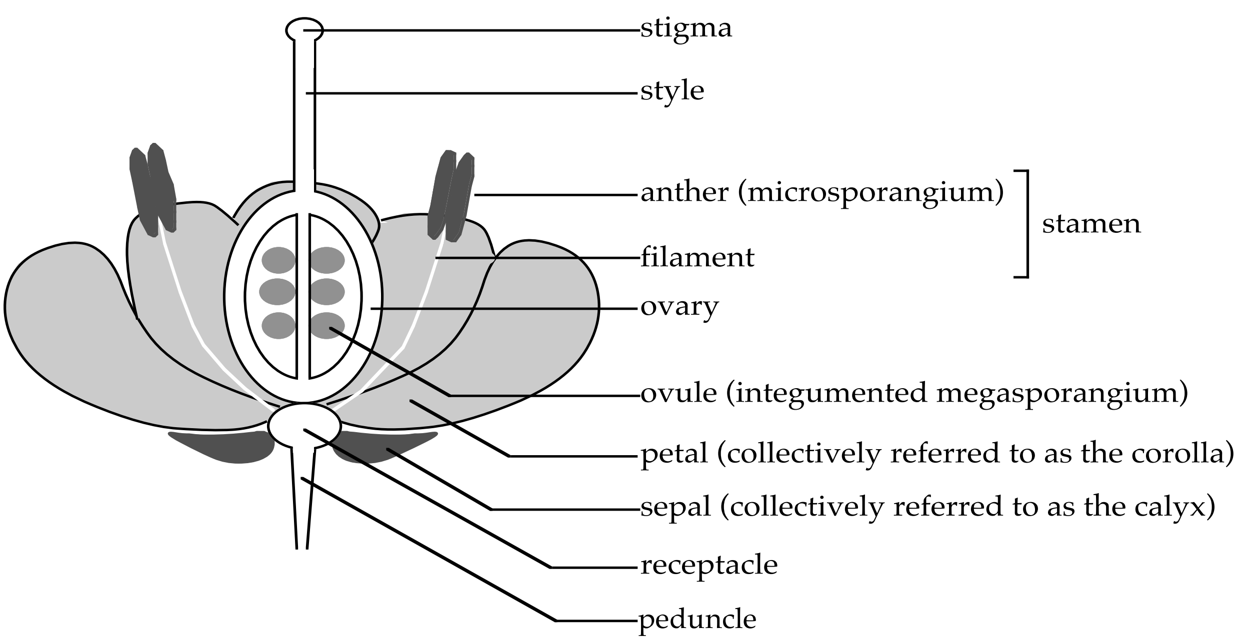


FIGURE 2: Diagram of a complete flower.

• ***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 (*i.e.*, petals and sepals) and androecium (*i.e.*, stamens). A **superior** ovary is inserted above the **receptacle**, to which the perianth and androecium are attached. An **inferior** ovary is inserted below the attachment point of the perianth and androecium. In some flowers with superior ovaries, and in all flowers with inferior ovaries (although not necessarily obvious), the perianth 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 with varying patterns or types of **placentation**. 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: 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, lycophytes and pteridophytes 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**. **Aggregate** fruits are derived 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 Rose 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)

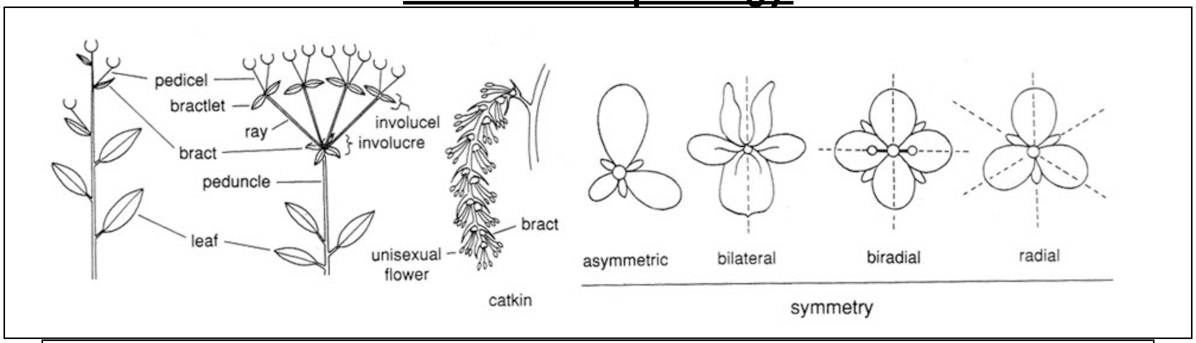
Exercises:

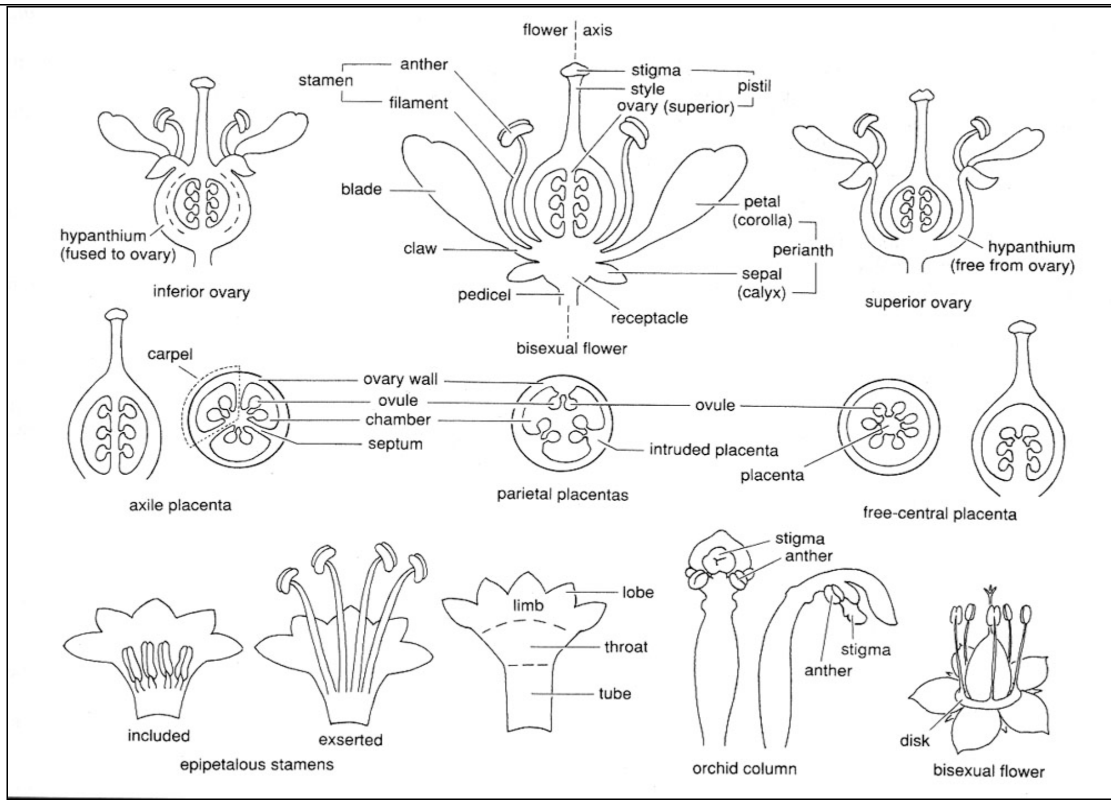
• Look at the fruits on display. Can you see and identify any other floral appendages that are still adhering to the fruit?

• 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?

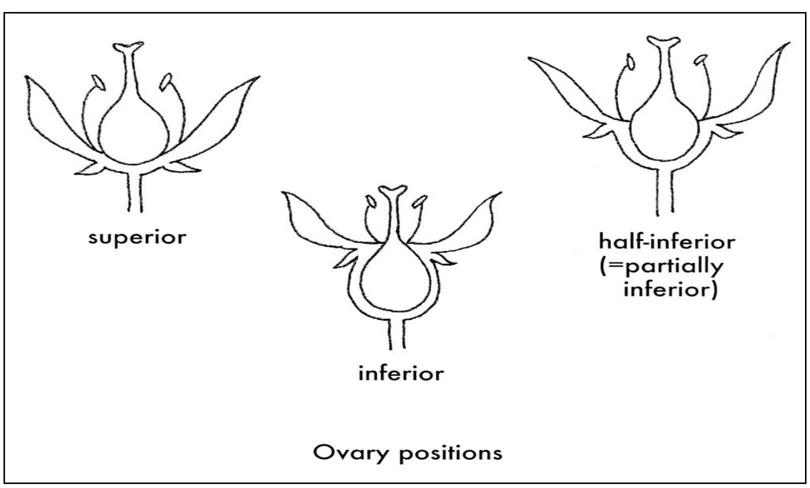
• Examine the different inflorescence types on display. Are the flowers sessile or stalked? How are they arranged on the stem? Are there any examples of flowers occurring singly (*i.e.* **solitary**)?

Flower Morphology





[Figures from p13-26. Hickman(ed.). 1996. *The Jepson Manual: Higher Plants of California*,]



Inflorescence Types

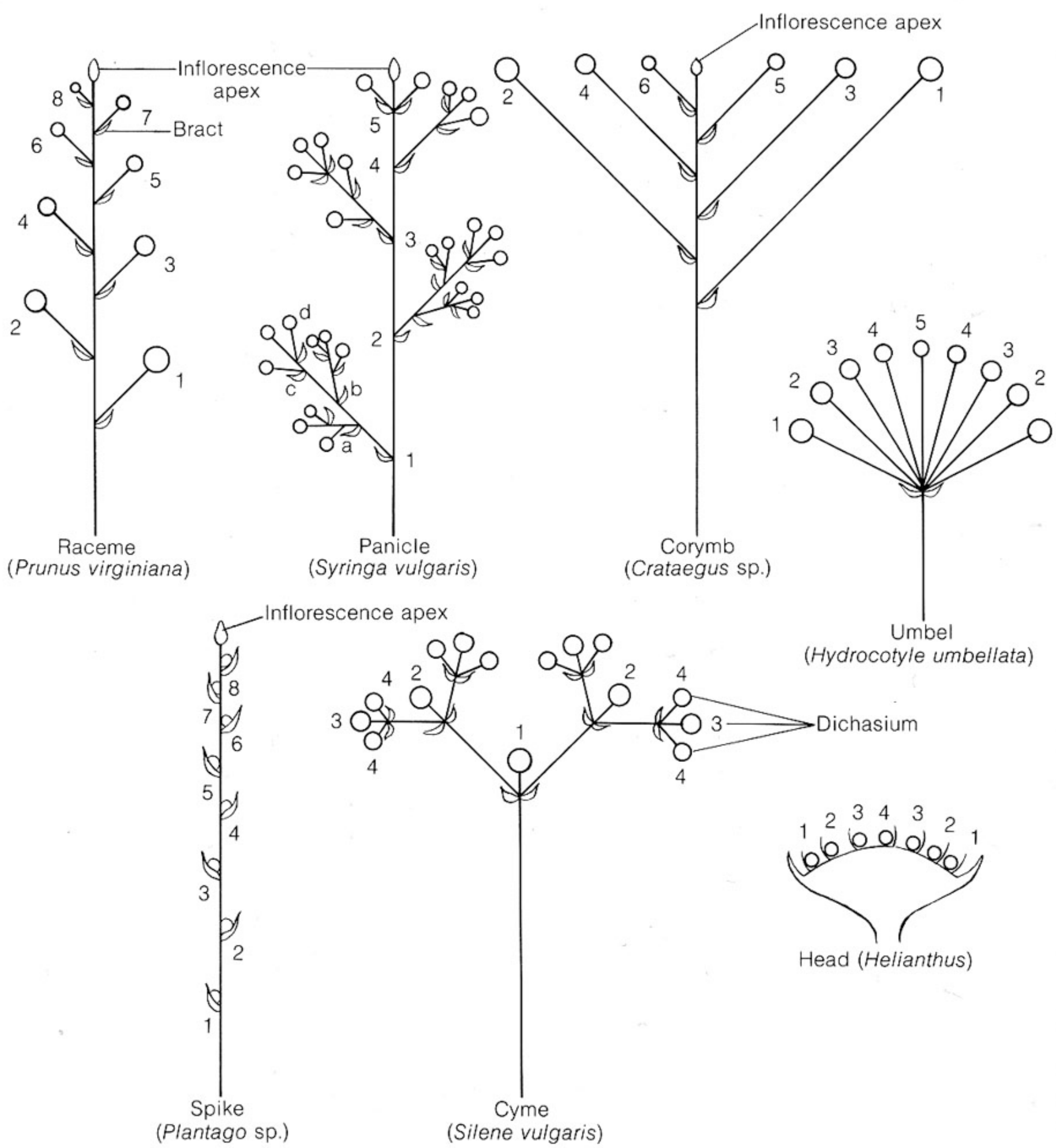


FIGURE 19-63 Diagrams of some of the common types of inflorescences in the angiosperms. Flowers are represented by circles and their order of development indicated in numerical sequence; in each inflorescence, flower 1 is the oldest in the group. The letters a–c, in the diagram of the panicle, depict the sequence of flower development in one of the lowest branches. See text for further explanation. [From *A Textbook of General Botany,* 2d edition, by R. M. Holman and W. W. Robbins. Wiley, New York. 1928.]

[Figure from p554, Gifford & Foster, 1989. *Morphology & Evolution of Vascular Plants.*]

Fruit Terminology

A CLASSIFICATION OF FRUIT TYPES

There are two ways of approaching the classification and naming of fruits. One is essentially morphological. Fruits are distinguished by their fleshiness, dehiscence, carpel number, etc. The second view is basically taxonomic. A particular fruit is given a name because of the family to which the plant belongs, with little regard to certain details of its structure. Following this view, the legume is the fruit of the Leguminosae, regardless of its general appearance. The scheme presented below is an artificial grouping of the traditionally recognized fruit types.

A. Dry fruits

B. Fruits 1-seeded and indehiscent

achene (=akene)-seed and pericarp attached only at the funiculus, the seed usually tightly enclosed by the fruit wall, as in the sunflower and buckwheat

cypsela-an achene with an adnate calyx, as in the aster family

utricle-a small, bladdery achene-like fruit with the seed loosely surrounded by the fruit wall, as in the pigweed

caryopsis (=grain)-seed and pericarp completely fused, as in the grass family

samara-a winged achene, as in the elms and ashes

nut-derived from a syncarpous gynoecium, but 1-seeded by abortion of carpels; exocarp usually hard; the fruit often subtended by an involucre; walnut, acorn

nutlet-a small nut

schizocarp-derived from a syncarpous gynoecium, the carpels separating from one another into 1-seeded indehiscent segments, as in the mallow and parsley family

B. Fruits 2-to many-seeded and dehiscent

capsule-derived exclusively from a syncarpous gynoecium; typically several-to many-seeded (rarely 1-seeded); several types are recognized:

poricidal-opening by a series of pores near the top, as in the poppy

pyxis (=circumscissile)-opening by a lid, as in the purslane

denticidal-opening apically, leaving a ring of teeth, as in the chickweeds

loculicidal-dehiscing lengthwise, the sutures opening within a locule, as in the iris

septicidal-dehiscing lengthwise, the sutures splitting a septum, as in the yucca

silique-gynoecium bicarpellate, the walls peeling away from a papery central partition (replum); the fruit type of the mustard family

silicle-a silique which is not more than 2-3 longer than wide

legume-unicarpellate, dehiscing along both sutures; the fruit type of the pea family

loment-a legume with pronounced constrictions between the seeds; dehiscing transversely between the seeds

follicle-unicarpellate, dehiscing along one suture; note that a follicle may be found in the apocarpous gynoecium (each carpel forming one, as in the rose and magnolia family) or the syncarpous gynoecium by means of the separation of carpels at maturity, as in the milkweeds

A. Fleshy fruits

C. "True fruits" (derived from a syncarpous gynoecium of a single flower)

drupe-exocarp the "skin"; mesocarp fleshy; endocarp bony; the seed and endocarp constitute a **pyrene;** peach

berry-entire pericarp soft, as in the tomato or grape

pepo-a berry with a leathery rind; derived from an inferior ovary; use often restricted to the squash family

pome-ovary inferior, surrounded by fleshy tissue usually interpreted as a hypanthium, as in the apple or pear

hesperidium-ovary superior; septations conspicuous, these lined with fleshy hairs; restricted to the citrus fruits

C. "False fruits" (the structures resulting from the coalescing of the separate true fruits of an apocarpous gynoecium or the coalescing of the fruits from an entire inflorescence)

accessory-fruit formed from the expanded dome-like receptacle of a single flower; covered with numerous achenes; known only in the strawberry and false strawberry

aggregate-fruit formed from the many separate dry or fleshy fruits of a single flower, as in the raspberry or magnolia

hip-a vase-like leathery hypanthium containing several achenes; restricted to the rose

multiple-fruit derived from the fusion of an entire inflorescence, as in the pineapple or sycamore

syconium-a hollow, vase-like inflorescence with the flowers lining the inside; restricted to the fig

[Text from Smith, 1977. *Vascular Plant Families.*]

Fruit Types - Examples

-67-

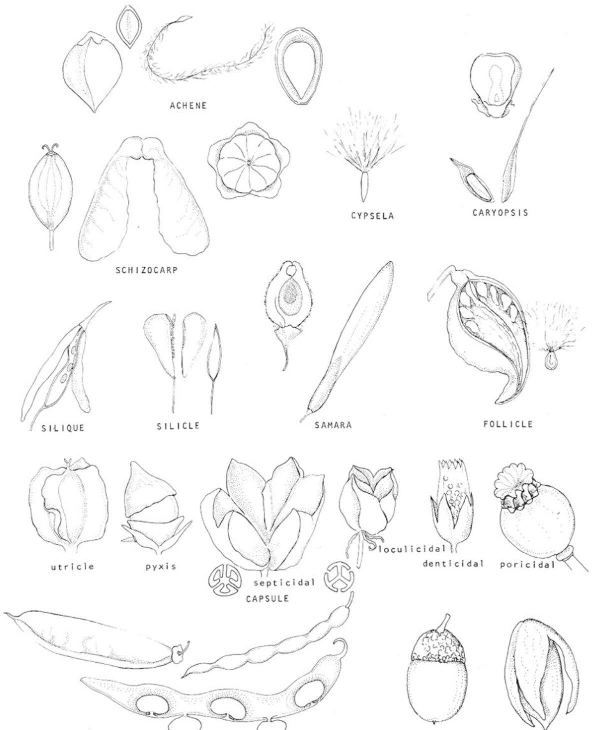


Fig. 19. **Dry fruit types.**

-68-

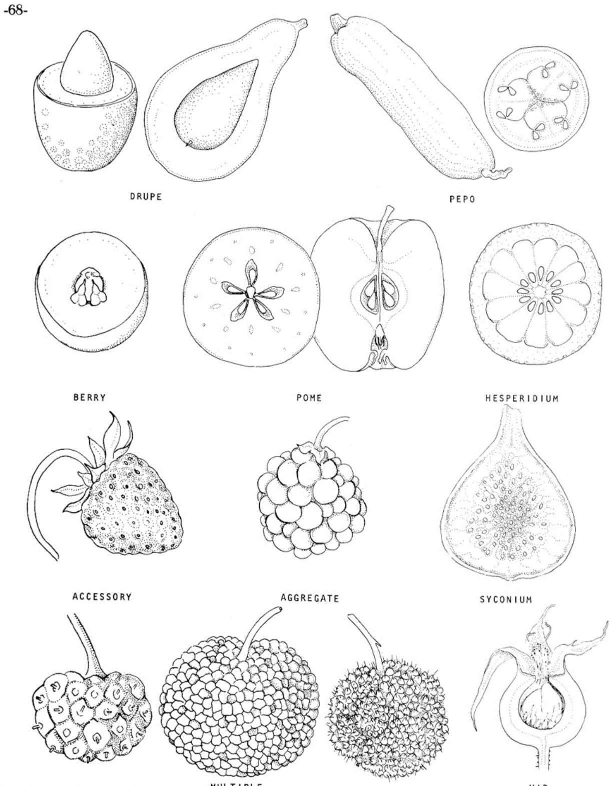


Fig. 20. **Fleshy fruit types.**

[Figures from Smith, 1977. *Vascular Plant Families.*]