Biology210 Laboratory

ANGIOSPERMS

Angiosperm (Flowering Plant) Reproduction

Raven 6th, p. 495-515; 7th, p. 434-451

A. Introduction

You studied the morphology and anatomy of the stems, roots, and leaves of the angiosperms in the first weeks of the term (labs 2 - 5). In Lab 9 we will concentrate on angiosperm reproduction.

The flower is the distinguishing characteristic of the angiosperms (the 'flowering plants'). In the majority of the angiosperms each flower contains both male and female parts, that is, the flower is **bisexual**. In some species, however, either the male (**stamens**) or the female parts (**carpels**) are lacking and the individual flower is male (**staminate**) or female (**carpellate**). If both staminate and carpellate flowers grow on the same plant, the species is **monoecious**; if they grow on separate plants the species is **dioecious**. The shape, arrangement and number of floral parts are useful features for identification, and depending on the pollinating agent, some or all of these parts may be variously modified. Microspores are produced by meiosis in **anthers** (part of the stamen) and develop into **pollen grains** (microgametophytes). In the carpel, megaspores (produced by meiosis in **ovules** in an **ovary**) develop into a megagametophyte (**embryo sac**).

Pollen grains are transferred to stigmas (receptive surface) most commonly by the wind, insects, or birds. Pollen tubes grow down the **style** to the ovules (Fig. 9-1). Double fertilization. unique to angiosperms, then occurs. One sperm fuses with the egg to form the zygote, and the other unites with the polar nuclei to initiate **endosperm** development (the nutritive tissue for the growing embryo). Following fertilization, the ovules become seeds and the ovary (plus or minus accessory structures) develops into the **fruit**. Fruits protect the seeds and are especially important in aiding seed dispersal by a variety of mechanisms.

B. Morphology of Flowers

A flower is a specialized reproductive shoot consisting of an axis bearing a maximum of four sets of 'appendages': **sepals**, **petals**, **stamens**, and **carpels**. (Fig. 9-1). If all four sets of appendages are present, the two outer sets are sterile. The outermost ones are the sepals. These are usually greenish, leaf-like, and in the bud they cover the other floral parts. The sepals are collectively (all sepals within one flower) called the **calyx**. Inside the calyx are the petals, which are usually more brightly colored and less leaf-like than the sepals. Collectively the petals are called the **corolla**. The calyx and corolla together are known as the **perianth**.

If the flower is radially symmetrical it is called **actinomorphic,** if bilaterally symmetrical it is **zygomorphic**.

The two innermost sets of appendages are concerned directly with reproduction. To the inside of the perianth are the stamens. Each stamen consists of a stalk, called a **filament**, and an **anther**, which contains four microsporangia. The stamens are collectively called the androecium. Carpels, collectively called the gynoecium, are

in the centre of the flower. Carpels are modified megasporophylls enclosing ovules. Each flower may have a single carpel, or several carpels which are either separate or fused into a single structure. A pistil is a structure that can be one carpal or a number of fused carpels. It is made up of: a basal **ovary** (which contains **ovules**); a receptive surface for the pollen grains, called a **stigma**; and a stalk connecting the ovary and stigma, called a **style** (see Fig. 9.1 below). Each space within the ovary is termed a **locule**.

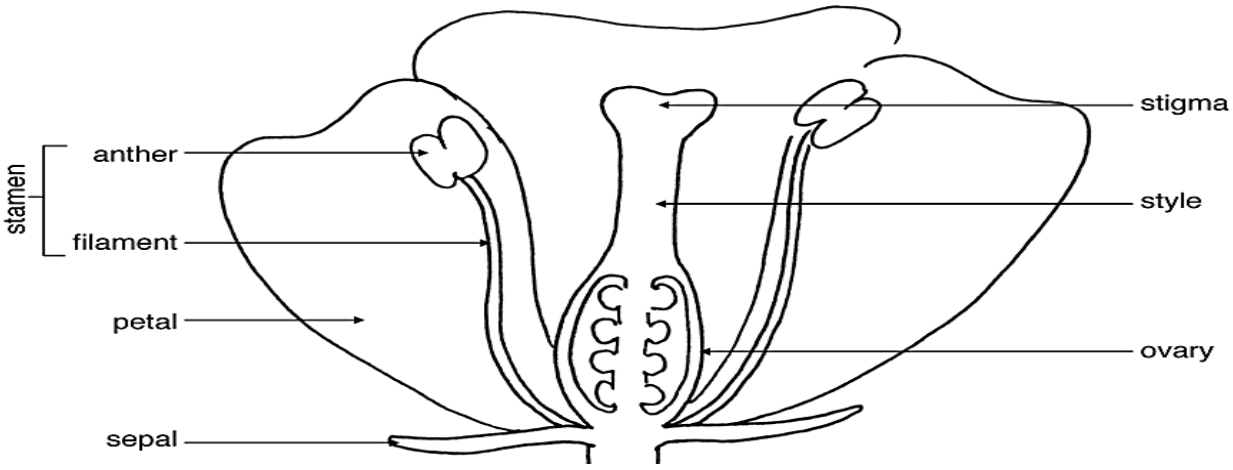

Fig. 9-1 DIAGRAM OF A "TYPICAL" FLOWER

- *Forsythia* Flower -

Examine a *Forsythia* flower under the dissection microscope. Tease apart the flower with a dissection needle, and identify as many of the structures mentioned above as possible. Note how the different parts are arranged to form the flower. Like the majority of flowers, the *Forsythia* is bisexual.

C. Development of Ovule & Seed

Recap (Seedless Vascular Plants): In the lycophytes and monilophytes, the diploid sporophyte is the dominant and obvious generation, alternating with an independent, relatively inconspicuous haploid gametophyte. In homosporous species (spores of one size only) the gametophyte develops from one type of haploid spore and bears both male and female reproductive structures whereas in heterosporous species (spores of 2 sizes; mega- and microspores) microspores develop into microgametophytes and megaspores into megagametophytes.

Seed Plants: Gymnosperms and the angiosperms are heterosporous. The microspore develops into the pollen grain - the pollen grain **is** the microgametophyte. The megagametophytes are not free-living, but remain on the sporophyte in an ovule which will ultimately develop into a seed (sperma means seed in Greek). In conifers, megagametophytes, complete with archegonia, develop from megaspores

within ovules of female cones upon the parent plants. Likewise in flowering plants a megaspore develops into a megagametophyte within an ovule. The ovule(s) is enclosed within the ovary, upon the parent plant. The megagametophyte in angiosperms is called embryo sac; archegonia are not present.

- The Mature Ovule (=the seed) -

There are several different types of seed. Seed development varies in behaviour, function and number of the cotyledons (seed leaves) and in the amount of endosperm remaining in the completely developed seed. We will look at only one common type.

- *Phaseolus coccineus* (scarlet runner bean) seed -

Examine the outside of the seed. Note the tough seed coat (which has been softened by soaking it) and, on one edge, the scar or **hilum** where the seed was attached to the placenta. Above that, the **micropyle** is visible as a small pore. Carefully peel away the seed coat. The bulk of the seed consists of the two cotyledons (seed leaves) between which (break them apart carefully) lies the rest of the embryo. You may be able to see the **radicle**, from which the root will develop, and the **plumule**, which will develop into the shoot (stem and leaves). The endosperm of the bean is completely digested by the developing embryo and is not present in the mature seed.

D. Flowers of Selected Species of the Angiosperms

There are several possible arrangements of floral parts relative to the ovary and of ovules within the ovary (see Fig. 9-2).

For floral parts/ovary insertion, a flower is said to be:

1. **hypogynous**: sepals, petals and stamens are attached to the receptacle below the ovary. The ovary in this case is superior.
2. **perigynous**: sepals, petals and stamens fused to form a cup-shaped structure called a hypanthium which is inserted beneath the ovary. The ovary in this case is still superior.
3. **epigynous**: sepals, petals, and stamens arise from the top of the ovary, or from a hypanthium inserted on the top of the ovary. The ovary of an epigynous flower is inferior.

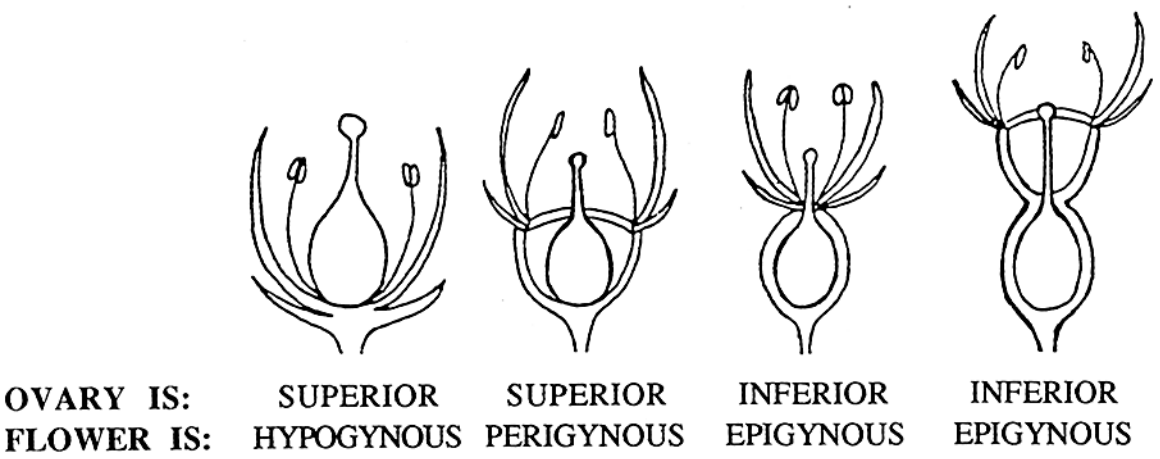

Fig. 9-2 HYPOGYNOUS, PERIGYNOUS AND EPIGYNOUS FLOWERS

The flowers in the lab have been chosen to illustrate these variations in ovary insertion and ovule attachment.

With respect to the attachment of ovules within the ovary, the ovules may be:

1. attached to the ovary wall, or to projections from the wall = parietal placentation.
2. attached to a central column in an ovary with more than one locule = axile placentation.

- Slide of ovary types - DEMO only

The place where the ovules are attached to the ovary is called the **placenta**. The slide on demonstration was prepared from cross-sections through four different flower ovaries. Identify and draw the two which show parietal and axile placentation. (see Raven 6th, p. 501, Fig. 21-9; 7th, p. 440, Fig. 19-9).

- *Tulipa* (tulip) flower -

The tulip is a good example of a regular hypogynous flower with a superior ovary. There are three petals and three petaloid (like a petal in colour and structure) sepals. When petals and sepals look similar they are called tepals. Observe the stamens and, if they are mature, the dehiscence (opening up) of the anthers. There is no style and the stigma is usually three-lobed. One lab partner should section the ovary longitudinally while the other does a cross-section. Compare your sections to determine the number of locules and the type of placentation.

In lab today you will get the opportunity to dissect a number of different types of flowers. The diversity we see in floral structure is a consequence of co-evolution with pollination vectors such as insects. The conifers we examined last week are wind pollinated and therefore do not have elaborate ways of attracting pollination vectors.

They produce copious amounts of pollen that are discharged into the wind. -

Wind pollination does occur in flowering plants as well and most people find their floral structures unremarkable (not really true once you take a closer look, especially at the grasses). When you examine the flowers on display consider how each flower attracts the pollinator with colour and fragrance, how pollination is accomplished (floral structure), and how the animal is rewarded for its effort. Refer to Appendix, page ii to help you with your investigation.

- *Antirrhinum* (snapdragon) or *Mimulus* (monkey flower) flowers -

Examine a flower under the dissection microscope. This is an example of a bilaterally symmetrical (**zygomorphic**) flower. Note number and position of the stamens. When an insect pollinator enters this flower on which side of its body would pollen be deposited? Identify the flower shape and the potential pollinator of this flower (refer to the Appendix, page ii)? Squash the anthers under a coverslip and note the round pollen grains under the compound microscope. Examine the ovary. What type of placentation? How many locules?

- *Narcissus* (daffodil) flowers -

In some flowers the upper part of the receptacle is expanded to form a tube upon which are borne sepals, petals and stamens together forming a ring or cup around the ovary. This structure is called an **hypanthium**. Identify the flower shape and the potential pollinator of this flower (refer to the Appendix, page ii)?

Examine a flower of *Narcissus* and compare it with Fig. 9-2 and 9-3. Is the *Narcissus* flower epigynous, perigynous, or hypogynous? The first thing to look for is the position of the ovary. Note that the corona (or trumpet) of the daffodil is an extension of the perianth (not part of the hypanthium). One lab partner should section the ovary longitudinally, while the other does a cross-section. Compare your sections.

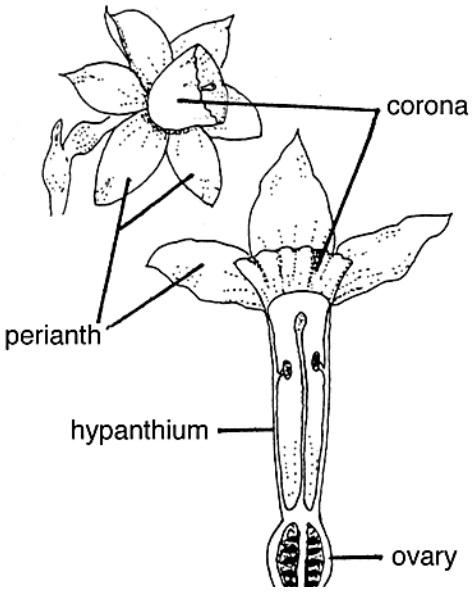

Fig. 9-4 *NARCISSUS* FLOWER

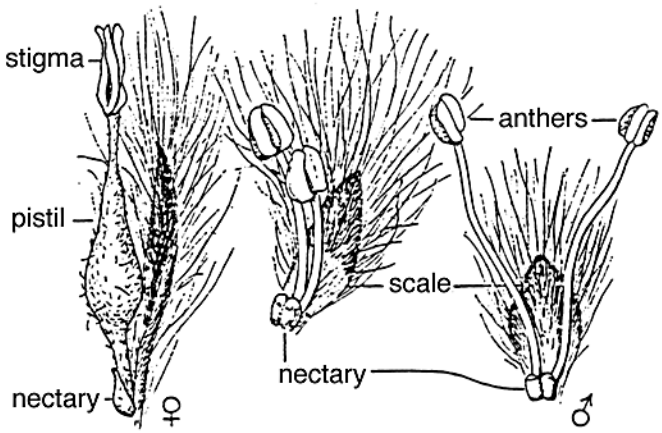

Fig. 9-5 *SALIX* FLOWERS

- *Prunus* (cherry) flower -

Examine a cherry flower under the dissection microscope. Note the cup-shaped hypanthium to which the stamens, sepals and petals are attached. What is the position of the ovary with respect to the other flower parts (see Fig. 9-2)? What type of flower is this? How many ovules would you expect to find in the ovary?

Identify the flower shape and the potential pollinator of this flower (refer to the Appendix, page ii)?

- *Salix* (willow) flower -

Male and female *Salix* flowers are borne in catkins (elongate clusters of many individual unisexual flowers) on separate plants (i.e. a **dioecious** condition). There is no perianth, and the carpels and stamens are borne in the axils of hairy bracts. Identify the flower shape and the potential pollinator of this flower (refer to the Appendix, page ii)? Examine male and female catkins and try to remove an individual flower from each. Note the glands (nectaries) at the base of each flower. Pollen can be transferred to female flowers by wind and/or insects. The flowers are modified to accomplish pollination either way by (a) long exserted stamens on long, pendulous catkins to accommodate wind pollination and (b) nectaries at the base of the bracts in carpellate and staminate flowers to attract insects (see Fig. 9-4). The fruit (a **capsule)** is covered with silky hairs. How would you expect the seeds to be dispersed?

- *Pericallis* (cineraria) or other composite

Pericallis is a member of one of the largest families of flowering plants, the Asteraceae, commonly called the 'composites'. What appears to be a single conspicuous flower is really a dense cluster or 'head' of small and inconspicuous flowers of two types. Identify the flower shape and the potential pollinator of this flower (refer to the Appendix, page ii)? The central disk flowers are tubular and epigynous with 5 stamens and an ovary with a single ovule. The ray flowers on the outer edge of the head are carpellate with one strap-shaped petal. (See Raven 6th, p. 527, Fig. 22-12; 7th, p. 459, Fig. 20-9).

Observe an entire head with your dissecting scope. Note that all the disk flowers are not at the same stage of development, an arrangement which ensures pollination at different times and therefore probably from different sources (refer to Fig. 9-5). Cut the head in half longitudinally. Observe the receptacle to which all the flowers are attached and the greenish bracts beneath the receptacle.

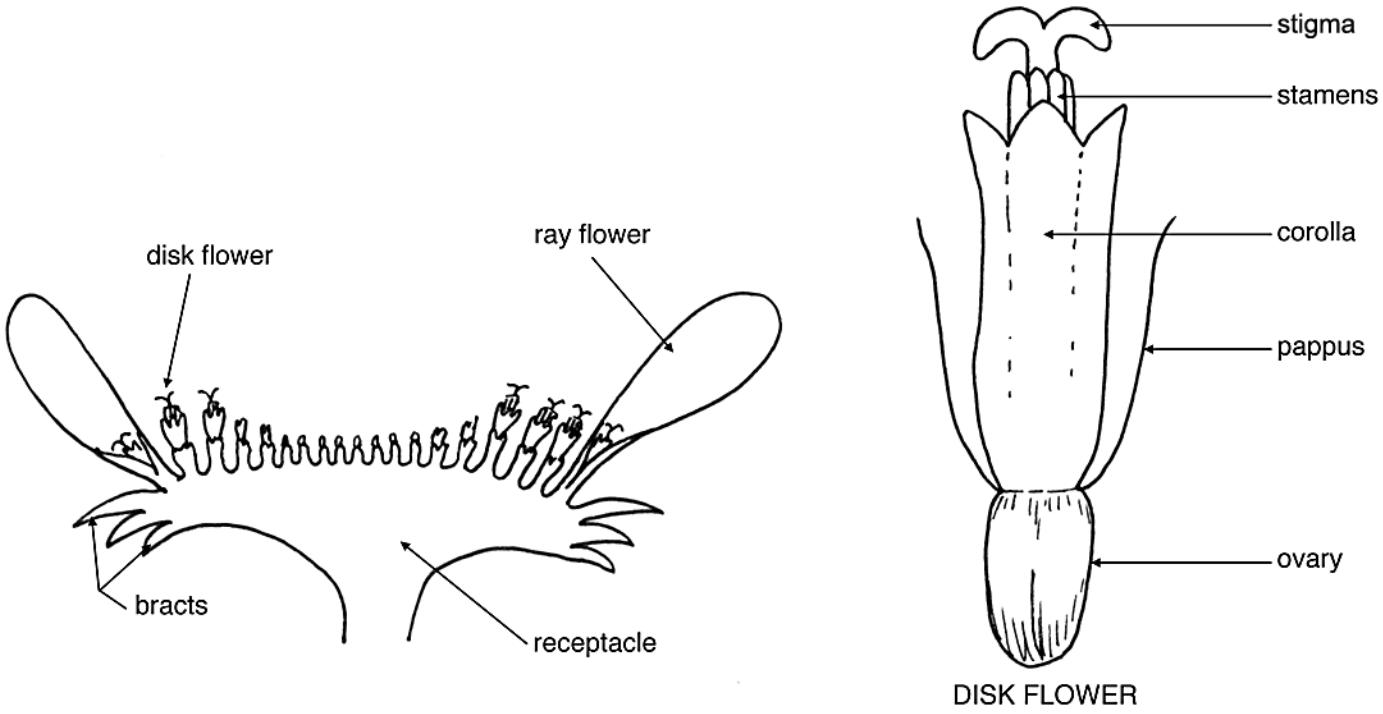

Fig. 9-5 COMPOSITE FLOWER

Detach a single ray flower from the periphery of the head and look for the style, stigma and ovary with one ovule (if you carefully cut into the ovary you can see the ovule). Now detach a disk flower and note the number of lobes of the corolla and the 5 stamens. The stamens have 5 free and separate filaments but their anthers are united in a ring around the style. Again, look for the ovary and ovule and determine their position relative to the other flower parts. You may also see a **pappus** (modified sepals) in the form of fine hairs attached at the base of the corolla. When the fruit is mature the pappus will aid in its dispersal by wind (as in a related plant, the dandelion).

Examine the flowers on demonstration. Refer to Appendix, page ii to determine the flower type and pollinator. Also consider how the flower attracts the pollinator and rewards it.

FLOWER:	FLOWER TYPE	POLLINATOR (PREDICTED)	REASON FOR YOUR CONCLUSION
A			
B			
C			

E. Development of the Fruit from the Flower

- *Solanum esculentum* - formerly *Lycopersicon esculentum* (tomato) flowers -

Examine a *Solanum* flower under the dissection microscope. Carefully dissect the parts, observing the sepals, petals, stamens, and carpel. The stamens are fused to the bases of the petals and have short filaments and elongated anthers. Are the anthers free or fused to each other? Note the position of the stigma. The ovary is divided into two main lobes like other members of the Solanaceae family (potato, tobacco, nightshade, etc.). Some cultivated tomatoes, however, have three or more lobes. What is the type of placentation? The pollination system of this type of flower is very interesting. It is called buzz pollination because bees hang from the flowers and buzz. The vibrations cause the release of pollen onto the underside of their abdomen. Pollen is an nutritious food source for bees. They are very good at collecting pollen from their bodies with combs on their legs.....but not good enough as some is left to be transferred to another flower - pollination accomplished!

- *Solanum esculentum* (tomato) fruit -

Take a fruit of *Solanum* and note the attachment of the sepals. Make a cross section of the fruit and compare the parts and their arrangement to those you observed in the flower. What did the fleshy part of the fruit develop from? What processes had to occur for the ovules to become seeds? How would you expect these seeds to be dispersed? What type of fruit is a tomato (refer to Fig. 9-7, Appendix page iii)?

- *Fragaria* (strawberry) flower and fruit demonstration -

Examine the strawberry flower on demo, noting particularly the arrangement of carpels. Many simple carpels (each with one ovary containing one ovule) are attached to the surface of the receptacle. After fertilization, the seed coat and ovary wall fuse to form a dry fruit (an **achene**) and these remain embedded on the surface of the swollen, red receptacle. It is the enlarged, reddened, tissue of the receptacle we find edible and appealing. Look at Fig. 9-6.

Compare the flower with the fruit. What type of fruit is the whole strawberry? (See Fig. 9-6, and pg *iii* of Appendix.) Why does the strawberry fit into more than one fruit category?

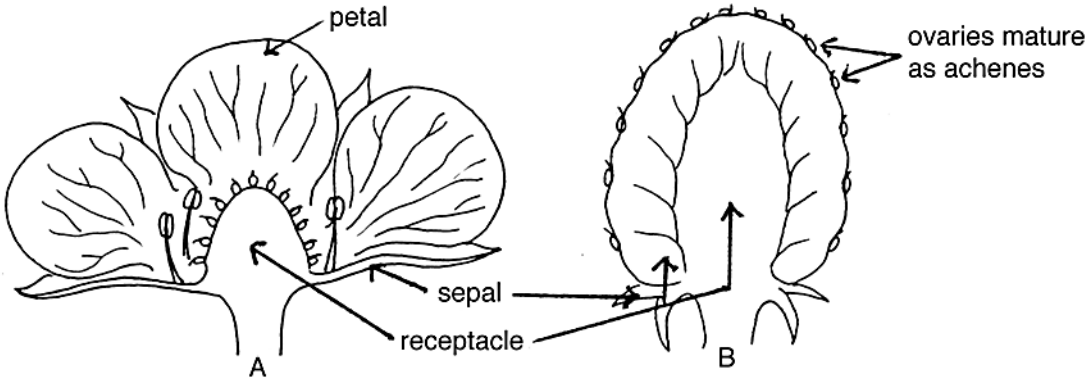

Fig. 9-6 *FRAGARIA* FLOWER (A) AND FRUITS (B)

F. Fruits of Selected Species of Angiosperms

Mature fruit is classified based on how many flowers or carpels/ovaries the structure developed from and whether or not it is fleshy or dry at maturity (refer to Fig 9-7 and page *iii* of the Appendix). The fruit wall is called the **pericarp** and it is often divided into three distinct layers: **endocarp** (inner), **mesocarp** (middle), and **exocarp** (outer) The great diversity of fruit types reflect the many different fruit dispersal mechanisms. Examine the samples on display and determine their fruit types (refer to Fig 9-7 and then page *iii* of the Appendix). Complete the table on the next page.

FRUIT:	FRUIT TYPE	REASON(S) FOR ANSWER
A		
B		
C		
D		

- *Ananas comosus* (pineapple) fruit -

The cultivated pineapple is a parthenocarpic fruit and it is usually seedless. A parthenocarpic fruit is a fruit that will develop and ripen without seeds if it is not pollinated and fertilized. Most fruits will abort if not pollinated, or if seeds fail to develop. Pineapples are self-incompatible so they will not produce seeds if pollinated with their own pollen. If clones with different incompatiblity alleles are grown near each other, pollination and fertilization may occur resulting in seedy pineapples. These, of course, are undesirable for marketing.

Each pineapple develops from a stalk bearing many flowers, each flower is surrounded by a bract; the whole inflorescence becomes a single pineapple. The edible part of the fruit consists of the coalesced tissues of the ovaries, the fleshy bases of the sepals and bracts, and the cortex of the flower stalk. The tough core of the pineapple is the inner part of the flower stalk.

Note the arrangement of the individual rhomboidal units on the pineapple. Each one is a whole fruit (a berry) developed from a single flower. The outer rind or shell consists of the upper parts of the sepals and bracts. Dissect one rhomboidal unit and cut through it longitudinally. You will find a small chamber just under the rind. Within the chamber are the withered remains of petals, stamens and style. Beneath the chamber you can find cavities within which are small, oval, white aborted ovules. Consult Fig. 9-7. What type of fruit is the pineapple?

BASIC FRUIT TYPE

Simple
develops from one carpel or several united carpels

Aggregate
develops from a number of separate carpels in one flower

Multiple
develops from more than one flower

Fig. 9-7 FLOWER AND BASIC FRUIT CATEGORIES
- Refer to Appendix iii

H. W.O.W.

aggregate fruit

calyx

carpel, carpellate, pistil, gynoecium, stigma, style, ovary

dehiscent

dioecious

epigynous

hypanthium

hypogynous

indehiscent

infloresence

irregular flower

locule

micropyle

multiple fruit

ovary: simple vs compound; inferior vs superior

ovule

perianth

pericarp: endocarp, mesocarp, exocarp

perigynous

petal, corolla

sepal, calyx

simple fruit

stamen. staminate, filament, anther, androecium