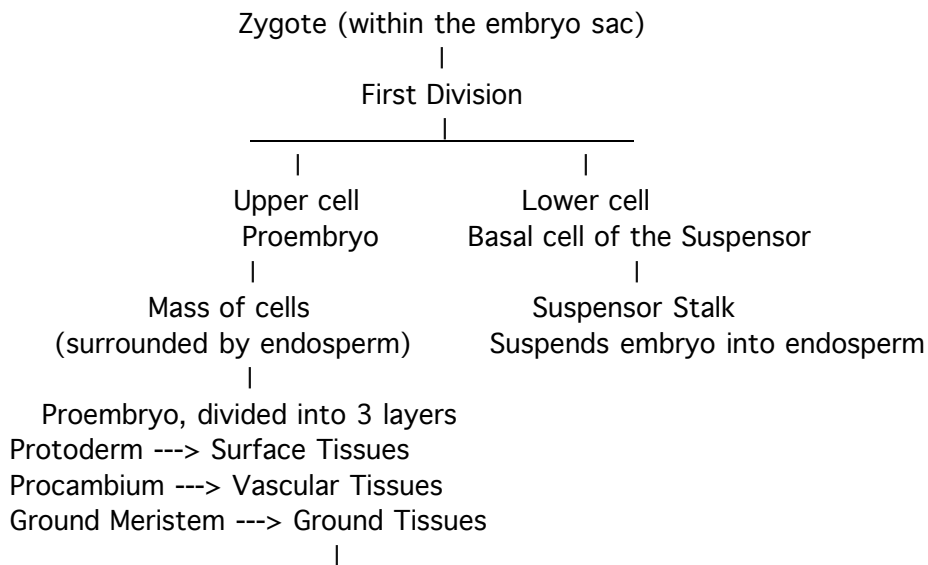


## Flowering Plants: Early Growth and Development - 1

Following the double fertilization in the flowering plants, the zygote develops into the embryo, the endosperm nucleus into the endosperm tissue, the embryo sac wall and integuments of the ovule into the seed coat and the ovary and accessory tissue into the fruit. In this section we will discuss the development of the embryo, seed and fruit maturation, dispersal and germination.

### Embryo Development

- The first division of the zygote produces a small proembryo cell and a larger basal cell that develops the stalked suspensor, which elevates the developing proembryo into the endosperm tissue.

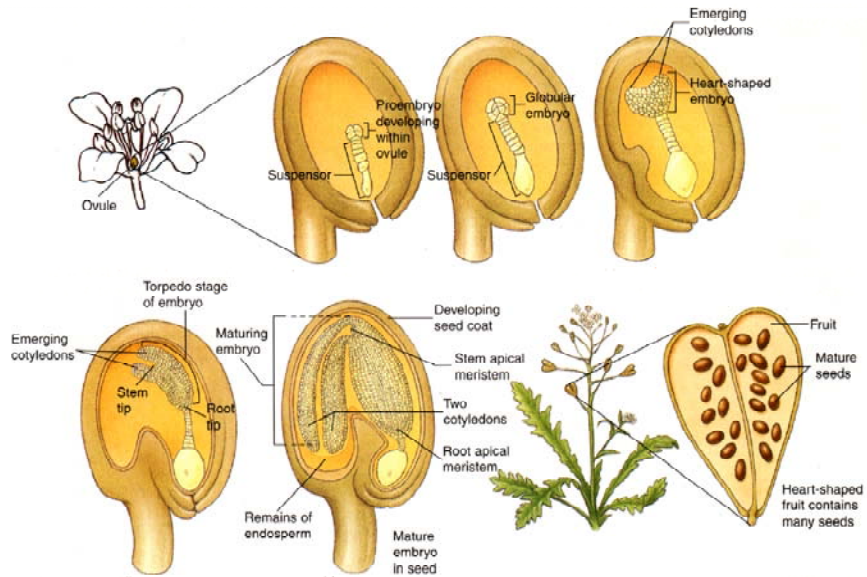


The embryo takes on the shape of an axis with meristems at both ends.

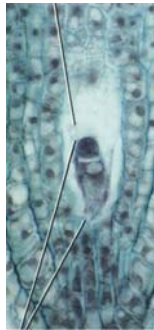
- The embryo meristems are the apical shoot meristem and the apical root meristem, from which structures of the shoot system and root system will ultimately develop.
- In addition, if a dicot, 2 bumps appear near the anterior; these are the 2 cotyledons, characteristic of dicot embryos.
- The cotyledons rapidly elongate, and the embryo is divided into regions, with respect to the cotyledons.
- The region above the attachment of the cotyledons is the **epicotyl**, which contains the apical shoot meristem
- The region below the attachment of the cotyledons is the **hypocotyl** that ends with the **radicle**, containing the apical root meristem.
- Typically the embryonic axis will have to fold, to fit within the embryo sac
- Endosperm may or may not be absorbed into the cotyledons. It may be consumed completely in the maturation of the embryo, or some may remain for germination.
- Some monocot cotyledons become modified into a **coleoptile**, surrounding the epicotyl and hypocotyl, and the **coleorhiza**, surrounding the radicle. This is common in grasses.

## Flowering Plants: Early Growth and Development - 2

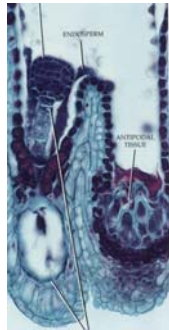
### Embryo Development in *Capsella*, Shepard's Purse, an Eudicot



Fertilization



2-cell Embryo



Young Embryo



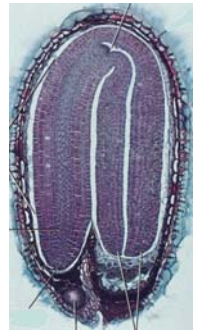
Heart Embryo



Cotyledon Stage

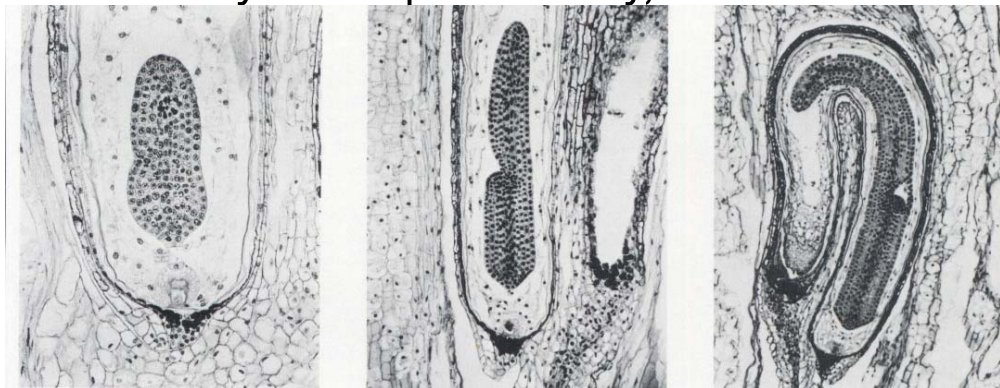


Bending Embryo



Mature Embryo

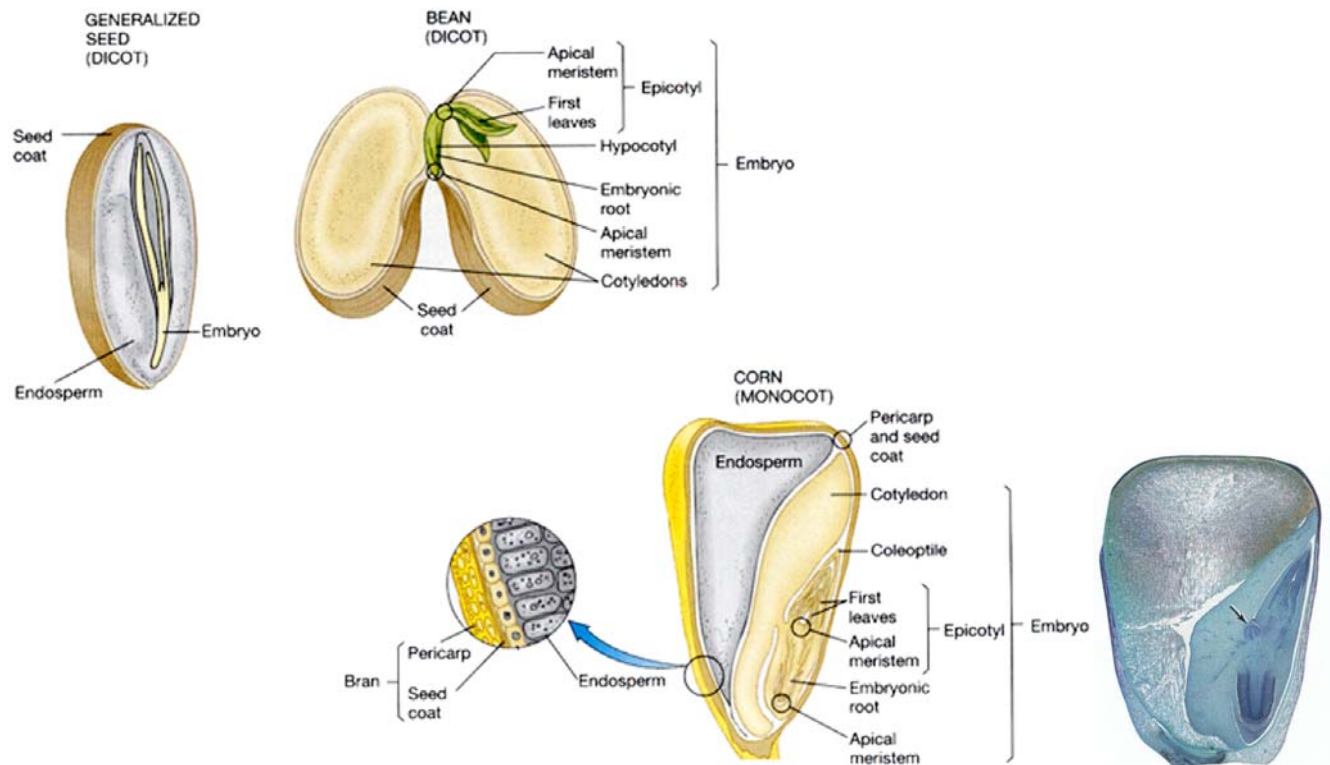
### Embryo Development in Lily, a Monocot



### Seed and Fruit Formation and Dispersal

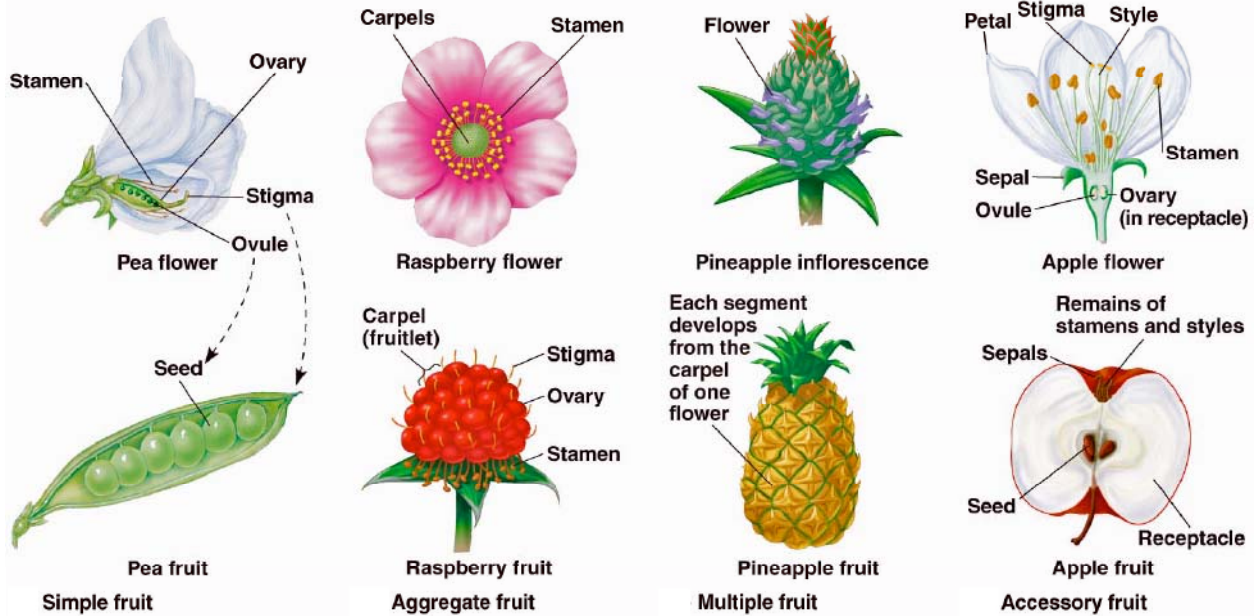
While the embryo is developing within the embryo sac, changes are also occurring in surrounding tissues. The **ovule** integuments and the **embryo sac** wall form the **seed coat**, which will protect the embryo until germination.

The mature seed is comprised of the embryo, endosperm nutrient tissue and seed coat. In some seeds, notably legumes, the cotyledons will absorb the endosperm tissue, becoming "fleshy", so that the bulk of the seed is endosperm. In many monocots, the cotyledon will be modified to form a **coleoptile**, which surround and protects the epicotyl and the **coleorhiza** that protects the radicle. In some grains, the cotyledon forms a nutrient-rich **scutellum** surrounding the embryo for germination. Nutrients also pass from the endosperm through the scutellum to the embryo.



## Fruit Structure and Development

The **ovary** (and possibly accessory tissue) will form the **fruit**, which further protects and aids in dispersal (distribution of the embryo to a new location for growth).



There are many types of fruits and seed coats, all adapted for protection of the developing embryo and for dispersal of mature seeds. Just as angiosperms require pollinators for transport of sperm, many angiosperms require dispersal agents, and use many of the same attractant and reward mechanisms. We will look at fruit types and fruit classification in the laboratory. *(A simple fruit classification can also be found at the end of this section of notes.)*

## Characteristics of Dispersal Agents

### Wind

- Small dispersal unit
  - Light in weight
  - Appendages to remain aloft
- Tufts of hairs  
Wings



## Flowering Plants: Early Growth and Development - 5

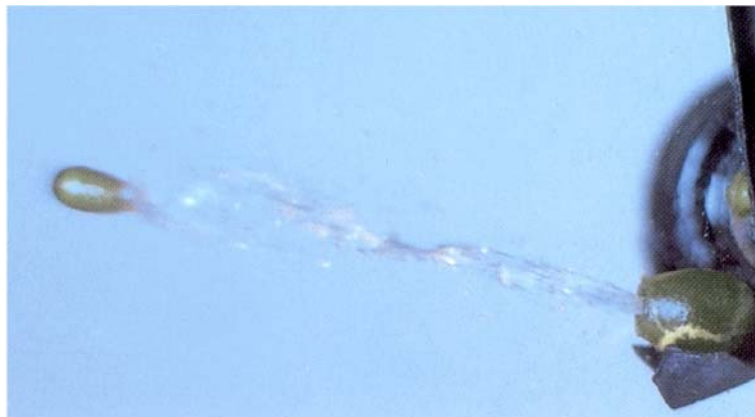
### Water

- Air bladders or spongy tissue for buoyancy
- Impervious seed coat



### Mechanical

- Pressure sensitive expulsion of seeds
- Humidity sensitive expulsion of seeds



### Animal

- Fleshy seed or fruit  
Animal consumes and seed passes through digestive tract (seed coat must be acid resistant)
- Eliaosomes  
Some seeds have nutrient bodies, called eliaosomes attached. Ants gather the eliaosomes for developing larvae and the attached seed gets dispersed during the journey back to the nest. Ant dispersal is called myrmechochory.
- Attach to Fur or feathers of animal and carried  
Attachment devices include:
  - Briers
  - Spines
  - Barbs or hooks
  - Bristles

## Flowering Plants: Early Growth and Development - 6



Dispersal by Consumption



Seeds with Eliasomes



Dispersal by Attachment

Dispersal is still a chance event. Seed must land in an area favorable to growth, and ideally at a time favorable for growth.

### Germination and Seedling Establishment

Many seeds mature at a time unfavorable for growth. Some essential condition for growth may be missing, such as warm temperatures or moisture. In areas where environments change seasonally, and when seeds mature at a "bad" time, most seeds have a built-in delay in germination, called **dormancy**. In dormancy, the seed experiences and "waits out" the bad time, and germinates when the surroundings are favorable for growth. Dormant seeds can remain viable for extended periods of time; the metabolic rate is very diminished, the seed coat protects and the moisture content of the seed is excessively low.

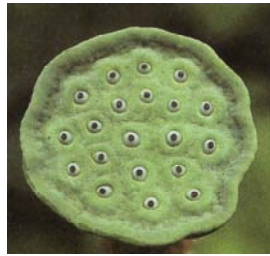
Dormant seeds monitor their surroundings in a variety of ways, chemical, mechanical and temporal.

- For some, the seed coat must be exposed to abrasion, to physically wear it away.
- Others undergo changes in hormone concentrations, notably abscisic acid and gibberellins.
- Many seeds break dormancy in response to environmental triggers such as temperature changes, fire, drought or light exposure.

## Flowering Plants: Early Growth and Development - 7

Germination is initiated when the seed experiences the "trigger" to break dormancy (which is the cessation of the "negative" experience. Most seeds will not germinate until the negative experience has taken place. For example, a seed that must experience cold, will not germinate if harvested and kept warm.

Some seeds have remarkable viability. There are documented records of seeds held in storage for decades that retain viability. Michigan State University underwent a long-term viability study with sets of seeds, removing them every decade and testing germination. A number were viable after a century. A lotus seed, *Nelumbo nucifera*, collected from a dry lake bottom in China germinated after 1200 years of dormancy. Once dormancy is broken, the seed can successfully germinate if the proper conditions are met.

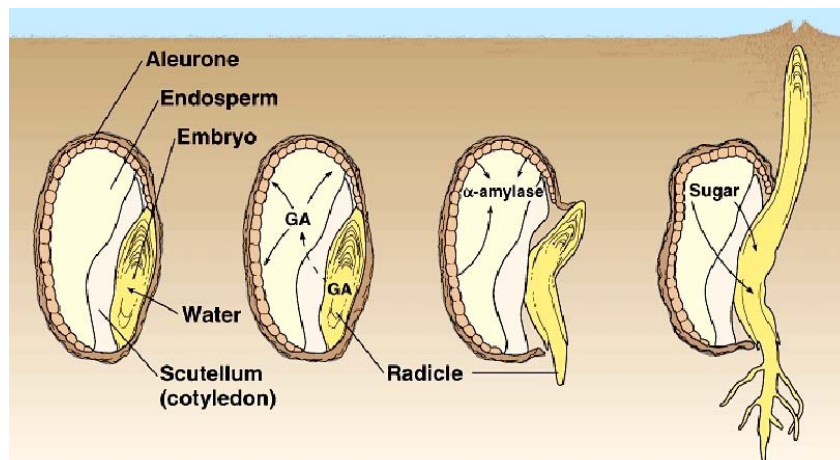


Lotus Fruit with Seeds

### Conditions needed for Germination (post dormancy)

1. Imbibition of much water, to restore the seed moisture content.
2. Sufficient oxygen to provide for rapid aerobic cell respiration
3. Warm temperatures to facilitate rate of enzyme activity

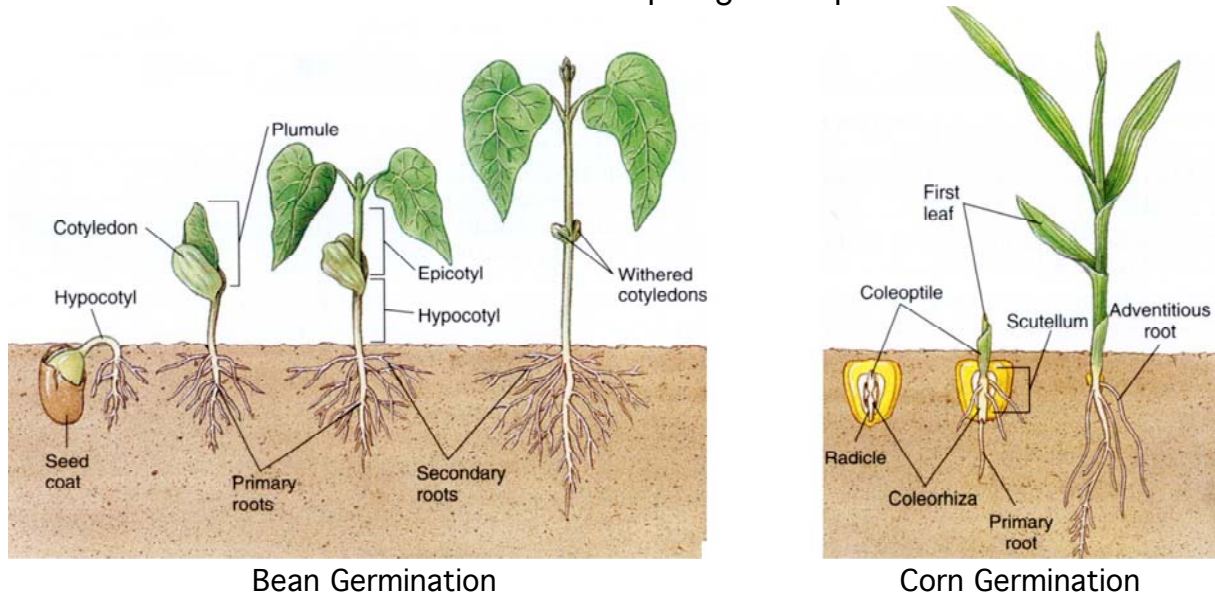
It also helps if the embryo has a good nutrient supply (often a mixture of carbohydrates, oils and proteins) for cell respiration. Hormones produced in the embryo regulate the conversion of stored nutrients in the seed for germination.



### Process of Germination

1. Emergence of the radicle, which is positively gravitropic
2. Emergence of the hypocotyl (or epicotyl), which is usually arched (from the bent embryo position). The bent hypocotyl protects the shoot axis meristem.
3. Upward (or negatively gravitropic) growth of the hypocotyl and shoot axis, which must be rapid. If nutrient reserve is consumed before the emergence above ground, the plant will die.
4. The exposure of the shoot to light triggers the development of chlorophyll and also straightens out the shoot.

Rapid establishment of roots for water and mineral absorption and chlorophyll development in the shoot are critical, so that the seedling can provide its own nutrient supply via photosynthesis. If everything is successful, a new plant is established which will continue to exhibit an open growth pattern.



Before we leave this subject, it is beneficial to mention two exceptions to normal seed development. (*Methods of asexual propagation will be discussed with our plant modified structures section.*)

### Apomyxis

Seeds are produced without fertilization

Example: Dandelion seeds

### Parthenocarpy

Many fruits can be produced without seed development. This process, called parthenocarpy, may or may not require pollination. Certain hormones regulate the maturation of the ovary into the fruit portion of the plant. Either mutation, such as with the navel orange, or the use of hormone sprays on flowers, can result in the maturation of the ovary without seeds. Parthenocarpic plants must be propagated asexually. Navel oranges, for example, are propagated by grafting branches that produce navel oranges onto other orange tree stock.

### Plants, Secondary Metabolites and Coevolution

There have been several opportunities in our discussion of flowering plant reproduction and development to mention coevolution in these processes, particularly with pollinating agents and with dispersal agents, two times in the life history of the flowering plant when it is beneficial for the plant to provide some of itself to another organism. The same phenomenon, lack of locomotion, that makes it necessary to have “outside” agents for these essential processes can be a negative to the plant during other periods of its life. The secondary metabolites of many plants are also successful coevolutionary mechanisms to help plants minimize predation.

Secondary metabolites include alkaloids, quinines, essential oils, (many of which are terpenoids or terpenes) glycosides, cyanogens, raphides (calcium oxalate crystals) and flavonoids. We call many of these substances phytochemicals, and are investigating them for possible health-promoting benefits. For the plant, they serve as anti-predator chemicals, either because they are distasteful to the potential predator or cause some other harm.

Unfortunately for plants, insects are genetically plastic with much genetic variation for tolerance to nasty chemicals. Some groups of insects specialize on feeding on certain plants. The deterrent chemical may be an attractant to those insects, which suffer no negative impact. For example, there is a group of insects that feed on cabbage family plants, whose glycosides deter most insects (and many humans, including a former president of the United States).

An insect may incorporate the distasteful or toxic substance into its body. The monarch butterfly feeds on milkweeds that contain distasteful alkaloids and glycosides. The monarch adults are distasteful to birds, a survival mechanism for the monarch. In classic evolutionary success, the viceroy, whose larvae do not feed on milkweeds, and are delicious, morphologically resembles the monarch, and does not get eaten by birds who mistake the viceroy for the distasteful monarch.

Wound areas of plants secrete substances that may trigger other parts of the plant to secrete anti-predator substances that will harm the predator if it continues to munch on the plant. In some cases these substances mimic insect growth hormones and alter the growth patterns of the insects. (*Plant responses to their environment will be discussed in a later unit.*)

The efficacy of secondary metabolites has been verified in laboratory situations. Many years ago, slugs were used as test organisms to elucidate the role of nicotine as a predator deterrent in tobacco. Strains of tobacco were grown with varying amounts of nicotine. Mature plants were exposed to slug predation. The advantage of using slugs was the slime trail left behind when the slug “visited”. Without the trail, it would not be possible to know if the plant was rejected, or if the predator just “missed” it. To a slug, they chose low and no nicotine tobacco. They might sample higher nicotine leaves, but rejected them, apparently having more intelligence when it comes to harmful chemicals ingested (or inhaled) than many people have.

## Fruit Classification

All fruits may be classified into three major groups on the basis of the number of ovaries and the number of flowers involved in their formation. The following outline includes most of the common types of fruits.

### A. Simple Fruits.

Simple fruits develop from a single matured ovary in a single flower. **Accessory fruits** have some other flower part united with the ovary.

#### 1. Fleshy Fruits, pericarp fleshy at maturity

- a. **Berry**, consisting of one or more carpels with one or more seeds, the ovary wall fleshy
  - (1) **Pepo** (an accessory fruit), a berry with a hard rind, the receptacle partially or completely enclosing the ovary
  - (2) **Hesperidium**, a specialized berry with a leathery rind and juice sacs
- b. **Drupe**, a **stone** fruit, derived from a single carpel and containing (usually) one seed. Exocarp a thin skin
- c. **Pome** (an accessory fruit), derived from several carpels, receptacle and outer portion of pericarp fleshy, inner portion of pericarp papery or cartilaginous, forming a core
- d. **Hip** (an accessory fruit), several separate carpels enclosed within the fleshy or semi-fleshy receptacle

#### 2. Dry Fruits, pericarp dry at maturity

- a. **Dehiscent fruits**, those which dehisce or split open when fully mature
  - (1) **Follicle**, composed of one carpel and splitting along a single suture
  - (2) **Legume**, composed of a single carpel and splitting along two sutures
  - (3) **Capsule**, composed of several carpels and opening at maturity in one of four ways:
    - (a) Along the line of carpel union (septicidal dehiscence)
    - (b) Along the middle of each carpel (loculicidal dehiscence)
    - (c) By pores at the top of each carpel (poricidal dehiscence)
    - (d) Along a circular, horizontal line (circumscissile dehiscence)
  - (4) **Silique**, composed of two carpels which separate at maturity, leaving a persistent partition between them

2. **Dry Fruits**, pericarp dry at maturity (con't)

b. **Indehiscent fruits**, those which do not split open at maturity

- (1) **Achene or akene**, a one-seeded fruit with the seed attached to the fruit at one point only
- (2) **Caryopsis or grain**, a one-seeded fruit in which the seed is firmly attached to the fruit at all possible points
- (3) **Samara**, a one- or two-seeded fruit with the pericarp bearing a wing like outgrowth. A modified achene
- (4) **Schizocarp**, consisting of two carpels which at maturity separate along the midline into two one-seeded halves, each of which is indehiscent
- (5) **Loment**, having several seeds, breaking into one-seeded segments at maturity
- (6) **Nut**, a hard, one-seeded fruit, generally formed from a compound ovary, with the pericarp hard throughout

B. **Aggregate Fruits.**

Aggregate fruits consist of a number of matured ovaries formed in a single flower and arranged over the surface of a single receptacle. Individual ovaries are called fruitlets. Many aggregate fruits are also accessory fruits.

C. **Multiple Fruits.**

Multiple fruits consist of the matured ovaries of several to many flowers more or less united into a mass. Multiple fruits are almost invariably accessory fruits.



**Follicles**  
Split along one carpel edge only; milk-weed, larkspur.



**Legumes**  
Split along two carpel edges with seeds attached to carpel edges; peas, beans.



**Samaras**  
Not split and with a wing formed from the outer tissues; maples, elms, ashes.



**Drupes**  
Single seed enclosed in a hard pit; peaches, plums, cherries.



**True berries**  
More than one seed and a thin skin; blueberries, tomatoes, grapes, peppers.



**Hesperidia**  
More than one seed and a leathery skin; oranges, lemons, limes.



**Aggregate fruits**  
Derived from many ovaries of a single flower; strawberries, blackberries.



**Multiple fruits**  
Develop from a cluster of flowers; mulberries, pineapples.



Follicles



Pepo - Heavy Rind Berry

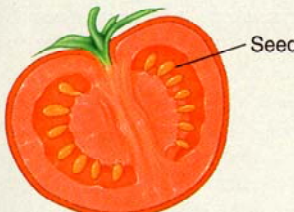


Hazel Nut



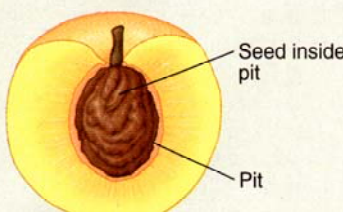
Macadamia Nut

**Guide to Common Fruit Types**



Seed

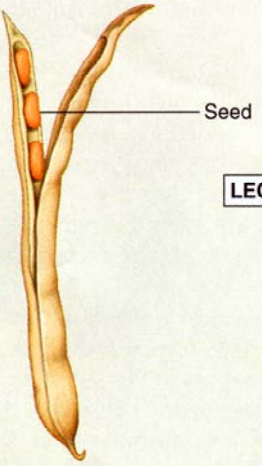
**BERRY**



Seed inside pit

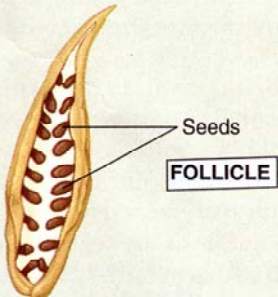
Pit

**DRUPE**



Seed

**LEGUME**



Seeds

**FOLLICLE**

I. Simple fruit — develops from a flower with a single pistil

A. Fleshy

- Berry — soft and fleshy throughout; usually has many seeds (tomato, grape)
- Drupe — hard, stony pit; single-seeded (peach, cherry)

B. Dry, splits open to release seeds

- Follicle — splits along one side (milkweed, columbine)
- Legume — splits along two sides (bean, pea)
- Capsule — splits along many sides or pores (poppy, iris)

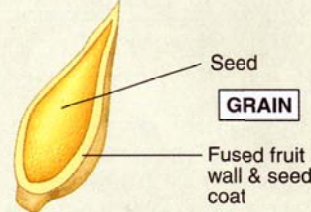
C. Dry, does not split open

- Grain — single-seeded; seed fully fused to fruit wall (wheat, corn)
- Achene — single-seeded; seed attached to fruit wall at base only (sunflower)
- Nut — hard, thick fruit wall (acorn, chestnut)

II. Aggregate fruit — develops from a flower with many separate ovaries (raspberry, blackberry)

III. Multiple fruit — develops from many flowers borne together on a common floral stalk; the ovaries of these flowers fuse together to form a single fruit (pineapple, mulberry)

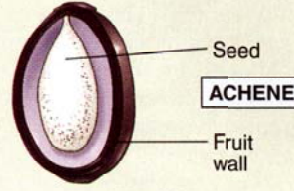
IV. Accessory fruit — develops from a flower in which the receptacle or floral tube enlarges and becomes part of the mature fruit (apple, strawberry)



Seed

Fused fruit wall & seed coat

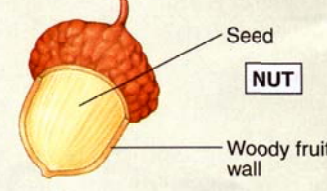
**GRAIN**



Seed

Fruit wall

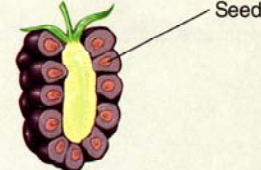
**ACHENE**



Seed

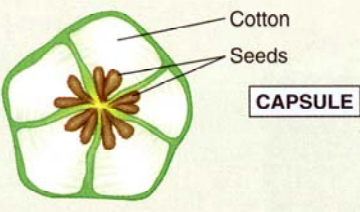
Woody fruit wall

**NUT**



Seed

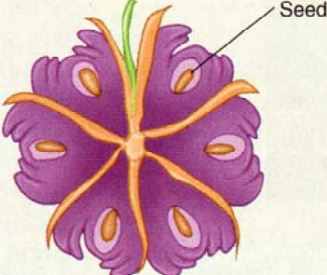
**AGGREGATE FRUIT**



Cotton

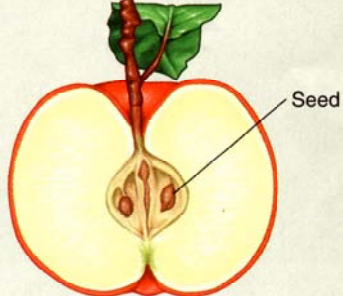
Seeds

**CAPSULE**



Seed

**MULTIPLE FRUIT**



Seed

**ACCESSORY FRUIT**