

Flower Structure

The flower is the reproductive structure for flowering plants (angiosperms). Flowers are extremely diverse in size, shape, color, and so on. This makes them excellent tools for distinguishing plants. As a physiologist, I can identify a few plants from just leaf and stem, but most of the time I need a flower to identify a plant.

The flower is a short branch (stem with leaves). The nodes of this branch are very close together; the internodes are typically extremely short. The leaves of this branch are of four types: sepals, petals, stamens, and carpels. The short branch is called the receptacle and the four kinds of leaves are attached to this receptacle. In most flowers there are more than two leaves of each kind on the flower, so the leaves are in a whorled arrangement (more than two leaves per node). We'll consider the flower from bottom to top:

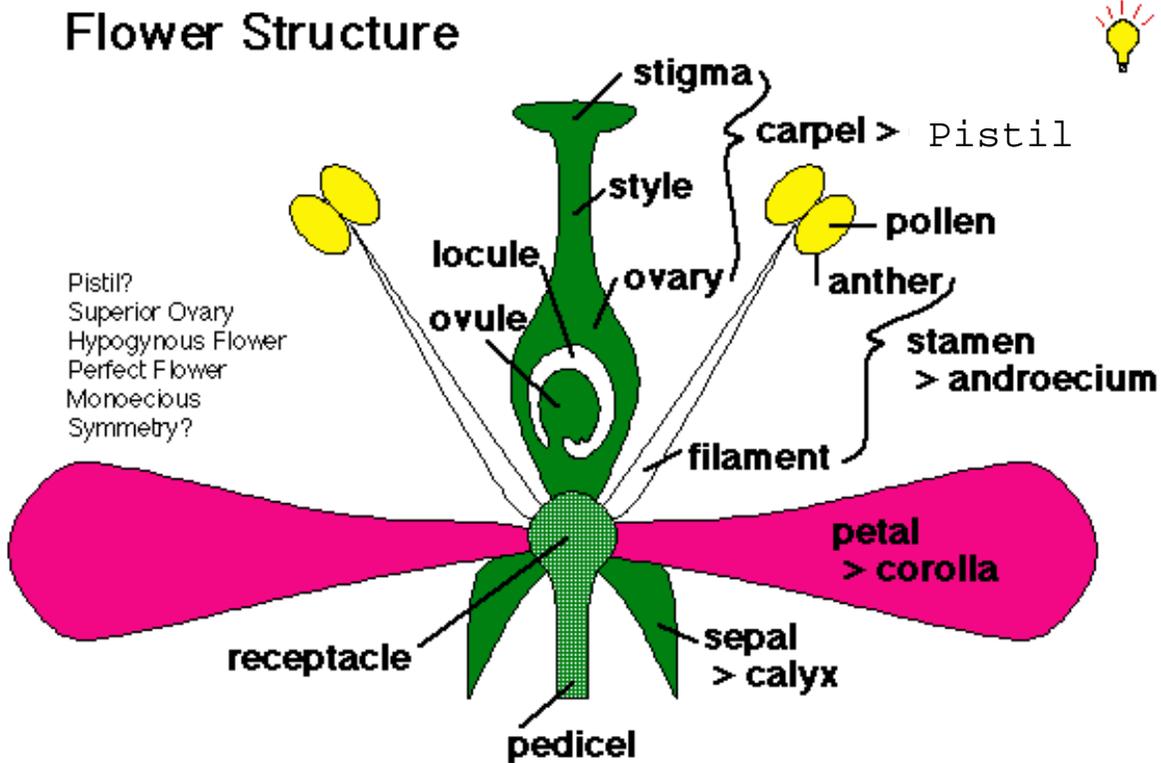
The lowest whorl on the receptacle is called the calyx. It is composed of a few or many sepals. In some species, sepals are green and photosynthetic. In other species, they are showy and almost indistinguishable from petals.

The next whorl on the receptacle is called the corolla. It is composed of a few or many petals. Please note the spelling of petal; it is **not** a bicycle part! The petals are typically showy and brightly colored. They serve to attract pollinators for many species. Sometimes they are extremely fragrant. They may also exude nectar (typically at the base of the petal or in a special nectar spur) to reward the pollinator. Color patterns might include nectar guides to point the way to the reward, or a "bull's eye" target among the petals might get the flying pollinator to notice the flower.

The next whorl on the receptacle is called the androecium (literally the male household). It is composed of a few or many stamens. The stamens are specialized leaves with two distinct sections: the filament (a long stalk) and the anther (usually four sacs containing pollen grains). The function of the filament is to lift the anther to a position to effectively release pollen grains into/onto the pollinator; the filament also serves to provide the anther with xylem and phloem connections to the rest of the plant. The anther serves to produce pollen grains. The pollen grains ultimately make sperm cells; thus the idea of stamens as a male unit.

The top whorl on the receptacle, in the center of the flower, is the pistil (literally the female household). It is composed of a few or many carpels. The carpels may be fused together into a single, compound pistil. Note the spelling of pistil; it is not a handgun! Carpels consist of three parts, a swollen base called the ovary, a stalk called the style, and a tip called the stigma. The ovary contains a chamber called a locule, and inside the locule is one or more ovules. The ovules contain an embryo sac, and the embryo sac contains the egg. The carpel is thus a female unit.

Sometimes a picture is worth a thousand words:



A flower can be radially or bilaterally symmetric. A sea urchin or a starfish has radial symmetry...this asterisk * has radial symmetry. There are several planes by which you can divide the organism (or flower) into essentially equal halves. A human is nominally bilaterally symmetric; there is only one plane of symmetry. You divide a human down the forehead, the end of the nose, the chin, the navel, and between the legs to get two equal sides (bi-lateral). Of course you are probably aware that the two sides of a human are not exactly equal. You have two eyes, but they're not the same size (to contradict the Sesame Street song). Your ears may not be attached at the same level on the sides of your head. Your heart is on one side, your liver is mostly on the other side. The appendix and spleen are found on only one side. In women, the mammary glands are not the same size. In men the testes are different sizes and are suspended differently to permit bipedal locomotion (walking on two legs). Thus a human is really asymmetric (lacking a plane of symmetry). The letter T is bilaterally symmetric. The longitudinal section of a flower shown above cannot reveal enough information to decide about symmetry, even though it might hint at least one plane of symmetry.

The flower shown above has an ovary in the superior position (the other flower parts are attached below the ovary on the receptacle). Other flowers might have the ovary sunken into the receptacle so deeply that the other flower parts appear to be attached on top of the ovary; in that case the ovary is in the inferior position.

The flower parts attached below a superior ovary are called hypogynous (below the female) while flower parts attached above an inferior ovary are called epigynous (above the female).

A flower with both male and female parts is called perfect or bisexual or hermaphroditic. Such a flower might be able to use its own egg and sperm to reproduce...this would be called a self-pollination or a self-cross. On the other hand, such flowers might produce pollen when the stigma is not receptive to pollen, thus ensuring out-crossing or cross pollination. Sometimes the stigma can recognize a pollen grain as its own and prevent it from growing in the style; this process is called self-incompatibility.

Some plants have unisexual (imperfect) flowers: staminate (male) flowers and pistillate (female) flowers. These can be on the same plant (monoecious) or on two different plants (dioecious). A begonia is an example of a plant that has unisexual flowers but is monoecious (one household). Holly is an example of a shrub that has unisexual flowers and is dioecious (two households). Thus in planting holly, you need to take precautions. First, you need to position the female holly plant where you want a shrub that will have the red fruits on it. Male shrubs never produce fruits! Second, you need to put a male holly somewhere in your landscape so that the females will be able to receive pollen to produce the fruit. You might put the fruitless male holly in a less conspicuous spot but near the females. Remember if you are at the nursery and select only shrubs with red fruits on them (a common error), those will be the last fruits you will see! You need at least one male...it "takes two to tango!"...to produce fruits the next year.

Thus the range of sexuality in plants is very broad: self-crossing hermaphrodites to out-crossing hermaphrodites, to unisexual flowers, to unisexual plants. But that is really only the beginning. Plants can change sex too. Cucumbers are famous for changing from male to bisexual to female and then to parthenocarpic as they grow. What is parthenocarpic? It means literally virgin fruit. The last flowers on some cucumbers do not need to be pollinated to produce a fruit...they make the fruit on their own!

Another interesting example is the *Abelmoschus* (hibiscus) in the greenhouse. The flowers last only one day and are bisexual. The flower hedges its bets. In the early morning the female parts stick out beyond the stamens to be pollinated with pollen from some other plant. If this happens, fine, but if it doesn't happen by afternoon, the styles curl backwards and push the stigmas against the stamens in the flower; it is a self-pollination. By evening the flower senesces and fruits begin to develop.

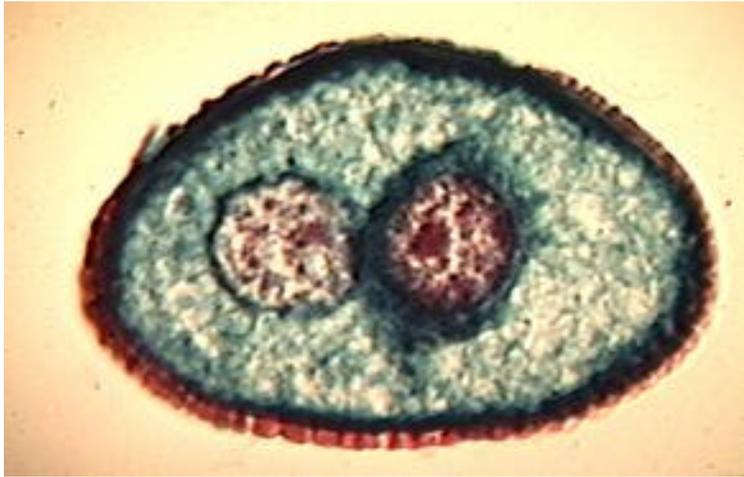
Pollen and Embryo Sac

Now that you know something about the flower and its parts, it is time to dig into some of the "business" end of what a flower does.

As you know, the anther of the stamen produces pollen grains. That in itself is an interesting process that I would discuss in detail with a course for biology majors. For this course, I'll leave it that indeed the anther makes pollen grains.

What is a pollen grain? This structure is almost dust-sized. It has an outer wall that, in some

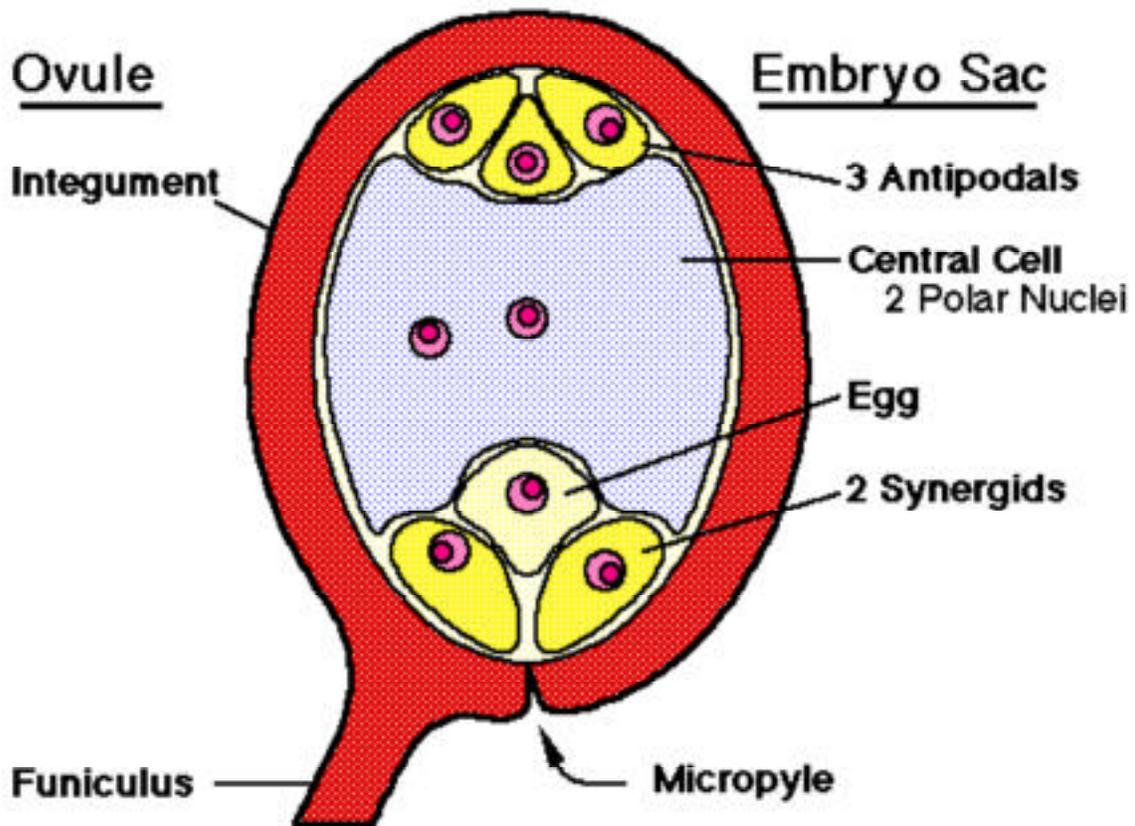
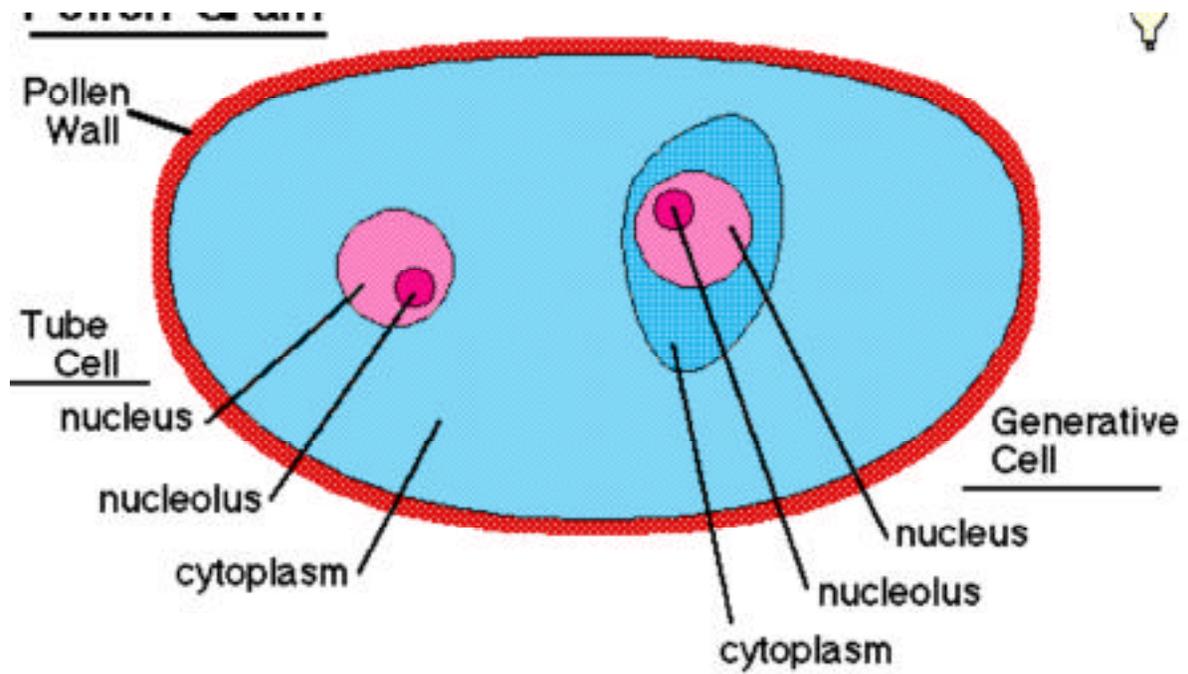
wind-pollinated species, is allergenic to humans. In the photomicrograph below, the thick wall appears somewhat reddish due to a dye used in the preparation of the microscope slide.



Inside the pollen wall are two cells. The cell with lots of bluish cytoplasm (filling up the inside of the pollen wall) is the tube cell. The smaller cell (on top of the tube cell) is the generative cell. Notice that both cells have a lavender nucleus and each nucleus has a red nucleolus. The nuclei of the two cells are the same size...the cells differ in the amount of cytoplasm present. The tube cell has much cytoplasm, the generative cell

has far less.

The tube cell grows to penetrate the pollen wall and then the stigma and style tissues of the carpel. This penetrating cell is now called the pollen tube. Its growth is chemotropic (grows toward a source of chemicals)...likely toward calcium, boron, and/or auxin. The chemical source is an ovule. The pollen tube's chemotropism results in the tube arriving in a small opening in the ovule's integument...the micropyle (see below).



Here is a labeled diagram of both the pollen grain and the ovule:

The pollen tube arrives in the micropyle of the integument of the ovule, and enters the embryo sac.

The synergids of the embryo sac literally put their energies together to burst the end of the pollen tube. Meanwhile, the generative cell has followed the pathway digested by the tube cell. Along the way it has divided to produce two sperm cells. The two sperm cells exit the pollen tube through the burst end.

One sperm cell unites with the egg. This process is called syngamy (union of gametes) or [gag] fertilization. I much prefer syngamy to fertilization (see below). The product of the union of egg and sperm is called a zygote, and it has two sets of master plans, one from each gamete. The zygote will divide and grow and differentiate to become a new embryonic plant with root, stem, and leaf. Ultimately it will become an adult plant.

The other sperm cell unites with the central cell. This is a second syngamy! It is a three-way fusion between the two polar nuclei of the central cell and the sperm cell. The resulting endosperm cell has three sets of master plans (one from sperm and one each from the two polar nuclei). The endosperm cell divides to form a nutritive tissue inside the seed. It accumulates nutrients from the mother plant and stores them away for the developing embryo inside the seed. The nutrients are stored as starch, protein, and/or oil. Initially the endosperm is liquid (the famous endosperm at this stage is cocoanut milk). Later the endosperm becomes cellular and solid (grated cocoanut "meat" is really endosperm). Solid endosperm of grain crops (wheat, barley, oats) is ground up to make flour (toast, cookies, "cereal") or cooked to make rice and so on. Endosperm is a very important food source for humans! Next time you slurp down a piña colada, think about drinking liquid endosperm!

Here is a view of an ovule. The antipodals are not well shown, but disintegrate anyway. The central cell is larger than the lower egg cell. The synergids are quite dark and elongate in this view:



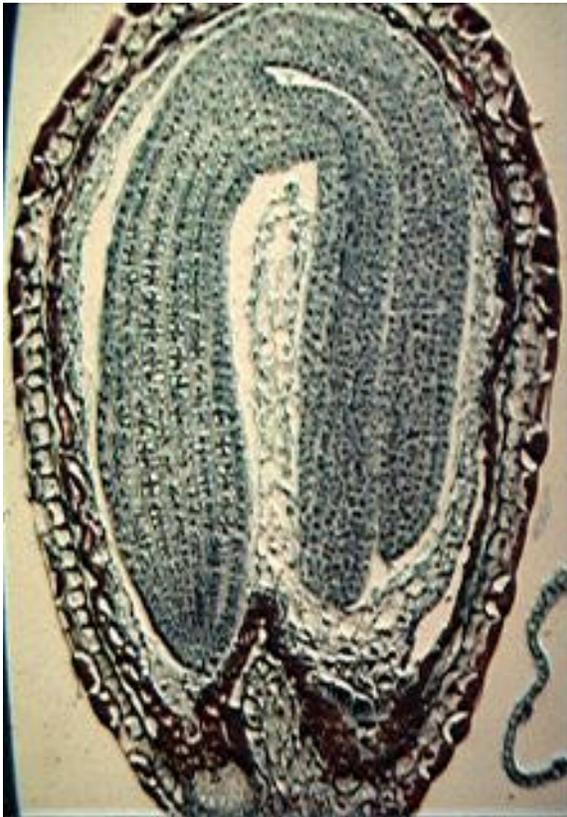
Ultimately, changes in the ovule result in further change. The egg becomes a zygote becomes an embryo with many parts. The endosperm gains nutrients and becomes solid nutrition for the embryo. The antipodals and synergids disintegrate. The integument becomes a seed coat. The ovule complete becomes a seed with the three important constituents: seed coat, storage tissue, and dormant embryo. The ovule continues to make hormones to cause the ovary wall to become a fruit. That is a subject for another time.

Seeds and Seed Germination

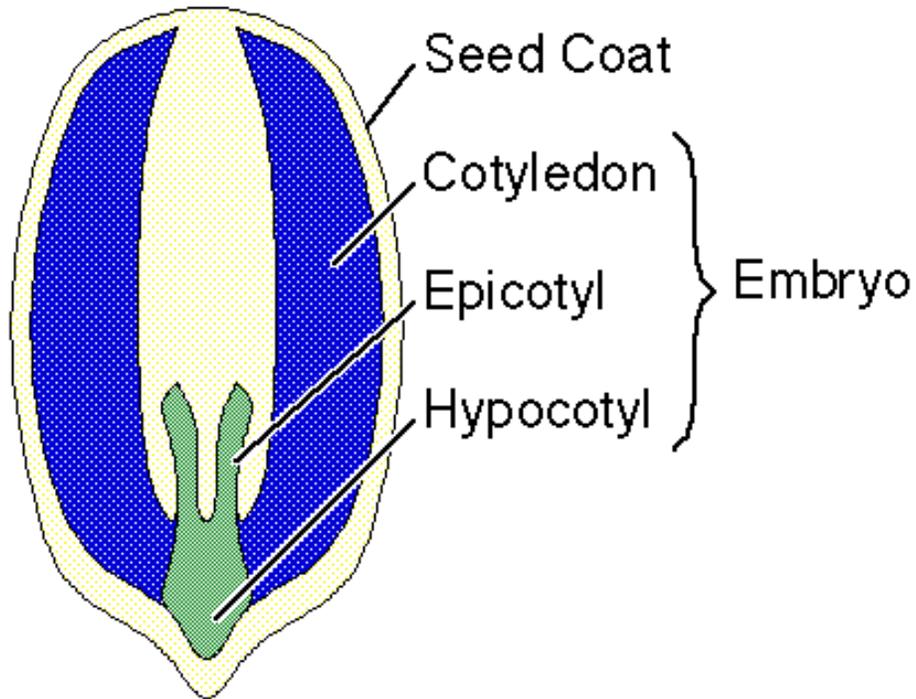
Seed Structure

Keep in mind that the ovule in the ovary is what becomes the seed. The integument of the ovule becomes the **seed coat**. Inside the integument of the ovule was the embryo sac. The antipodals and synergids senesce and disintegrate. The central cell united with one sperm cell to make **endosperm**...a nutritive tissue that accumulates starch, protein, and fats to provide for the growth of the embryo. The egg cell of the embryo sac united with the other sperm cell to make a **zygote**. The zygote grows and becomes a true **embryo** inside the integument.

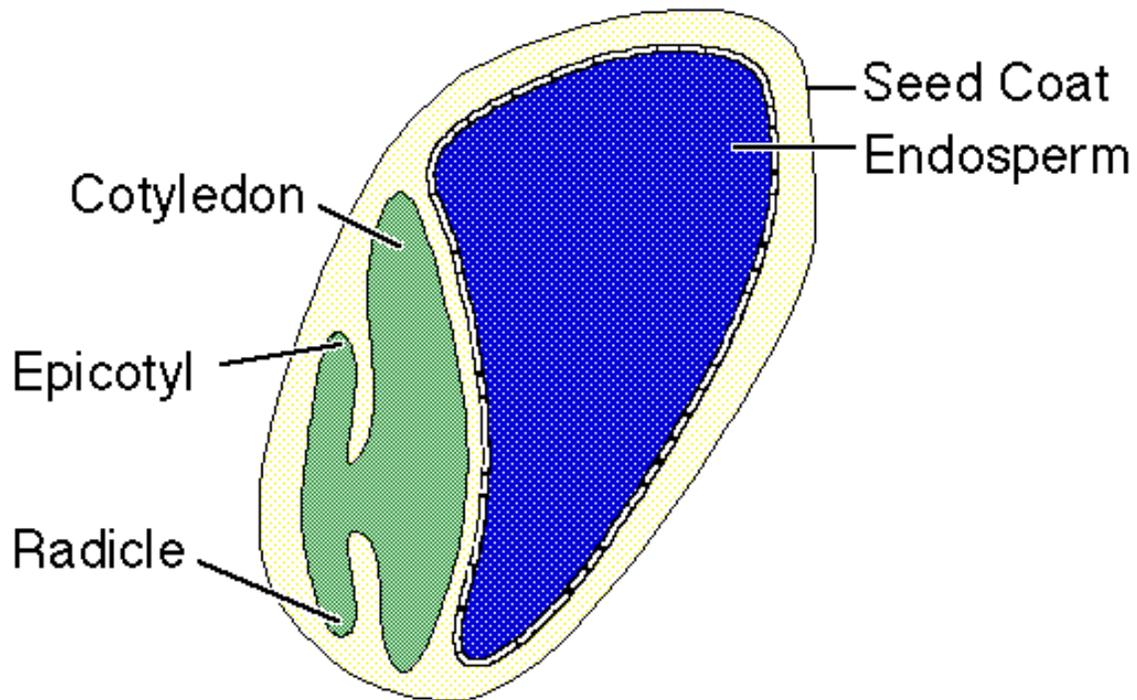
When you have a **Dormant Embryo**, a **Storage Tissue**, and a **Seed Coat**, then you have a **SEED**. In some seeds, the endosperm is retained as the storage tissue. In other seeds the endosperm is more or less used up to put storage chemicals into the embryo itself (commonly in the cotyledons). Below are diagrams and a photo of some seeds.



Dicot Seed Structure



Monocot Seed Structure



Seed Germination

The seeds are carried inside the fruit by animals called dispersers. The animal usually feeds on the fruit (ovary wall), but "tosses" the seeds (or passes them through its digestive system). This assures that seeds end up **far away** from the "mother" plant, where they can develop without competition from "mom."

When it comes time for a seed to sprout, the diagram below might assist you.

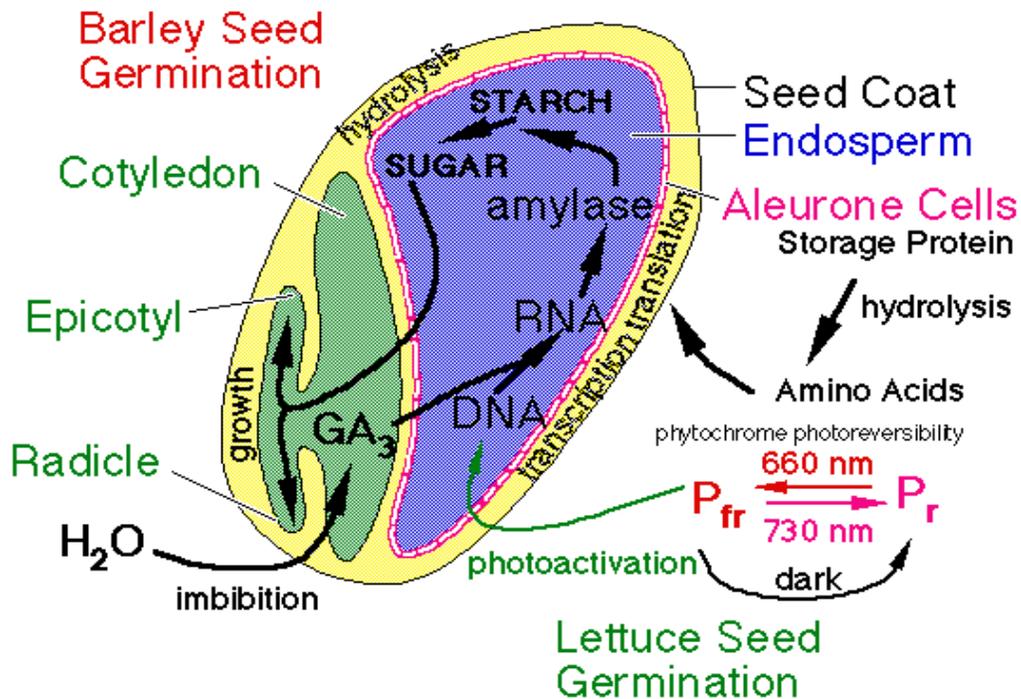
Some seeds sprout with just water and reasonably warm temperatures. This is true of most common garden plants. Wild species usually have some kind of deeper dormancy to avoid sprouting in late summer/fall when the seeds are dispersed. This assures that tender seedlings are not frozen at a young age, but do not appear until warm weather arrives in springtime. Examples of mechanisms are indicated in the figure below.

SEED GERMINATION = radicle emergence

Seeds Lacking Dormancy Moisture Warmth

Dormant Seeds need more than this:

- Thick Seed Coat Scarification
- Thin Seed Coat Light or Darkness
- Insufficient Development After-ripening with Fungi
- Inhibitors Vernalization
- Abscisic Acid Repeated Leaching
- Phenolic



Also shown above is a mechanism for seed germination in two species: Barley and lettuce.

The hormone signal in barley (Gibberellic acid) activates DNA in the aleurone cells. Transcription and translation of a gene for amylase results in the production of that enzyme inside the aleurone cells. This enzyme is shipped by ER into the Golgi, sorted and packaged into vesicles, and exported through the cell membrane by exocytosis. The amylase is thus dumped into the endosperm area. There the amylase breaks down starch into sugar which is transported to the embryo. The sugar fuels respiration in the embryo so it can grow. The radicle protrudes from the seed coat, and germination is accomplished.

A similar mechanism exists in lettuce (no aleurone and a dicot), but the activating chemical is a pigment called phytochrome. This chemical exists in two different forms: Pr and Pfr. How a lettuce seed responds depends on how much of each of these two forms is in each cell. Typical lettuce seed batches germinate 30-60% if placed in darkness because at least this many seeds have enough Pfr to stimulate germination. If, however, you put the lettuce seeds in red light (660 nm), the red light causes all the Pr to change into Pfr. Now 85-95% of the seeds can sprout because they all have an abundance of Pfr inside. On the other hand, if you put lettuce seeds in far-red (730 nm) light, the far-red light causes all the Pfr to change into Pr. In far-red light, then, all the seeds have essentially no Pfr and so very few (0-5%) actually sprout. You carried out these experiments in lab, so you know about this already.

From: **Koning, Ross E.** "Pollen and Embryo Sac". *Plant Physiology Website*. 1994.
http://koning.ecsu.ctstateu.edu/plants_human/pollenemb.html. 3/05/00