Important Angiosperm Foods: Cereals & Legumes

Although there are several major lineages of plants, our society relies essentially on just one of these, the angiosperms, for food. Today you will acquaint yourselves with some of the two major group angiospermous food plants and their products.

Before Coming to Lab: Read sections A (intro), A1, A2, A3, B (intro), B2, and B3. Then answer the following questions.

1. What is a cereal and which lab page did you find the definition?

2. What is a pulse and on which page did you find that definition.?

3. What is the technical definition of a legume fruit and on which page...?

4. Which, the cereals or the pulses, are the most important to humanity in terms of total calories consumed?

5. Which had more abundant starch: cereals or pulses?

6. Which has more abundant protein: cereals or pulses?

A. Cereal Morphology & Anatomy

Cereals are grasses (family Poaceae) cultivated for their edible grains. The grain of a grass is a particular type of fruit unique to the family called a "caryopsis." Cereals include wheat, maize (aka corn in the USA), rye, barley, oats, and rice among others. They are generally the most important food source for humanity in terms of the total calories they contribute to your diet, either directly or indirectly.

Table 1. Cereals discussed in this lab manual and their native ranges.

Species (common name)	Native Range, Origin of Domestication
Avena sativa (oats)	Europe
Hordeum vulgare (barley)	SW Asia
Oryza sativa (common rice)	SE Asia
Triticum aestivum (bread wheat)	SW Asia
Zea mays (corn, maize)	Mexico
*Zizania aquatic*a (wild rice)	North America

1. Gross Observations of Caryopsis.

Dissecting Scope and 1-day imbibed maize kernel from back/side of room.

What you commonly call the kernel of corn is actually the 1-seeded fruit (caryopsis). Imbibition (the process whereby a seed absorbs water) has been allowed to occur for 1-day in order to soften the caryopsis and allow you to section it. Specifically, cut this in half lengthwise to view the parts of the fruit and seed (Fig. A1). Use forceps to position for easy viewing with dissecting scope or make a thin section of the kernel if you have trouble with using the forceps to hold cut surface up for viewing with scope.

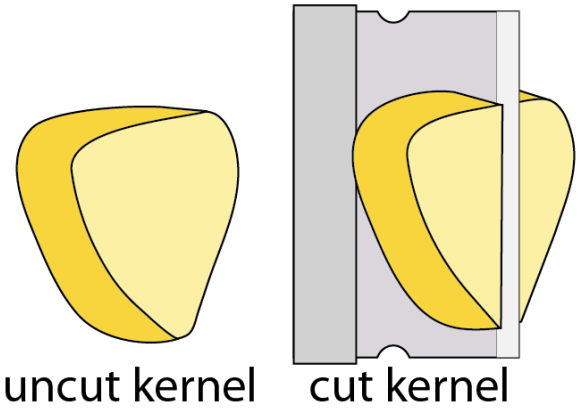


Fig. A1. Cut a soft maize kernel in half longitudinally, perpendicular to broad face.

1a. Draw and label the parts as follows: the (1) embryo (aka "germ"; in lower corner), (2) endosperm (most of seed), and (3) the fused seedcoat/pericarp (aka "bran").

1b. Add a drop of potassium iodide onto the cut section. This will stain any starch and improve viewing.

What tissue is staining positive for starch? That is, what will be the young seedling's food source?

1c. Look at an unsectioned, intact maize kernel: *Can you see the position of the embryo from the outside with the naked eye? Explain.*

2. Microscopic Observations of Caryopsis.

Compound Scope and Prepared Slide of "Zea (Maize) Embryo".

Observe this longitudinal section through a maize caryopsis with embryo, and let's add some detail to our observations above.

2a. Using Figure 8.29 in Stern's (p. 141), draw the caryopsis seen on the slide and label the parts of the fruit and embryo that are also listed below. Fill the space provided.

Parts of the embryo

1) **Cotyledon** (aka scutellum in grasses)
   = the single seed leaf.
2) **Coleoptile** = a sheath-like hood surrounding the plumule.
3) **Plumule** = the embryonic shoot apex containing the epicotyl, shoot apical meristem, and first non-cotyledonous leaves.
4) **Radicle** = the embryonic root.
5) **Coleorhiza** = a sheath-like cap covering the radicle.

Parts of the endosperm

Aleurone Layer = the outermost layer of the endosperm which is protein-rich, whereas most of the endosperm is starchy. During germination, the enzyme amylase is secreted by both the aleurone layer and the scutellum to break down the endosperm's starch into the sugar maltose to feed seedling development.

Draw the maize caryopsis anatomy here

3. Grass Seedlings.

10-day and 5-day old maize kernels/seedlings from side/back of room.

3a. Examine and draw them below and be sure to label all the structures seen in Figure A3 below.

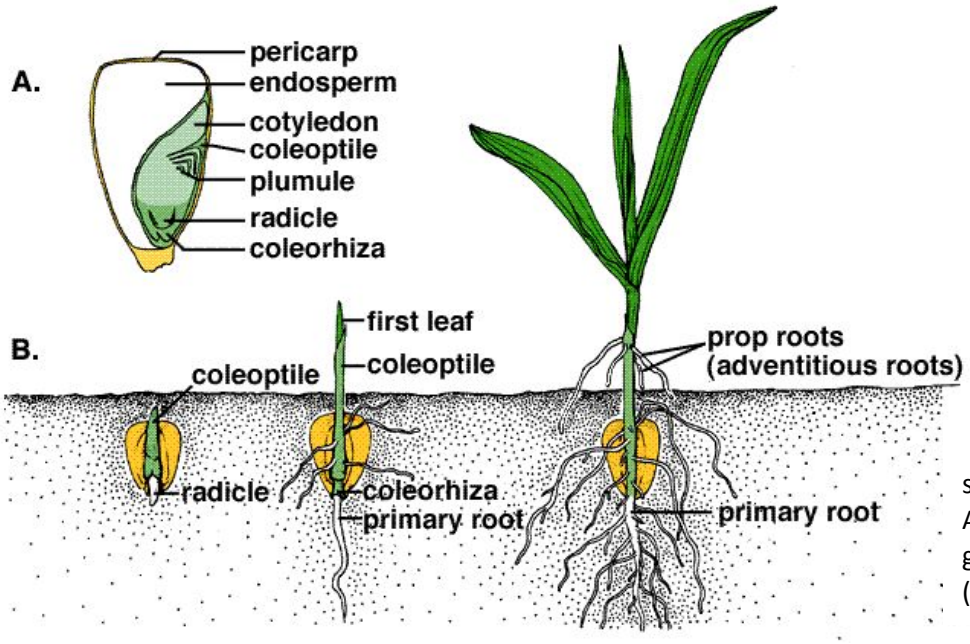


Figure A3: Maize seedling structure and germination. A, pre-germination; B, post-germination. From Stern (1997).

3b. What's the difference between the lateral roots off of the primary root and the so-called adventitious roots?

3c. Suggest a functional role for the coleoptile and coleorhiza (Hint: think sheathing and protection, but of what and when?).

3d.Where is the single cotyledon during germination? What is its role?

4. Morphological Comparison of Maize with Wheat, Rice, and/or Barley Caryopses.

Dissecting Scope and Dry Maize, Wheat, and/or Rice Caryopses.

At your bench are the non-imbibed (hard, dry) caryopses of maize and at least one other cereal such as wheat, rice or barley. Although they are similar anatomically, compare them with the naked eye and dissecting scope and be sure you can distinguish them morphologically. Make notes of how they are similar and different.

5. Wheat Flour vs. Flours from other Cereals.

Two unknown flours in side/back of room, labeled "Flour A" and "Flour B".

Put your Compound Scopes away. You are done with them and you do not want to get them dirty in this next exercise.

- Take about 100 ml of flour each from "A" and "B" in two different 100 ml beakers back to your bench.
- Remove about 60 ml of flour and place it on your table, and add about 16 ml of water to the remaining 40 ml of flour in the beaker.
- Stir until you work it into a sticky mass.
- Coat your hands and the dough ball with the extra dry flour so you can remove the dough from the beaker and knead into a ball repeatedly without it sticking to your hands or the table.
- Once well kneaded, try to flatten each type into a small, flat pizza-like shape about 4 inches diameter.

a. Which type was more elastic?
b. Which type was easier to spread flat without it coming apart?
c. What is the identity of your unknown flours? The two are wheat and rice, yet it is only wheat that has a special protein in the endosperm called gluten. Gluten is what gives wheat dough its elastic properties and is the reason wheat is preferred for making leavened breads, cakes, etc. Explain how this works?

6. Popcorn.

Popcorn is a corn variety whose pericarp is too hard to grind and so tranditionally it was popped in order to make it soft enough to eat. The ability of popcorn to pop relies on the water content in the endosperm and the thickness and hardness of the bran (seedcoat-pericarp fusion product).

- Using a clean (eating-safe) Dixie cup, weight a half of Dixie cup of corn (tare away the Dixie cup weight).
- Pop said amount of popcorn in hot-air popper.
- Reweigh the popped corn.
- Calculate the percent water in unpopped popcorn kernels by weight. Show your work.

If available: Clean your hands and eat some other popcorn that has already been prepared for you by your instructor in the front of the room or other location.

7. Morphological Comparison of Maize with Wheat, Rice, and/or Barley Mature Plants.

Living Plants and/or Herbarium Specimens of Grasses in side/back of lab.

What characteristics do all the cereal, wild or ornamental grasses in the room have in common? How are they different? Can you distinguish one from another if you saw them in a field?

Table A5.1. Compare the vegetative attributes of the grass specimens in the back/side of the room. Use the following as only a rough guide for comparison.

species	**Root System** (fibrous or taproot)	**Posture** (prostrate vs. erect)	**Branching** (unbranched, branching at base only, branching throughout)	**Prop Roots** (present or absent)	**Internode** (solid vs. hollow)	**Leaf Base** (sheathing or not)	**Leaf Blade** (linear or broad)	**Leaf Venation** (parallel, pinnate, or palmate
Maize								
Wheat								
Common Rice								
Foxtail Grass								
Bamboo or other large grass								
Crabgrass								

Below, Typical Grass Inflorescence and Flower Structure.

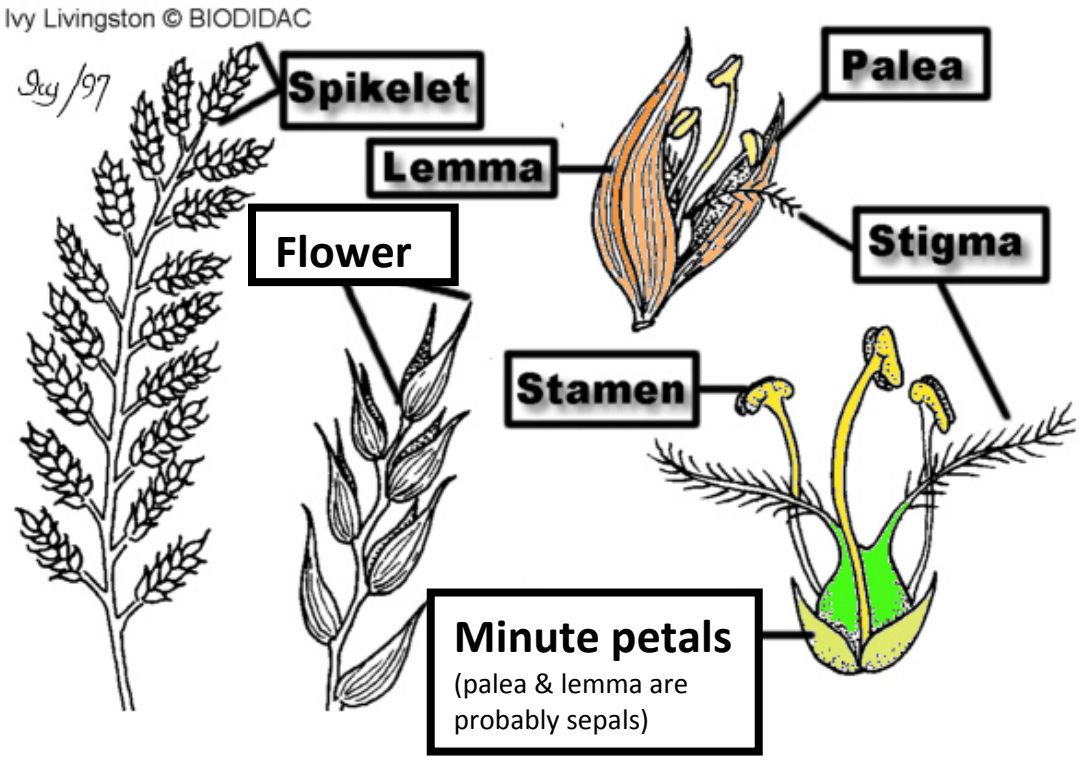


Table A5.2. Compare the <u>reproductive attributes</u> of the grass specimens in the back/side of the room. Use the following as only a rough guide for comparison. The figure above should help.

species	**Inflorescence Sex** (Inflorescences bisexual or unisexual)	**Inflorescence Position** (terminal vs. axillary)	**Inflorescence Gross Shape/Appearance** Draw them and describe general appearance	**Awns on glumes, palea or lemma, etc.** (absent, present but short, present & long)	**Packing of Grains** (tight in cobs vs. loose, etc.)
Maize					
Wheat					
Common Rice					
Foxtail Grass					
Bamboo or other large grass					
Crabgrass					

B. Legumes

The legume family (Fabaceae or Leguminosae) is defined by the fruit type that all members share: a legume, which is 1-carpellate pistil that will dry and dehisce (open) along two margins at maturity – allowing the seeds to fall out. Pulses are a subset of legumes that are harvested for their edible dry seeds. Legumes are second in terms of importance to humanity for food and whereas cereals are valued primarily for their calorie-rich starch in their endosperm, the pulses are valued primarily for their extremely high protein content and only secondarily for their starch and oil content.

Table B. Legume pulse species discussed in this lab manual and their native ranges.

Species (common name)	**Native Range, Origin of Domestication**
Arachis hypogaea (peanut)	Brazil, S America
Glycine max (soy)	E Asia
Lens culinaris (lentil)	E Mediterranean, SW Asia
Pisum sativa (pea)	E Mediterranean, SW Asia
Phaseolus lunatus (Lima bean)	Lima Peru & Vicinity, S America
Phaseolus vulgaris (common beans)	Central America

1. Legume Fruits.

Various Ripe (Dry) and Unripe (still fleshy) Legume Fruits.

Examine the various fruits from the side/back of the room at your desk, return any undamaged fruits when done.

a. Ripe fruits are dry and are either open or in the process of opening. Examine these.

Draw a dehisced legume: in your drawing be sure to indicate the color of the ripe fruit, draw any seeds and illustrate how and where they are attached to the carpel wall. Be sure to identify and label any pedicel and remnant style plus stigma still attached to the fruit.

If there are seeds, where are they attached relative to the lines of dehiscence?
a) far removed b) very near.

If no seeds, then they have fallen out but there are still remnant funiculi (the funiculus is what attached the seed to the ovary wall) and you can therefore still answer this question.

Is the ovule/seed attachment to just one side or two sides of the fruit?

Along a suture, do the seeds or funiculi alternate from one side to the other or are they all on the same side?

How does the legume differ from the caryopsis? Complete the table below.
Table B1. Comparison of legumes and caryopses.

Fruit Type	***Dry or Fleshy @ Maturity ?***	***Seediness*** *(1 or more than 1?)*	***Seed Fusion*** *(fused to pericarp or free from pericarp)*	***Dehiscence*** *(dehiscent or indehiscent)*
Legume *(bean family)*				
Caryopsis *(grass family)*				

b. Unripe fruits are still green, relatively soft, and have not yet dehisced. Examine these.

Do you recognize any of these unripe legumes? If so, where have you seen them before and what are their common names?

For human consumption of the entire fruit, why are the <u>unripe</u> fruits picked?

Although these are eaten as a "vegetable", they are technically fruits, aren't they. Explain.

Make a cross section of one string bean and locate any of the vascular bundles that run the length.

In your experience, are these vascular bundles the softer or tougher part of the edible fruit?

<u>2. Legume Leaves.</u>

In addition to their distinctive fruits, members of the legume family have fairly distinctive leaves, being generally <u>compound</u> to some degree and having a <u>pulvinus</u> (swollen portion) at the base of the petiole where it joins the stem and often at the base of the <u>petiolule</u> (leaflet stalk).

Living Plants or Herbarium Specimens at Legume Leaves station.
Examine the various living plants or herbarium specimens in the back or side of the room and fill in the table.

Table B2. Vegetative attributes of various members of the legume family.

Plant Name	**Habit** (herbaceo-us or woody)	**Posture** (prostrate, erect, scrambling/ vining)	**Phyllotaxy** (alternate, opposite, whorled, or rosette)	**Leaf Complexity** (trifoliate, 1-pinnate, 2-pinnate, or palmate)	**Pulvinus** (obvious or not)	**Stipule Form** (describe if present)	**Tendrils** (absent or present)
a. Clover (*Trifolium*)							
b. Crown vetch (*Coronilla*)							
c. Black locust (*Robinia*)							
d. Mimosa (*Albizia*)							
e. Pea (*Pisum*)							
f. Soybean (*Glycine*)							
g. Common bean (*Phaseolus*)							

3. The Peanut Fruit & Embryo.

Fresh Roasted Peanuts from the Side or Back of the Room. Wash & clean your hands. Then take a peanut fruit and crack it open, save one seed for the questions below and eat the other(s) if you like.

a. Did your peanut fruit break along one or two sutures? How is that similar or dissimilar to the other legumes you examined?

Note: After pollination, the peanut flower is pushed underground by its pedicel where the fruit develops. However, through evolution the peanut fruit has lost its ability to dehisce and so it is a modified legume. Underground, the pericarp will eventually rot and the seeds will germinate and grow from their position.

b. Do you think the unusual underground position of the peanut fruit facilitates seed germination in anyway?

c. **The saved seed:** use your fingers to split the peanut embryo into its two natural "halves". One half will be one cotyledon, separated from the rest of the embryo, and the other half will be the second cotyledon with the embryo axis still attached. Note that the endosperm is absent from the mature legume seed because it is absorbed by the 2 cotyledons during development.

Label the parts of the photograph below /next page (taken by W.P. Armstrong of "Wayne's Word" on the Web) with the following terms pertaining to embryo structure.

Seedcoat = outer cell layers of the seed; hard and protective in most seeds, papery and easily removed in the peanut.

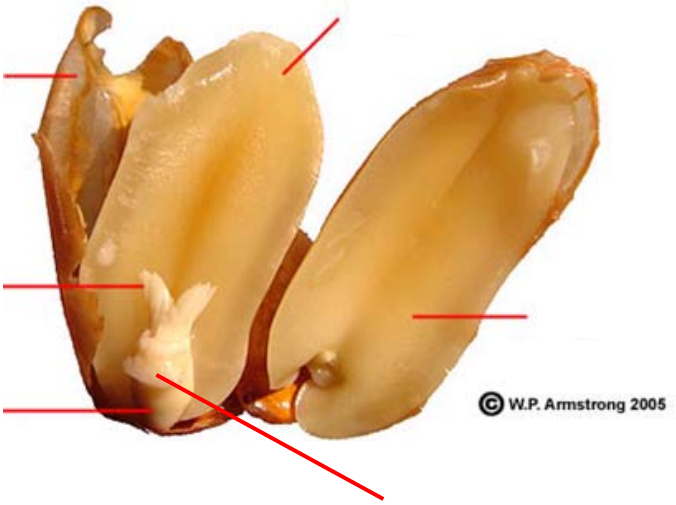
Cotyledon = the "seed leaves", of which there are two in all legumes and dicots, and part of the embryo; in legumes they are packed with starch and proteins absorbed during development from the endosperm, and they will supply nutrition to seedling upon germination.

Hypocotyl = the embryonic stem below the cotyledons.

Radicle = the embryonic root axis below the hypocotyls.

Plumule = the short shoot (including epicotyls and first true leaf primordia) above the cotyledons.

Cotyledon Scar = the scar left by a cotyledon on the rest of the embryo when you split the peanut in half and thereby tore the cotyledon off of the embryo.



4. Kidney Bean and Pea Seeds & Embryos.

1-day Imbibed Seeds from side or back of room.

Examine kidney beans and peas that have been soaked in water overnight. Tear off the seed coat, break off a cotyledon and compare and contrast these via drawings with the peanut.

a. How is the seed and embryo structure in all three species of legume similar?

b. Is the position of the embryo or attachment point and shape of the cotyledons different in the kidney bean or pea relative to the peanut? How so?

c. How does the legume seed differ from the grass seed with respect to endosperm at maturity?

d. How does the legume embryo differ from the grass embryo with respect to cotyledon number and presence or absence of the coleoptile & coleorhiza?

5. Legume Seedlings.

10-day and 5-day Old Bean & Pea Seedlings from side/back of room.

Remove a 1 day-imbibed seed as well as 5- and 10-day old seedlings (clean off all dirt) and take them back to your desk for drawing.

Bean

Be sure to label the
(1) seed coat
(2) 2 cotyledons,
(3) hypocotyl,
(4) radicle, and
(5) plumule (including epicotyl) on all three stages.

Bean Embryo
(1-day imbibed)

Bean Seedling
(5-day imbibed)

Bean Seedling
(10-day imbibed)

Pea

Be sure to label the
(1) seed coat
(2) 2 cotyledons,
(3) hypocotyl,
(4) radicle, and
(5) plumule (including epicotyl) on all three stages.

Pea Embryo
(1-day imbibed)

Pea Seedling
(5-day imbibed)

Pea Seedling
(10-day imbibed)

How do the pea and bean seedlings emerge from the soil? How are they similar and different? Hint: focus on position of cotyledons and the curvature of the emerging stem as you answer the questions below.

a) In the bean seedling, it is the _____ that elongates to raise the shoot out of the soil.

a) root *b) hypocotyl* *c) epicotyl*

b) In the pea seedling, it is the _____ that elongates to raise the shoot out of the soil.

a) root *b) hypocotyl* *c) epicotyl*

c) How does the hook-like curvature of the emerging stem facilitate the emergence and protection of the important shoot apical meristem through the soil?

6. Bean or Alfalfa Sprouts From the Grocery.

Live Sprouts from Grocery, side or back of room. Take back to your desk.

Take a "sprout" and answer the following:

a) The edible sprouts from the store are simply _____. (seeds, seedlings, or fruits?)

b) Be sure you can ID the radicle, hypocotyl, cotyledons and any plumule of a sprout and seed coat remannts.

7. Pulses from the Grocery.

a. Interpreting Pulse Seed Morphology.

Dry Legume Seeds from the back of room. Examine any one of the red or darker colored legume seeds available in beakers or dishes in the back of the room. Fill in the blanks below based upon your study of the seed and extrapolation from the detail of ovary and ovule structure in figure 7.2 (next page).

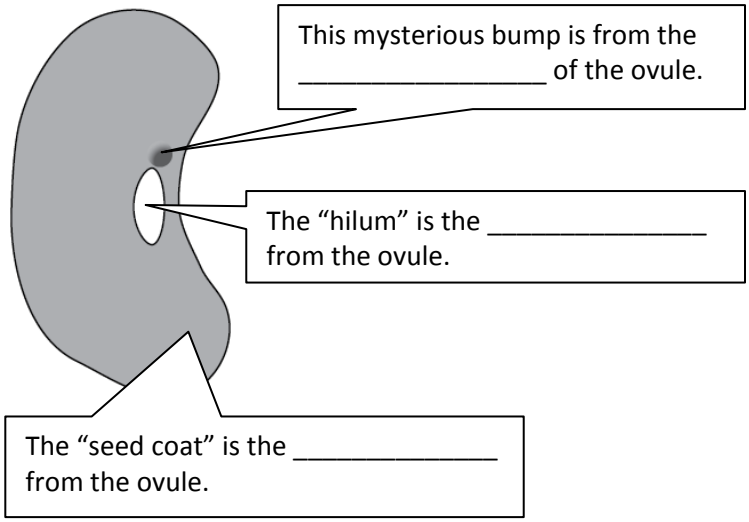


Figure 7.1. A typical bean seed.

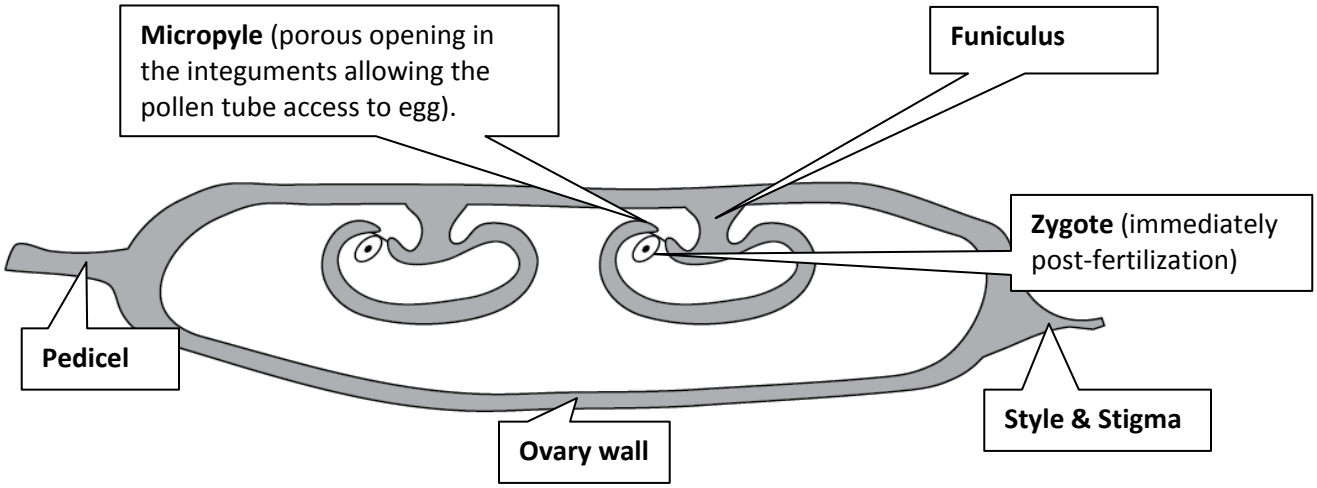


Figure 7.2. Pistil structure and ovule structure just after fertilization.

b. Bean Identification.

Dry Legume Seeds from back of room. Be sure you can identify and distinguish between all of the different kinds of beans. If you take them back to your bench, please return them to the correct beakers in back of room.