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Seeds - Development, Structure and Function

H. C. Potts

SEEDS - DEVELOPMENT, STRUCTURE AND FUNCTION

Howard C. Potts[1]

You depend upon seeds for your livelihood but what do you know about this amazing product of nature? What is a seed - this thing on which we all depend so heavily?

As you know, we plant seeds, grow seeds, harvest seeds, dry seeds, clean seeds, grade seeds, package seeds, store seeds, test seeds, and hopefully sell seeds - yet most of us don't have the capability to set down and outline, even in simple botanical terms, the basic processes and structures involved in the complete life cycle of a seed from flower formation through germination. Let's face it, seeds are our baby. Why this taboo on the sex life, structure and function of seeds? We can no longer blame Queen Victoria for our ignorance about sexual reproduction. Surely every professional should know and understand the produce from which he earns his living. How professional are you or how professional am I in this respect?

Somewhere in your educational career you have been told about the birds, the seeds and the flowers. The major portion of my discussion will deal with "the flowers."

There is a point in the life cycle of every plant when the balance of physiological processes shifts from vegetative growth to the development of reproductive structures. It is at this point that seed development really begins. For the remaining period of the growth cycle, the plant's entire physiological being is geared to development of the reproductive structure which we call a seed.

Generally we do not concern ourselves with this shift in growth emphasis until we observe its visible expression in the form of flowers, panicles, ear shoots, etc. But morphological studies indicate that by the time these outward expressions of reproduction are observed the plant has used approximately one half of the total time that it will devote to reproduction. Time wise, then, we really get interested in this ballgame only after the first 4 1/2 innings have already been played. Then we jump and yell "send me in coach" or we decide to call the game because of a dry field.

Fortunately for us, plants are not as "pessimistic" as people. Except in the most unusual circumstance, every plant will produce at

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least one good seed or die trying. This basic drive for reproduction of the species is apparently much stronger in plants than in animals.

As seedsmen we must always remember that the plant does not produce seed for our use but to maintain itself. Have you observed the fact that plants produce only the number of seed that can be completely developed rather than producing a larger number of partially developed seed? Maybe people are not as "smart" as plants!

Let us now turn our attention to the sequence of events that naturally occur in the development of the seed giving consideration to the structure and function of the developed seed.

All seed producing plants have flowers! Some are pretty, some ugly, some small, some large - they come in an endless variety of colors, sizes, and shapes. There are "boy" flowers and "girl" flowers but most flowers are hermophidites - that is, the flower has both the male and female reproductive organs in the same flower. Some weird ancient botanist designated these as perfect flowers. Now, let's look at a typical flower and delve into its sex life.

Plate 1 is a cut-away drawing of a typical flower and is labeled with the scientific names of the various parts of a complete flower. Technically, all of the sepals together are called the calyx and all the petals together are called the corolla. These structures have no direct role in reproduction.

Of primary concern are the stamen, which is the male flower, and the pistil, which is the female flower. You will note that the stamen has two principal structures, the filament and the anther. The anther is the "business end" of the stamen and the filament the stalk which supports the anther. In each species it positions the anther to allow it to most effectively perform its role of production and distribution of the male sex cells which we call pollen. When the anther splits, releasing the pollen, its role is completed. In most species there are several hundred times as many pollen grains produced as there are female flowers needing fertilization. Thus, the male flower says "here it is girls" and the "girls" may or may not be interested.

The pistil consists of three basic parts: the stigma, style and the ovary, which may contain one or many ovules. The stigma may be knobby, featherlike, or long and slender. Regardless of the shape it is normally covered with a sticky stigmatic fluid which acts both as an adhesive to hold the pollen grain and to supply moisture for the pollen grain's germination. When pollen of one species lands on the stigma of another, it normally will not germinate, although in closely related species it may.

The style performs two functions. First, it is responsible for the physical placement of the stigmatic surface in a predetermined position which will increase the probability of the desired pollen

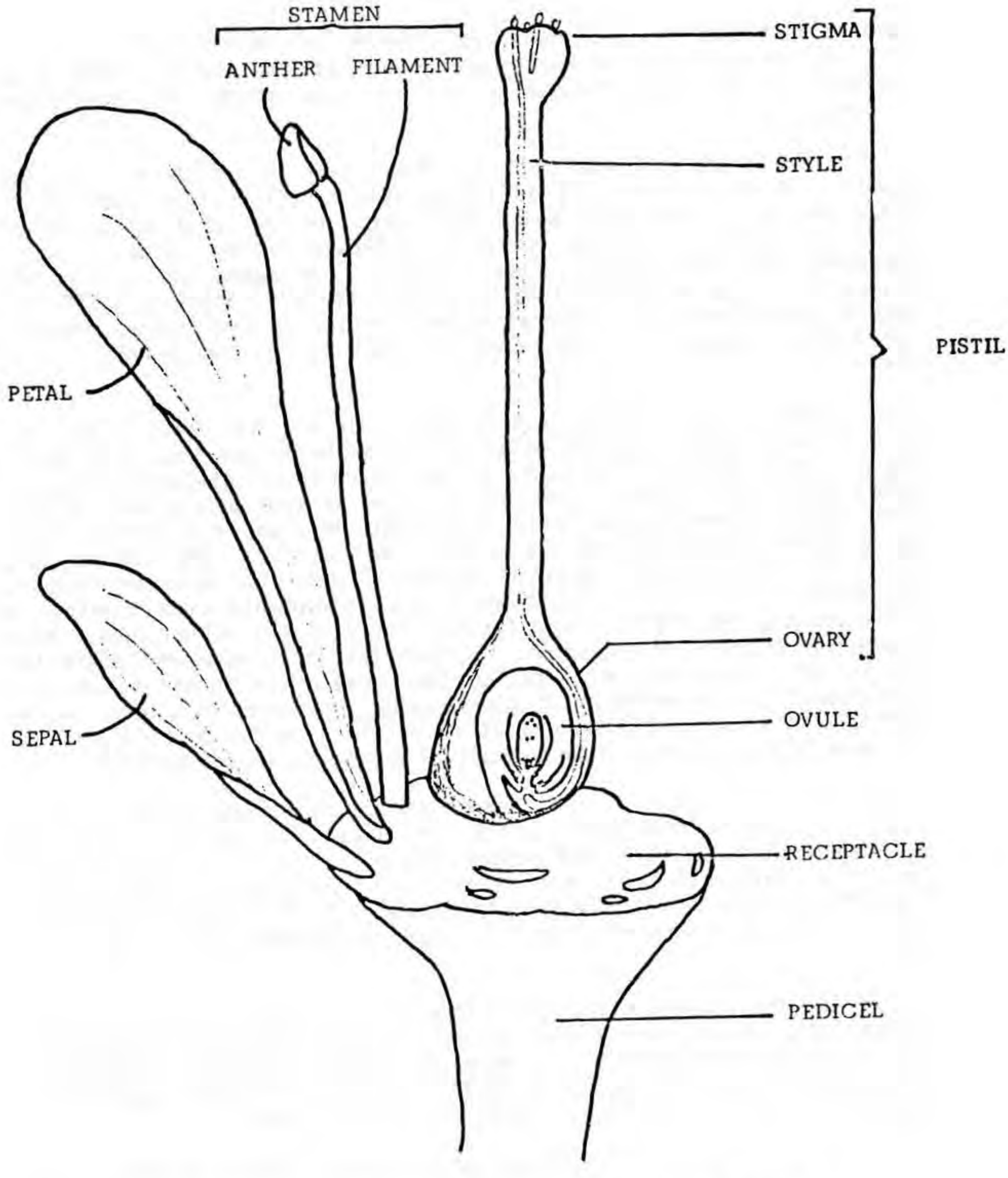


PLATE 1 CUTAWAY VIEW OF TYPICAL PERFECT FLOWER

landing on the stigma. Second, its internal cellular structure is such that it protects and enhances the growth of the pollen tubes from desirable pollen and discourages pollen tube growth of undesirable species.

The ovary is that part of the flower in which we have the greatest interest because it is inside this structure that the seed or seeds develop. The organ which gives rise to the seed is called an ovule and there may from one to several thousand ovules inside an ovary, depending upon the species. Corn, sorghum, lespedeza and zinnias are examples of ovaries containing a single ovule. Soybeans, alfalfa, watermelon and okra have several to many ovules in each ovary. Regardless of the number of ovules, each one conducts its own private little affair.

Let's take a close look at the ovule and its parts (Plate 2). Here we see a cross section of a typical ovule inside the ovary wall. The principle parts of the ovule are the funiculus, integuments, micropyle and the embryo sac. The funiculus, or as some people call it the ovule stalk, connects the ovule to the mother plant functioning similarly to the umbilical cord in animals and rockets. The integuments, there are normally two, serve as delicate fingers to hold and support the embryo sac. At the point where the integuments come together a small opening remains to allow for the entry of the pollen tube. This opening is called the micropyle. Between the inner integuments and the embryo sac a layer of cells called the nucellus is formed to aid the nourishment of the embryo. In some species the nucellus gives rise to embryos and subsequently seed which do not require the participation of the male. Such an event is an example of a process called apomixis.

The embryo sac is the "heart" of the ovule and the location of female egg cell which when fertilized gives rise to the seed. In addition to the egg cell most mature embryo sacs contain 7 other cells; the three anitpodal cells are relatively unimportant as are the two synergid cells which are located on either side of the egg cell. The 2 polar nuclei are very important in seed development as we shall see later.

In most species the development of both the male and female reproductive organs are syncronized and they reach maturity together. If they do not mature together I believe you can readily recognize that the more advanced sex will go "looking for a partner." Plants where this normally occurs we refer to as being cross pollinated.

There are several other mechanisms which lead to cross pollination. The mechanics of pollination and fertilization are simple. For each ovule (egg cell and polar nuclei) to be fertilized a pollen grain of the same species must land on the stigmatic surface. This is pollination. After the pollen grain germinates (Plate 3) the two sperm cells remain near the growing point of the pollen tube. When the pollen tube passes through the micropyle reaching the embryo sac it ruptures

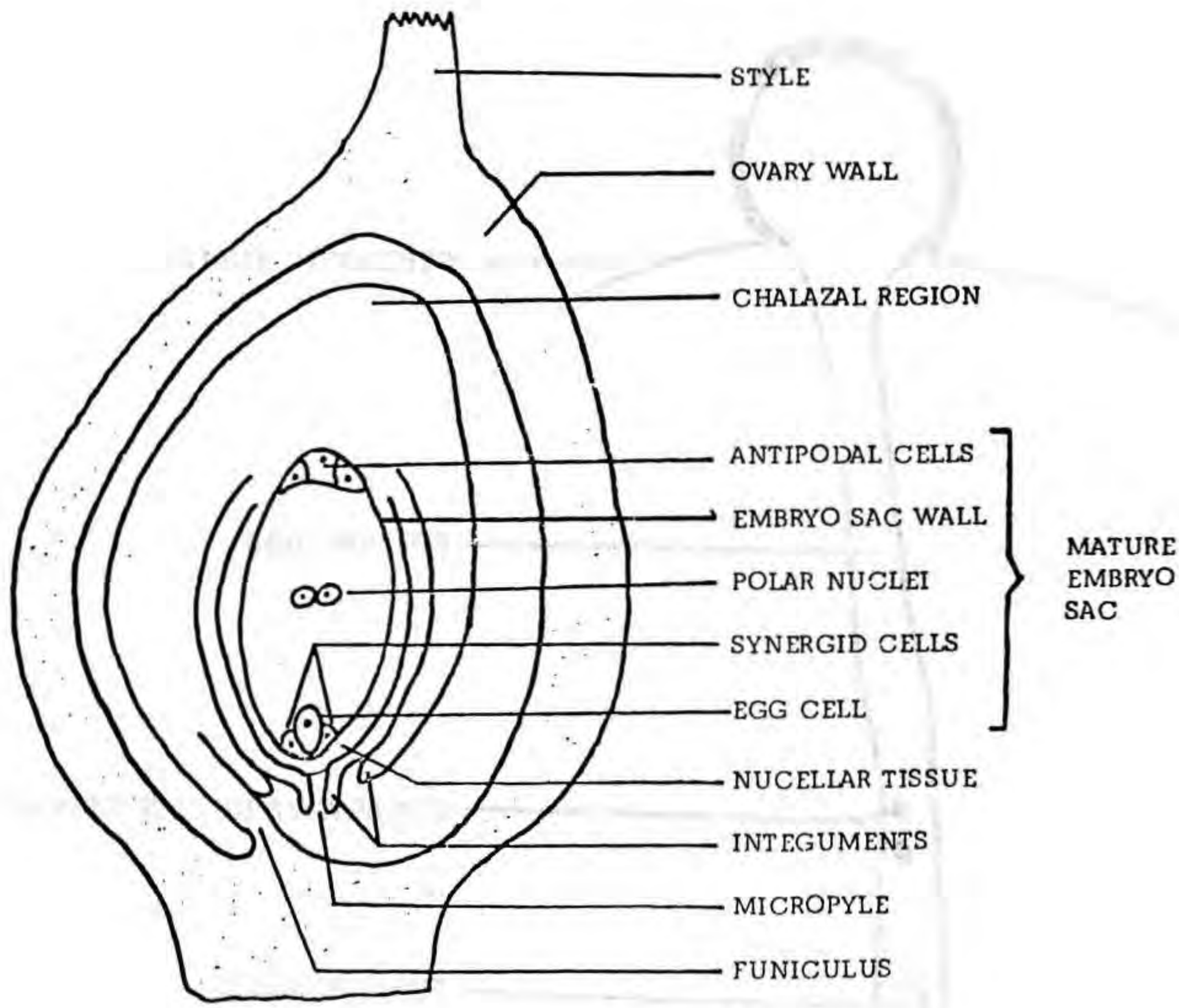


PLATE 2 CROSS SECTION OF OVARY AND OVULE

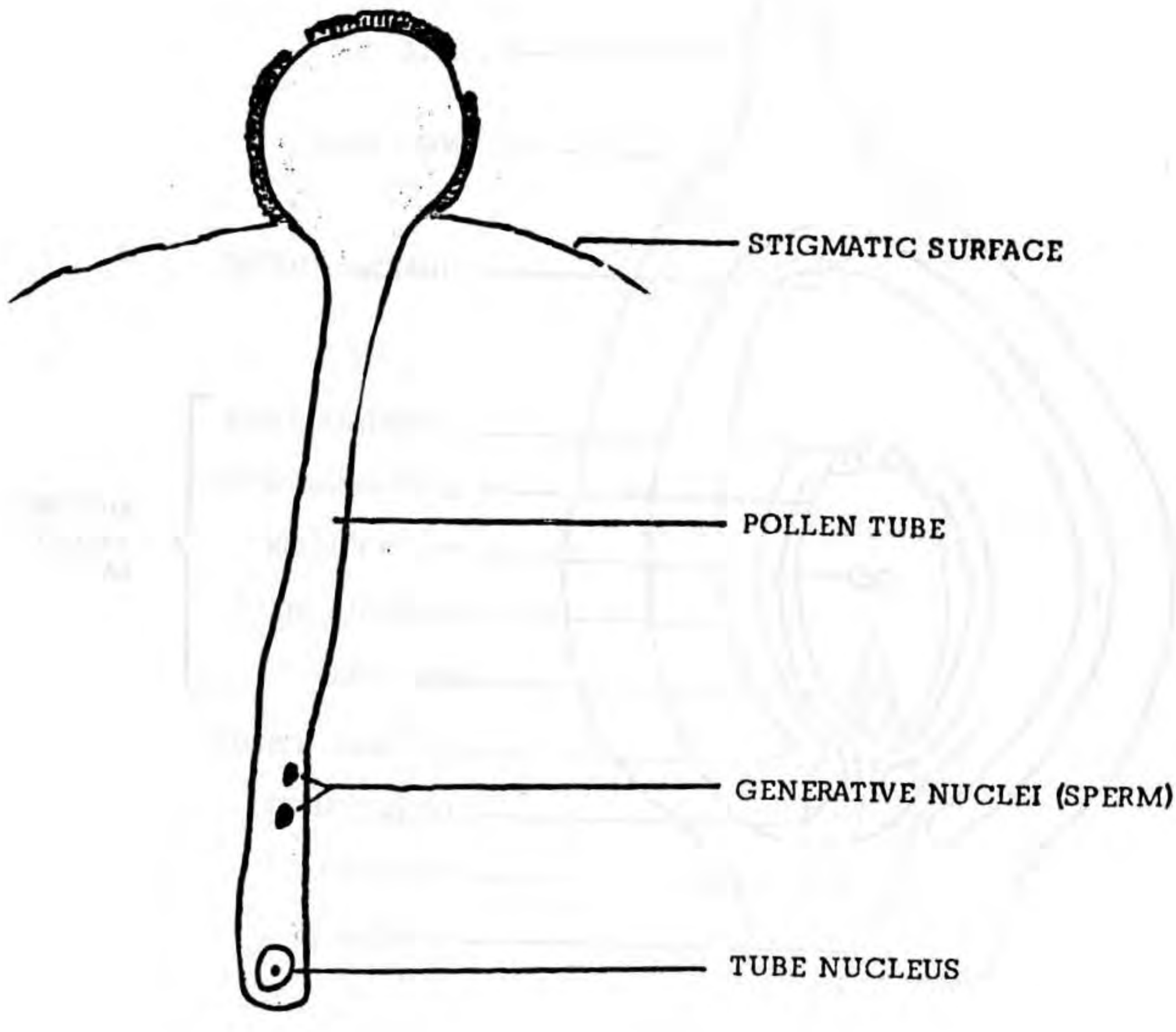


PLATE 3 GERMINATED POLLEN GRAIN

releasing the two sperm into the embryo sac. One sperm units with the two polar nuclei and the other with the egg. This process is called double fertilization and is unique to the plant world.

The union of a sperm and the egg forms a cell called the zygote. It is this cell which starts the new generation and gives rise to the embryo. The other union forms the endosperm which we often refer to as part of the embryo, though technically it is not. The primary function of the endosperm is to provide nourishment for the embryo as it develops. The five antipodal and synergid cells degenerate shortly after fertilization.

The newly formed cells start division almost immediately with the endosperm initially dividing the more rapidly of the two. With the first division of the zygote, which is always on a transverse plane, the polarity of the new plant is established. That is the new cell formed nearest the micropyle will give rise to the roots and other associated parts. The other new cell will give rise to the above ground; stem, leaves and eventually flowers. You can turn the plant any way you want but it won't change this fact.

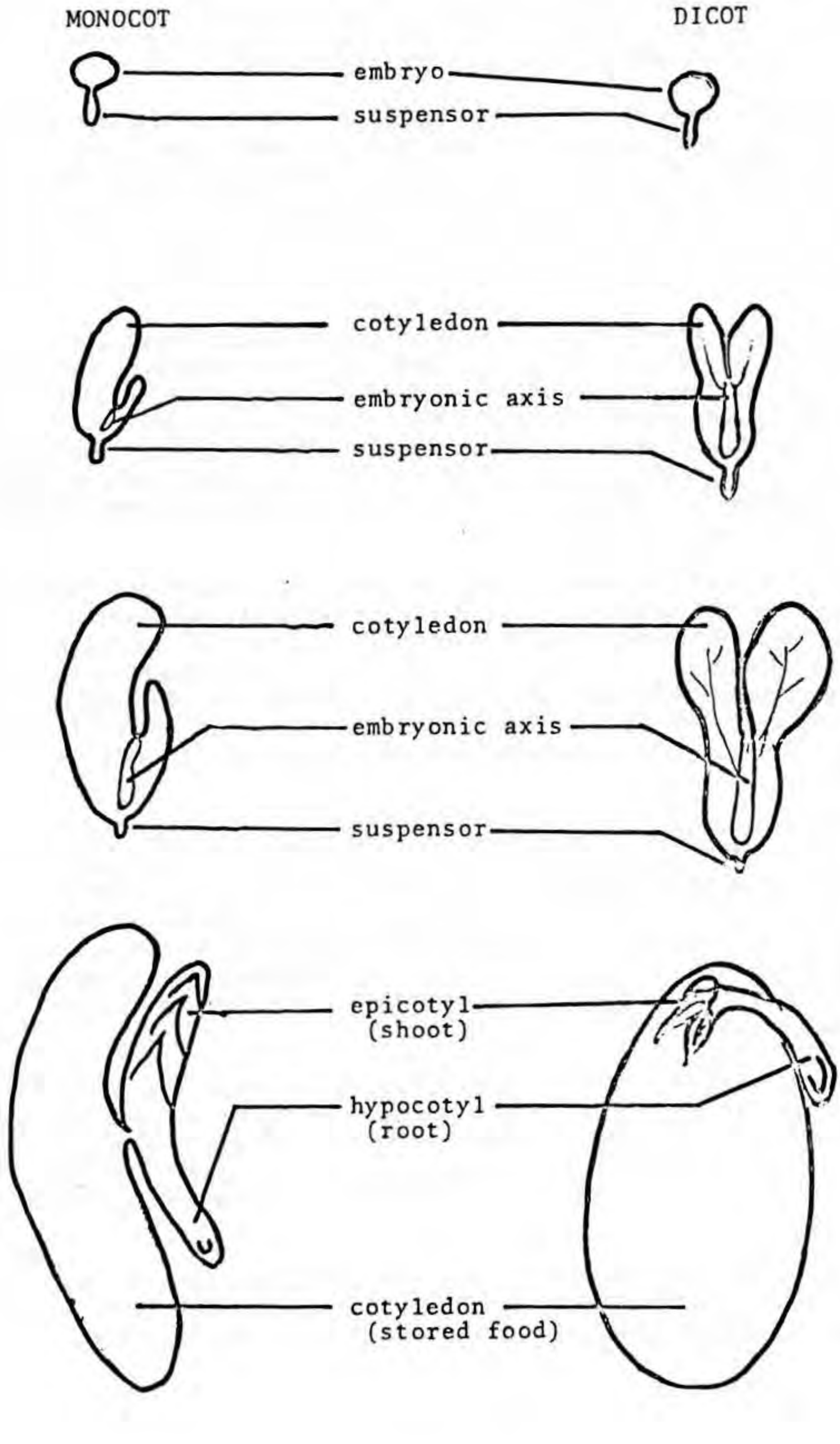
For the next few hours, days, or weeks the embryo and endosperm cells divide rapidly with the plant's entire system being devoted to the nourishment and development of the embryo. If the soil cannot provide the chemical compounds required for the seeds' development some compounds are transferred form other parts of the plant to nourish the seed. Thus, we often see the familiar symptoms of nutrient deficiency accentuated as the seeds develop but it's too late to add chemical fertilizers.

A few days after fertilization of the egg cell we can see the first signs of distinction between the dicotylodonous (seeds having two cotyledons) and monocolyledonous (seeds have one cotyledon) species. Up to this point essentially the entire developmental process is the same. A brief study of Plate 4 will reveal that the presence or absence of the second cotyledon is the primary difference in embryo development from now until maturity. Otherwise, the essential structures of the developing embryos are the same.

You will notice that at maturity seeds of both the monocot and the dicot have (a) an embryonic axis, which terminates at one end with the embryonic root and at the other with an embryonic shoot, (b) a source of stored food, in the cotyledon(s) and in some species the endosperm or nucellus and (c) a protective covering, called the testa or seed coat.

When using the term maturity I believe that some of you might think of a golden field of grain. If you do, you are not thinking with me. A seed is mature when it reaches the stage of maximum dry weight.

PLATE 4 4 STAGES OF EMBRYO DEVELOPMENT



It is at this strategic stage in the development of a seed which signifies the attainment of maximum potentiality for performance, in most economically important species.

Attaining maturity may be regarded as a positive process which includes: increase in seed size, accumulation of dry weight, development of the essential structures, a loss of moisture, and an increase in viability and vigor. Almost immediately following maturity, the seed enters a negative phase which is characterized by a decline in viability and vigor caused by respiration, high temperature, high humidity, mechanical injury and time. This phase is terminated by the death of a seed. This can be visualized by observing Plate 5.

Thus, the waving field of golden grain does not represent a field of mature seeds rather the field is a terribly exposed storage place for seeds which have already entered the negative phase we call deterioration. Therefore, our concept of maturity is very important when considering harvesting, drying, storage, an subsequent field performance of the seeds.

Let us now consider some aspects and characteristics of mature seeds which are determined by the developmental processes already discussed. As I indicated a seed consists of an embryonic axis, stored food and the testa or seed coat. To equate the botanical terms used in discussing the flower and seed development into terms of the seed, refer to Plate 6. The seed coat, hilum and micropyle can be observed rather easily on most seeds. A simple cross section follows identification of the other essential organs of a seed (Plate 7).

Most seeds have one or more structural weaknesses which are an unending source of problems to us as seedsmen. It seems that God, in his infinite wisdom, overlooked the brutality to which man would subject seeds of the various species. On the other hand, maybe we should change some of our methods to better align them to the seeds with which we deal.

Consider the seed coat which, when undamaged, is a better protectant than any seed treatment that we may add. In the coconut or brazil nut the seed-coat is hard and offers excellent protection to the delicate embryo but most seeds are not so fortunate. Rather they are protected by a thin shell like an egg which, in our mechanical age, is easily broken by dropping or at best a slightly more severe shock. We are fortunate that many of the seeds we use are either so small, light, or are protected by additional coverings as in the case of many of the grasses, and, therefore, escape our attempts to kill them.

In many species the embryonic axis is exposed (Plate 8) and like our nose catches the brunt of a headlong impact. But unlike our noses the embryonic axis once broken cannot be taped over and left to heal. The removal of the seed coat from many seeds will reveal the axis' exposed position.

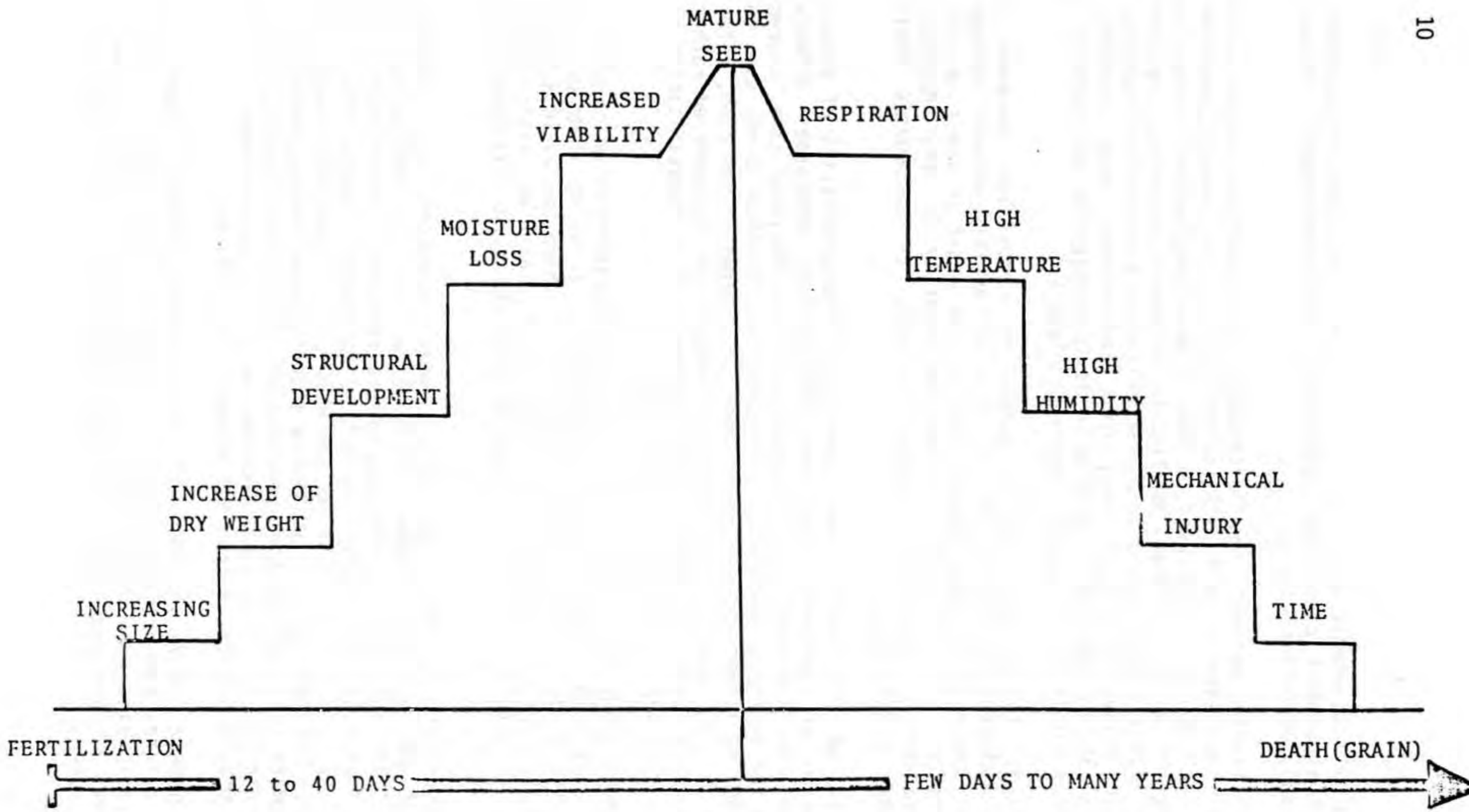


PLATE 5 THE RISE AND FALL OF A SEED'S CAPABILITIES

AT FLOWERING	AT MATURITY
OVARY	FRUIT (SOMETIMES COMPOSED OF MORE THAN ONE OVARY PLUS ADDITIONAL TISSUES)
OVULE	SEED (SOMETIMES COALESCES WITH FRUIT)
INTEGUMENTS	TESTA (SEED COAT)
NUCELLUS	PERSIPERM (USUALLY ABSENT OR REDUCED)
2 POLAR NUCLEI + SPERM NUCLEUS	ENDOSPERM (TRIPLOID-3N)
EGG NUCLEUS + SPERM NUCLEUS-------ZYGOTE	EMBRYO (DIPLOID-2N)
MICROPYLE	MICROPYLE
FUNICULUS	HILUM (SCAR LEFT BY BREAKING OF THE FUNICULUS)

PLATE 6 RELATIONSHIP OF FLOWER TO MATURE REPRODUCTIVE STRUCTURES

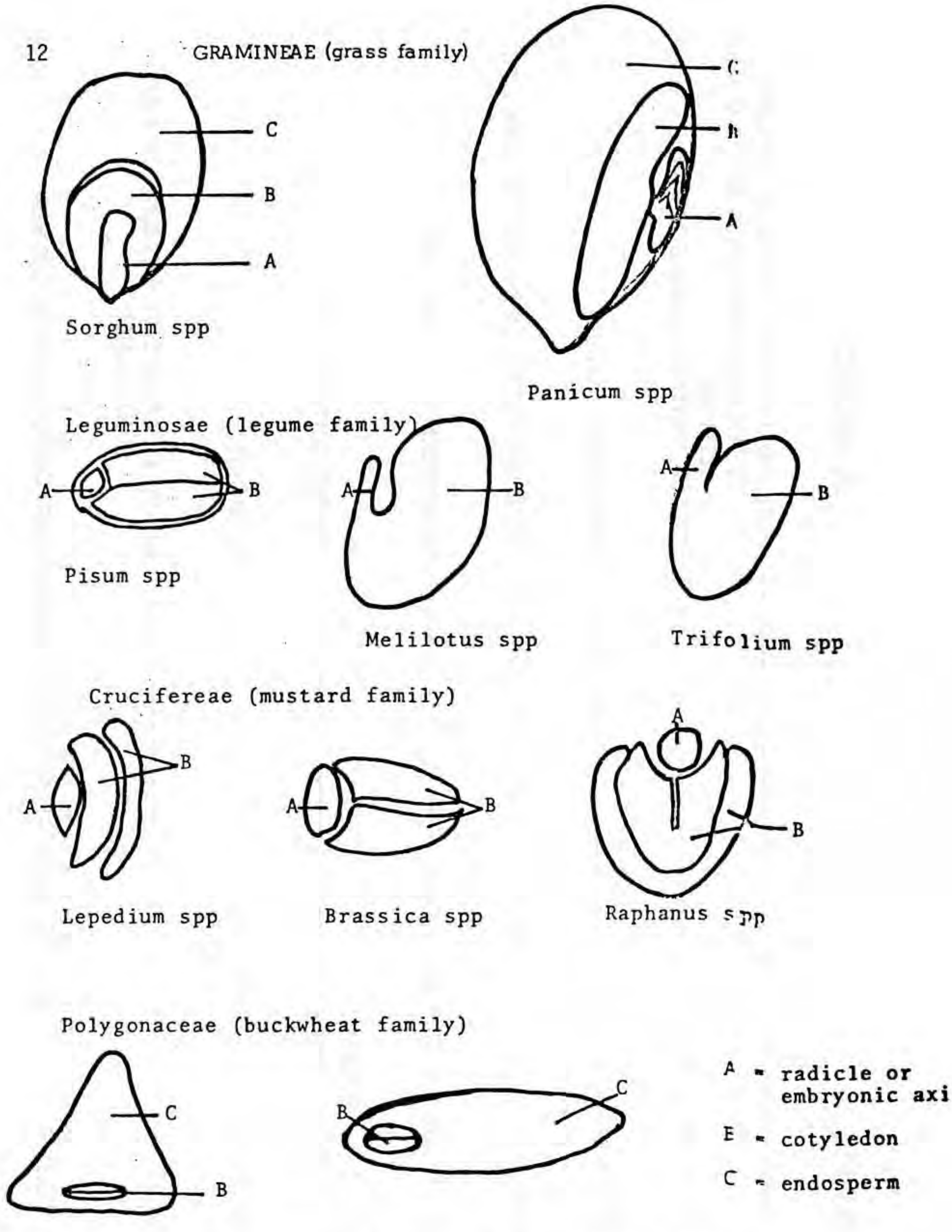
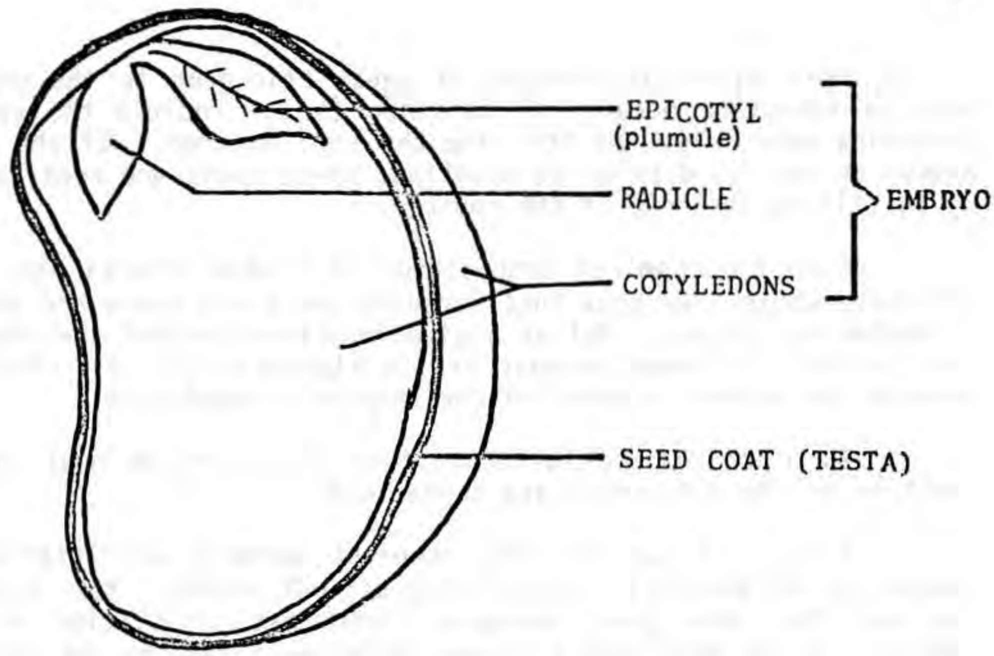


PLATE 7 STRUCTURAL RELATIONSHIPS OF VARIOUS SEEDS



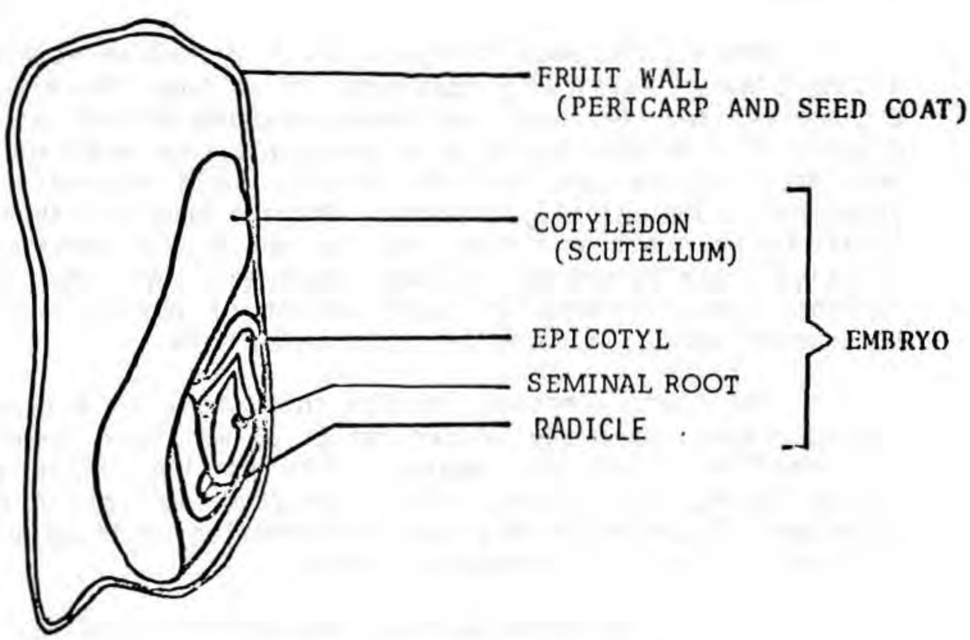


PLATE 8 STRUCTURE OF TYPICAL DICOT AND MONOCOT SEEDS

Here again the embryos of seeds belonging to the grass family have an advantage because in addition to the radicle the seminal root primorida were formed by the time the seed matured. If the radicle is broken or destroyed prior to planting, these roots are ready and capable of fulfilling the role of the radicle.

Even the chemical composition of a seed affects its ability to withstand abuse. We know that soybeans and field beans are very subject to mechanical injury. But at a given moisture content the field bean is more subject to damage because of its high starch to oil content simply because the starch is more brittle than oily substances.

As a logical conclusion to this discussion we must consider the function of the seed which are three fold:

First, it carries the inherent genetic characteristics from generation to generation essentially without change. Yes, I am aware of the fact that some plant breeders claim that irradiation of seeds has resulted in the development of new varieties. Yet, no one has presented data to prove that this exposure was responsible for the new varieties; rather they state that a line or strain was selected from a field planted with seeds exposed to ionizing radiation. There is a distinct difference.

Second, the seed functions as an effective storage system for a living plant. Physically speaking, if we took the most scientifically engineered and equipped refrigerated-dehumidified storage room and dropped it from the top of a building you know what would happen. Yet, most seeds of the same specific gravity would be unaffected by the same treatment. Biologically speaking, leave a head of cabbage on a kitchen table for a month and then try to use it. A cabbage seed would be relatively unaffected by the same treatment. No other container or its contents can withstand an equal amount of physical and environmental punishment and still perform its intended role.

The third function, brings this story to a close and this, is reproduction. When the proper ratios of moisture, temperature, oxygen and sometimes light are reached, this amazing little package of life spring forth, root first, into a structure we call a seedling. Then once again the miracle of a seed is forgotten until we see the beauty of a flower or the golden field of grain.

Now as we continue through this meeting,
then go our separate ways:
I ask that each of you remember not;
my simple words of praise;
But rather, behold the seed I have,
and the amazing role it plays.