How Seeds Are Formed

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A FLOWER exists to produce seed.

For that, two organs are essential.

The stamen produces pollen grains that later form the male cells, or sperms. The stamen has a stalk, or filament, at the tip of which is the pollen sac, or anther.

The pistil, usually in the center of the flower, is the female organ. Normally it has three fairly distinct parts: The ovary, which contains one or more immature seeds, called ovules; above the ovary, a slender style, or tube; at the tip of the style, the stigma, on which the pollen is deposited.

The stamen and pistil are called essential organs because they are necessary if there is to be seed.

Two other organs—sepals and petals—are not directly involved in sexual reproduction. Some flowers do not have them. We call them accessory organs. A flower that has all four organs is a complete flower.

The sepals are the lowermost of the four organs. Usually they look like leaves. Their main function is to protect the bud until it has developed into a flower. The sepals collectively are called the calyx.

Above and inside the calyx are the petals, known collectively as the corolla. In many flowers they are brightly colored. The petals of many flowers have glands—nectaries—in which a sweet liquid, called nectar, is secreted.

The colors, the nectar, and the odors of essential oils produced by the petals of many flowers attract insects, hummingbirds, people, and other creatures, which, with wind and gravity, may transfer the pollen from the anther to the stigma to fertilize the ovules.

Sometimes the reproductive organs are formed in separate flowers on the same plant. Such plants are said to be monoecious. The watermelon, cucumber, and other members of the gourd family are examples.

Individual plants of some species have one-sexed flowers—that is, flowers on a plant may have only stamens, and the flowers of another plant of the species may have only pistils. To such plants the term dioecious is applied. The holly is an example.

A SEED is a ripened ovule containing an embryo.

A fruit, in terms of origin, is a ripened ovary containing the seeds.

Both ovule and ovary are in the pistil of the flower. To identify seeds and fruits correctly, one has to follow the development of these parts to maturity.

The botanical definition of a fruit is much broader than the popular meaning of the word. For example, the mature bean pod is the fruit of the bean plant, and bean seeds are ripened ovules. The bean pod originates in the bean flower as a minute ovary, which contains ovules so small as to be scarcely visible without a magnifying glass.

Fruit and seeds are present in miniature form in the flower as ovary and ovules, hence the importance of the flower in the development of the seed.

Each female flower in the corn plant has an ovary containing a single ovule, and the mature grain, or fruit, is single seeded, and the ovary wall and the seedcoat are united to form a single covering. Many ovaries are arranged together on a common receptacle, which later becomes the cob of the ear of corn. The long, slender silk is the style through which the pollen tube grows to reach the ovule. A grain of corn is a familiar example of a single-seeded fruit that is commonly called a seed.

All the important cereals are members of the grass family, and have one-seeded fruits.

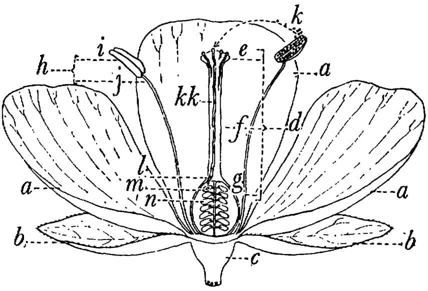
The large sunflower and other members of the aster family, such as lettuce, dandelion, and aster, produce one-seeded fruits.

By contrast, the ovary of the watermelon flower contains many ovules, which mature to produce the many-seeded watermelon (fruit).

The plants that produce seed are in two natural divisions.

Gymnosperms, the "naked-seeded" plants, bear cones and produce seeds on the surface of cone scales. Among them are such trees as pine, fir, cypress, cedar, and redwood. In the gymnosperms, ovules are produced in female cones, and the pollen is produced in male cones. Pollen is carried to the ovule-bearing female cones by the wind, and each ovule matures into a "naked" seed. This group has no structure comparable with the fruit of the angiosperms, the other division, which are the true flowering plants.

A Typical Flower



a–a–a, petals (corolla); b–b, sepals (calyx); c, receptacle; d, pistil (composed of: e, stigma; f, style; g, ovary); h, stamen (composed of: i, anther; j, filament); k, pollen, kk, pollen tube; l, sperm nuclei; m, egg cell; n, ovule.

THE SEED-PRODUCING plants—spermatophytes—originated from lower forms of the plant kingdom through a long series of evolutionary changes in both the reproductive and vegetative structures.

The four great divisions of the plant kingdom, beginning with the simplest and ending with the most complex, are algae and fungi; liverworts and mosses; ferns and fern allies; and the seed plants, the spermatophytes.

Algae and fungi lack differentiation of the plant body into true roots, stems, and leaves, although some of the forms may have structures that resemble those organs. Sexual reproduction makes its appearance in this group, but the sex organs and spore-producing structures are usually one celled and primitive. Most of the algae live in water, and the simple, reproductive structures seem to depend on water for functioning and distribution.

Liverworts and mosses are essentially land plants. The zygote—the fertilized egg—is retained in the female sex organs for some time, during which it divides to form a mass of cells, the young sporophyte—or asexual phase of the plant's life cycle. During this period, the sporophyte gets its food, water, and other essentials of life from the gametophyte—the part of the plant which produces gametes, or sex cells—and thus is parasitic on it.

The many-celled and differentiated sporophyte is structurally adapted to withstand drying out and is linked with the beginning of the existence of plants on land. In water plants, such as algae, the zygote is protected against drying, since it is bathed in water at all times.

Mosses have sporophytes that are about equal in size to the gametophyte but depend on the latter for nourishment.

The ferns and fern allies are the first great group of plants that develop an independent sporophyte with true roots, stems, and leaves.

This is one of the most important steps in the evolution of the plant kingdom. The development of a vessel system, which allows water and food to be conducted rapidly through stems, roots, and leaves, was mainly responsible for this advance.

The sporophyte is the dominant plant body in this group, and the gametophyte is usually quite small, though still independent and selfsustaining. Spores are disseminated as asexual bodies when conditions are favorable and develop into small, separate gametophytes.

In seed plants, the last big step in plant evolution, the sporophyte is completely dominant over the gametophyte. Spores are retained in special organs of the sporophyte (essential parts of the flower), and male and female gametophytes are formed within these organs.

The fertilized egg in all lower plants develops immediately into the mature sporophyte, but in seed plants it grows for a time and then goes into a dormant condition to form the seed.

Some of the lower algae multiply only by mitotic cell division—a process of exact splitting of the chromosomes, resulting in two identical cells where one existed before.

Beginning with the higher algae and extending through the rest of the plant kingdom, a process known as alternation of generations is the framework of evolutionary change.

That means that a sexual generation (gametophyte) alternates with an asexual phase (sporophyte). In algae and fungi, the gametophyte generation is the dominant plant body, and the sporophyte, usually quite small, is parasitic on the gametophyte.

Evolutionary differentiation from this point on involved a gradual reduction in size of the gametophyte and consequent increase of the sporophyte.

In the seed plants, reduction of the gametophyte generation has reached the point at which the male gametophyte (pollen tube) and the female gametophyte (embryo sac) are much reduced and are parasitic on the sporophyte—an exact reversal of the relation of the two phases in algae.

Special cells of the ovule and anther differentiate into embryo-sac-mother-cells and pollen-mother-cells, all having the diploid or sporophytic number of chromosomes.

The mother cells divide by a process called meiosis, which results in the daughter cells receiving half the number of chromosomes characteristic of the species. Male and female gametophytes derived from the daughter cells—pollen grains and embryo sacs—thus have nuclei with the reduced or gametophytic number of chromosomes. Fusion of sperm and egg at fertilization restores the double, or diploid, chromosome number in the new embryo or sporophyte.

The goal of plant evolution seems to have been the vegetative development and specialization of the sporophyte, with consequent reduction in the gametophyte.

Sexual reproduction in seed plants, resulting in the formation of a young resting sporophyte, the embryo of the seed, is highly efficient. The success of the seed plants in dominating the vegetation of the earth undoubtedly can be ascribed to development of the seed, which makes possible the dispersal of plant species over wide areas and their survival through periods of unfavorable environmental conditions.

The formation of seed in the higher plants depends on processes of sexual reproduction in the flower. One should know the nature of these processes and where they occur.

Six steps in the development of reproductive plant structures leading to formation of seed are:

The formation of stamens and pistils in flower buds;

the opening of the flower, which signals the sexual maturity of these organs;

pollination, which consists in transfer of the pollen from the stamen to the pistil; germination of the pollen; and formation of the pollen tube;

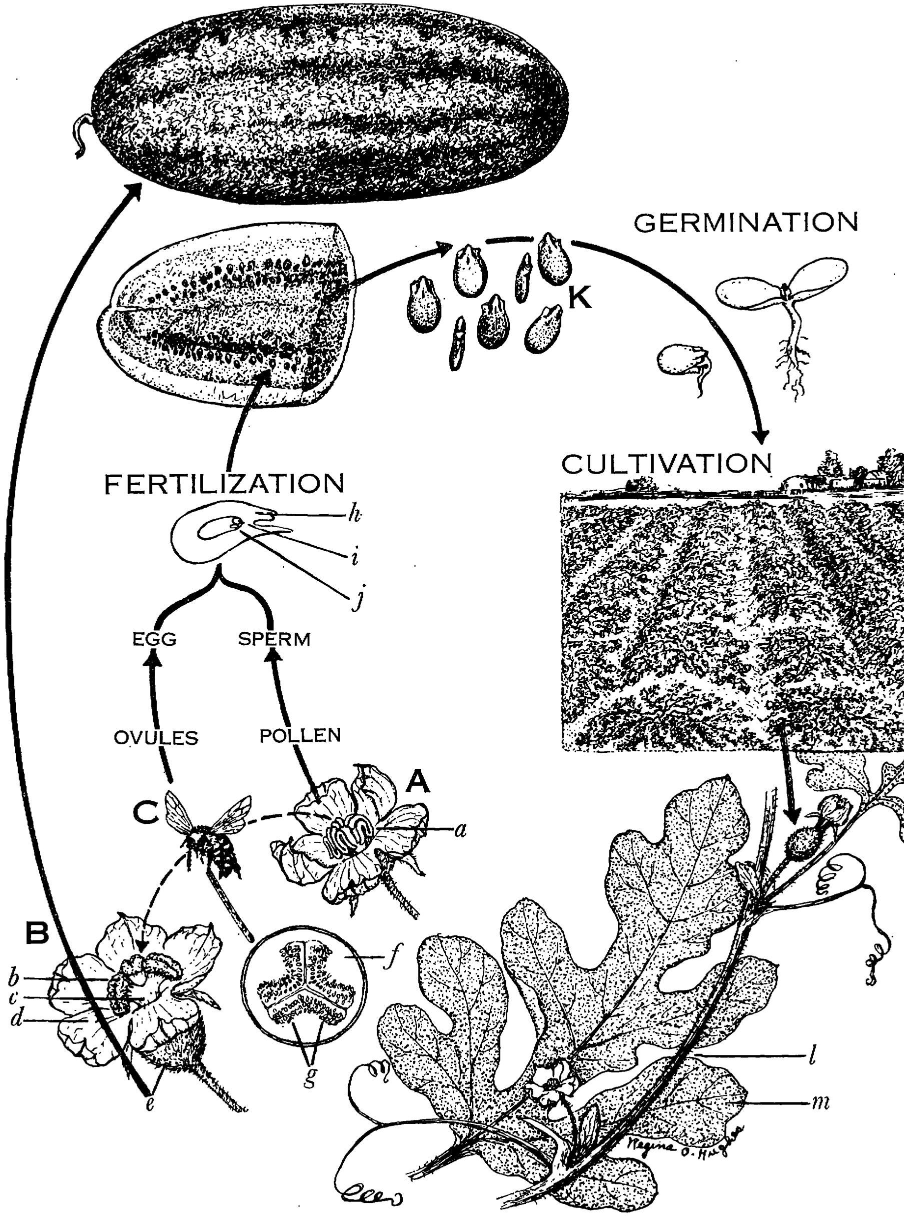
fertilization of the egg and polar nuclei by the sperm nuclei from the pollen tube;

growth of the fertilized egg and its differentiation into an embryo plus a surrounding coat—the seed; and

maturing of the seed, usually with an accumulation of stored food.

Pollen grains are carried from the stamens to the stigma of the pistil by

Watermelon from Flower to Fruit



A, *male flower;* B, *female flower;* C, *pollinating insect (honey bee); a, stamens; b, stigma; c, style; d, petals (corolla); e, ovary (develops into mature watermelon fruit); f, cross section of ovary; g, ovules; h, ovule at time of fertilization; i, egg; j, sperm nucleus;* K, *mature seeds (Honey Cream variety); l, portion of mature plant (vine) bearing male and female flowers and tendrils; m, mature leaf.*

insects, wind, or gravity. This crucial step may be seriously impeded if conditions are not right.

An example: Honey bees pollinate clover flowers in fields grown for seed production. If the clover flowers during a long rainy period, the bees cannot fly, and the seed crop may fall far short of the normal because of inadequate pollination.

Insects are attracted to flowers by odor, color, or nectar. Some of the clovers produce great amounts of nectar. Much of the commercial honey available in markets is made by bees working in clover fields. This is an example of partnership in Nature, in which the bees, by pollinating the clover blossoms, play a necessary part in seed production and in return receive nectar for their services.

The pollen grain germinates on the surface of the stigma and produces a long, slender tube, which grows through tissue of the style to the ovule. Two male nuclei, or sperms, move down each pollen tube to the ovule. One unites with the egg in the embryo sac of the ovule; the other with the two polar nuclei. This is called double fertilization.

The fertilized egg develops into a rudimentary plant, the embryo of the seed, the starting point of the next plant generation. The fertilized polar nuclei develop into a tissue called the endosperm, which surrounds and nourishes the growing embryo.

The endosperm in most seeds is absorbed completely by the embryo by the time the seed matures. Among the plants whose seeds contain no endosperm are bean, watermelon, garden pea, and pumpkin. The edible part of the coconut is endosperm. In corn, wheat, and other cereals, the endosperm makes up a large part of the nutriment in the seed.

After fertilization, the embryo, which starts as a single cell, grows rapidly, and the ovule expands to accommodate the enlarging structures within. The embryo is a mass of undifferentiated cells in its early stages.

As enlargement continues, three well-defined structures are formed: The epicotyl, or young shoot; the hypocotyl, or young root; and the one or two cotyledons, or seed leaves.

Usually the cotyledons of the embryo become thickened to permit storage of food materials, such as starch, sugar, oil, or protein. The accumulation of stored food in the embryo or other parts of the seed usually signals maturity. The period of "filling" of the embryo, or endosperm, is one of stress on the mother plant, because large amounts of organic food materials must be manufactured by the leaves and transported to the developing seeds.

Finally, enlargement of the embryo ceases, the parts become dry, and the seed becomes a dormant living organism prepared to withstand adverse conditions.

The mature seed we have discussed so far from the standpoint of origin as a ripened ovule. Structurally, though, the seed is a resting embryo plant, which is surrounded by a seedcoat and may have an endosperm.

The embryo has one or more cotyledons, which in many instances will serve as foliage leaves when the seed has germinated.

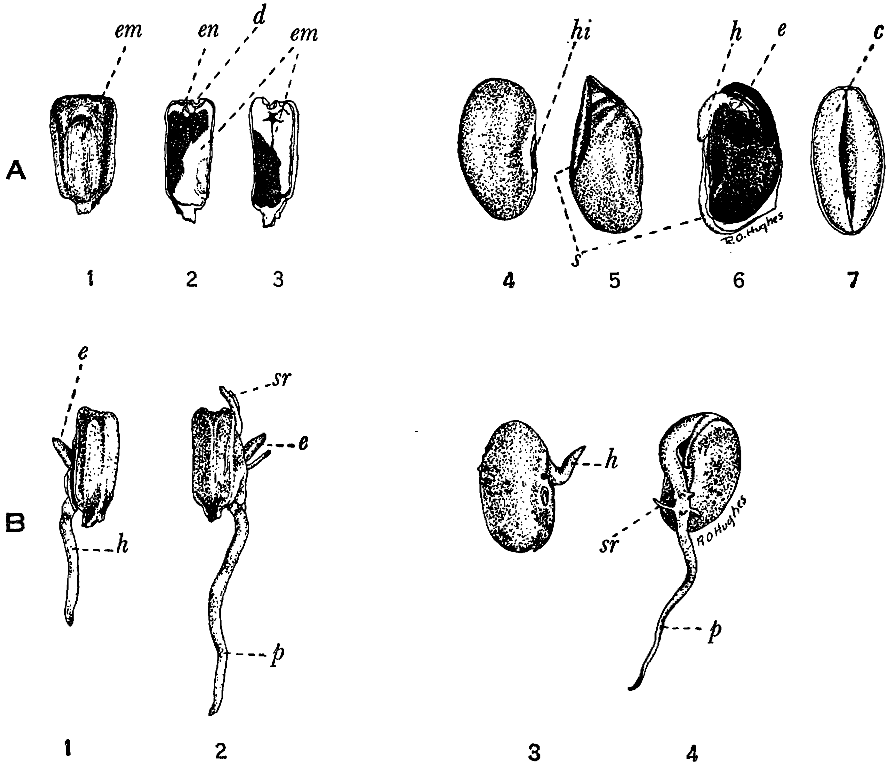
Between the cotyledons are located two growing points—the hypocotyl, which will produce the root, and the epicotyl, which will give rise to the shoot.

One of the wonders of the seed is that the entire aboveground part of the plant develops from the tiny epicotyl, and the elaborate root system originates in the small hypocotyl.

Because the early growth and enlargement of epicotyl and hypocotyl after germination of the seed will depend on the food supplies stored in the cotyledons and other parts of the seed, the seed is important as a storage organ.

The seedcoat, or testa, is developed from one or two outer layers or integu-

Soaked (A) and Germinating (B) Seeds of Dent Corn (Left) and Great Northern Bean (Right)



A_1, *flat side of grain;* A_2, *longitudinal section of grain, narrow side showing starchy endosperm stained dark with iodine—embryo not stained;* A_3, *longitudinal section of grain, narrow side, showing embryo stained dark with Sudan IV, a dye that is specific for fats and oils. The starchy endosperm is unstained;* A_4, *side view of soaked bean;* A_5, *unstained cotyledon of bean with attached portion of seedcoat;* A_6, *cotyledon of bean stained with iodine to show high starch content—epicotyl and hypocotyl low in starch;* A_7, *longitudinal section of soaked bean showing two fleshy cotyledons.* B_1 *and* B_2, *germinating grains;* B_3 *and* B_4, *germinating beans; c, cotyledon; d, dent in grain; e, epicotyl; en, endosperm; em, embryo; h, hypocotyl; hi, hilum; p, primary root; s, seedcoat; sr, secondary root.*

ments of the ovule. These layers form a covering, whose function is to protect the embryo against drying out, mechanical injury, and attacks by insects, fungi, and bacteria. Usually the outer coat is hard and durable, and the inner one is thin and membranous. Often the two seem to be fused into one layer.

The seedcoat and fruit wall may develop appendages or special structures that adapt the seed to certain ways of dissemination. In cotton, for example, long fibers produced by epidermal cells of the cotton seed cling to passing objects, and the seeds thus are carried from place to place.

THE SEED usually matures at the same time the fruit ripens.

Fruits are classified as simple, aggregate, or multiple.

The simple fruits are further classified as dry and fleshy.

In certain fruits, the wall, or pericarp, which sometimes is called the seed vessel, is composed of three layers—exocarp, mesocarp, and endocarp.

The peach is a one-seeded fleshy fruit whose pericarp has three layers—the outer skin (exocarp); the fleshy edible part (mesocarp); and the hard, bony pit (endocarp), which surrounds the seed.

One has to have some knowledge of fruit classification if he wants to identify seeds correctly as to origin and structure. The fact that a blackberry is not a berry but an aggregate fruit and watermelon is a hard-rinded berry indicates that common terms do not always indicate the true structure of a fruit.

We should remember that the fruit is a device for seed distribution and that its structure is related to the way in which seeds of each species are dispersed.

FROM THE STANDPOINT of function, a seed is a device for the reproduction, preservation, increase, and dissemination of the plant species.

The many different ways in which seeds are dispersed illustrate the complexity of Nature's plan in providing for the perpetuation of plant species. Dryness is a factor of great importance in this connection. At low moisture content, the living embryo respires very slowly, and some seeds remain viable for many years, even if they are subjected to harsh conditions.

The food stored in seeds is also important. The reserves supply energy to the embryo as it resumes growth during germination. The young seedling plant is thus given a start in its new location, often a long distance from the mother plant that produced the seed.

Furthermore, the stored food has a part in Nature's plan of seed distribution, for it is attractive to animals. Squirrels bury many more acorns and nuts in the soil than they ever consume as food. Some of these seeds sprout and grow into young oak and hickory trees to replace overmature individuals in the forest.

Many examples may be cited of the interdependence of plants and animals based upon stored food in the seed. Notable is man's use of seeds for food.

This point leads to a related one. Despite the marvelous mechanisms that produce and disperse seed, many of the improved varieties of crop plants would perish under natural conditions. People, who need the seeds for food, have bred and selected crop plants adapted to their needs. Such improvement and specialization have been possible only because the seed is a product of sexual reproduction in the flower. The sexual reproduction means that the plant, represented by the embryo of the seed, may show traits inherited from either or both parents and consequently be different from either.

That is the key to the improvement of useful, beautiful plants.

THUS, seeds serve us in at least three ways. A large part of agriculture has to do with producing seeds that are used for food and as materials for many other uses. Many seeds are grown for planting, so farmers can have the best seed for the next crop. Seeds are the basis of all procedures to improve plants through breeding.

Plant explorers search all parts of the world for unusual plants that might furnish valuable characters for the plant breeder. Resistance to disease has been bred into many crop plants by use of a wild seed that in itself was worthless. Desert plants frequently provide drought-resistance characters valuable in breeding dryland crops.

Man's dependence on the crops he has developed through work with seeds behooves us to learn more about their origin, structure, and function.

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