Morphogenesis in Plant

Morphogenesis (from the Greek morphê shape and genesis creation, literally "the generation of form") is the biological process that causes a cell, tissue or organism to develop its shape. It is one of three fundamental aspects of developmental biology along with the control of tissue growth and patterning of cellular differentiation.

The process controls the organized spatial distribution of cells during the embryonic development of an organism. Morphogenesis can take place also in a mature organism, such as in the normal maintenance of tissue by stem cells or in regeneration of tissues after damage. Cancer is an example of highly abnormal and pathological tissue morphogenesis. Morphogenesis also describes the development of unicellular life forms that do not have an embryonic stage in their life cycle. Morphogenesis is essential for the evolution of new forms.

Morphogenesis is a mechanical process involving forces that generate mechanical stress, strain, and movement of cells, and can be induced by genetic programs according to the spatial patterning of cells within tissues.

In other words

Morphogenesis, the shaping of an organism by embryological processes of differentiation of cells, tissues, and organs and the development of organ systems according to the genetic "blueprint" of the potential organism and environmental conditions.

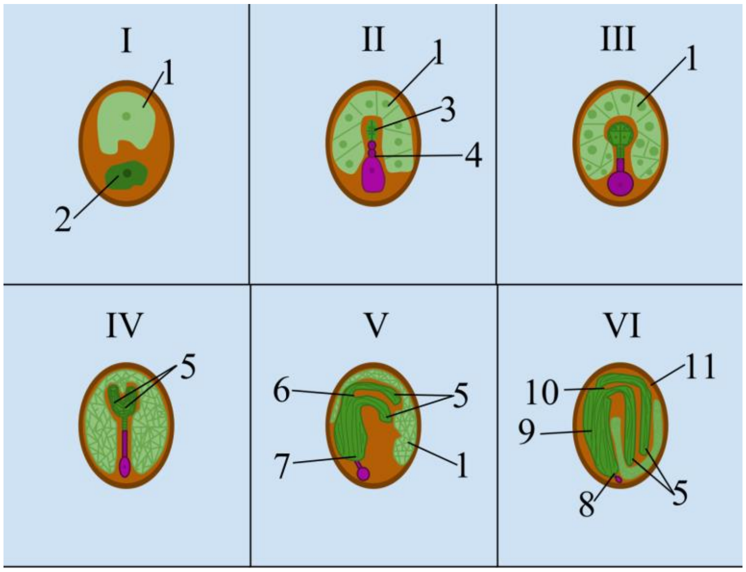
Plant morphogenesis is brought about chiefly through differential growth. Permanent embryonic tissue results in a morphogenetic potential that varies greatly with the environment and continues to produce new organs throughout the life of the plant.

Plant Embryonic Development (Embryogenesis)

Plant embryonic development, also plant embryogenesis is a process that occurs after the fertilization of an ovule to produce a fully developed plant embryo. This is a pertinent stage in the plant life cycle that is followed by dormancy and germination. The zygote produced after fertilization must undergo various cellular divisions and differentiations to become a mature embryo. An end stage embryo has five major components including the shoot apical meristem, hypocotyl, root meristem, root cap, and cotyledons. Plant embryonic development results in an immature form of the plant, lacking most structures like leaves, stems, and reproductive structures. Plants pass through a phylotypic stage that evolved independently and that causes a developmental constraint limiting morphological diversification.

Morphogenic events

Embryogenesis occurs naturally as a result of single, or double fertilization, of the ovule, giving rise to two distinct structures: the plant embryo and the endosperm which go on to develop into a seed. The zygote goes through various cellular differentiations and divisions in order to produce a mature embryo. These morphogenic events form the basic cellular pattern for the development of the shoot-root body and the primary tissue layers; it also programs the regions of meristematic tissue formation. The following morphogenic events are only particular to eudicots, and not monocots.



Six moments in embryogenesis

I. Two cell stage
II. Eight cell stage
III. Globular stage
IV. Heart stage
V. Torpedo stage
VI. Maturation

1. endosperm
2. single celled zygote
3. embryo
4. suspensor
5. cotyledons
6. shoot apical meristem (SAM)
7. root apical meristem (RAM)

Two cell stage

Following fertilization, the zygote and endosperm are present within the ovule, as seen in stage I of the illustration on this page. Then the zygote undergoes an asymmetric transverse cell division that gives rise to two cells - a small apical cell resting above a large basal cell. These two cells are very different, and give rise to different structures, establishing polarity in the embryo.

apical cell

The small apical cell is on the top and contains most of the cytoplasm, the aqueous substance found within cells, from the original zygote. It gives rise to the hypocotyl, shoot apical meristem, and cotyledons.

basal cell

The large basal cell is on the bottom and consists of a large vacuole and gives rise to the hypophysis and the suspensor.

Eight cell stage (Octant)

After two rounds of longitudinal division and one round of transverse division, an eight-celled embryo is the result. Stage II, in the illustration above, indicates what the embryo looks like during the eight cell stage. there are four distinct domains during the eight cell stage. The first two domains contribute to the embryo proper. The apical embryo domain, gives rise to the shoot apical meristem and cotyledons. The second domain, the central embryo domain, gives rise to the hypocotyl, root apical meristem, and parts of the cotyledons. The third domain, the basal embryo domain, contains the hypophysis. The hypophysis will later give rise to the radicle and the root cap. The last domain, the suspensor, is the region at the very bottom, which connects the embryo to the endosperm for nutritional purposes.

Sixteen cell stage (Dermatogen)

Additional cell divisions occur, which leads to the sixteen cell stage. The four domains are still present, but they are more defined with the presence of more cells. The important aspect of this stage is the introduction of the protoderm, which is meristematic tissue that will give rise to the epidermis. The protoderm is the outermost layer of cells in the embryo proper.

Globular stage

The name of this stage is indicative of the embryo's appearance at this point in embryogenesis; it is spherical or globular. Stage III, in the photograph above, depicts what the embryo looks like during the globular stage. 1 is indicating the location of the endosperm. The important component of the globular phase is the introduction of the rest of the primary meristematic tissue. The protoderm was already introduced during the sixteen cell stage. The ground meristem and procambium are initiated during the globular stage. The ground meristem will go on to form the ground tissue, which includes the pith and cortex. The procambium will eventually form the vascular tissue, which includes the xylem and phloem.

Heart stage

The heart stage is a transition period where the cotyledons finally start to form and elongate.] It is given this name in eudicots because most plants from this group have two cotyledons, giving the embryo a heart shaped appearance. The shoot apical meristem is between the cotyledons. Stage IV, in the illustration above, indicates what the embryo looks like at this point in development. 5 indicates the position of the cotyledons.

Pro embryo stage (Torpedo)

This stage is defined by the continued growth of the cotyledons and axis elongation. In addition, programmed cell death must occur during this stage. This is carried out throughout the entire growth process, like any other development. However, in the torpedo stage of development, parts of the suspensor complex must be terminated. The suspensor complex is shortened because at this point in development most of the nutrition from the endosperm has been utilized, and there must be space for the mature embryo. After the suspensor complex is gone, the embryo is fully developed. Stage V, in the illustration above, indicates what the embryo looks like at this point in development.

Maturation

The second phase, or postembryonic development, involves the maturation of cells, which involves cell growth and the storage of macromolecules (such as oils, starches and proteins) required as a 'food and energy supply' during germination and seedling growth. The appearance of a mature embryo is seen in Stage VI, in the illustration above.

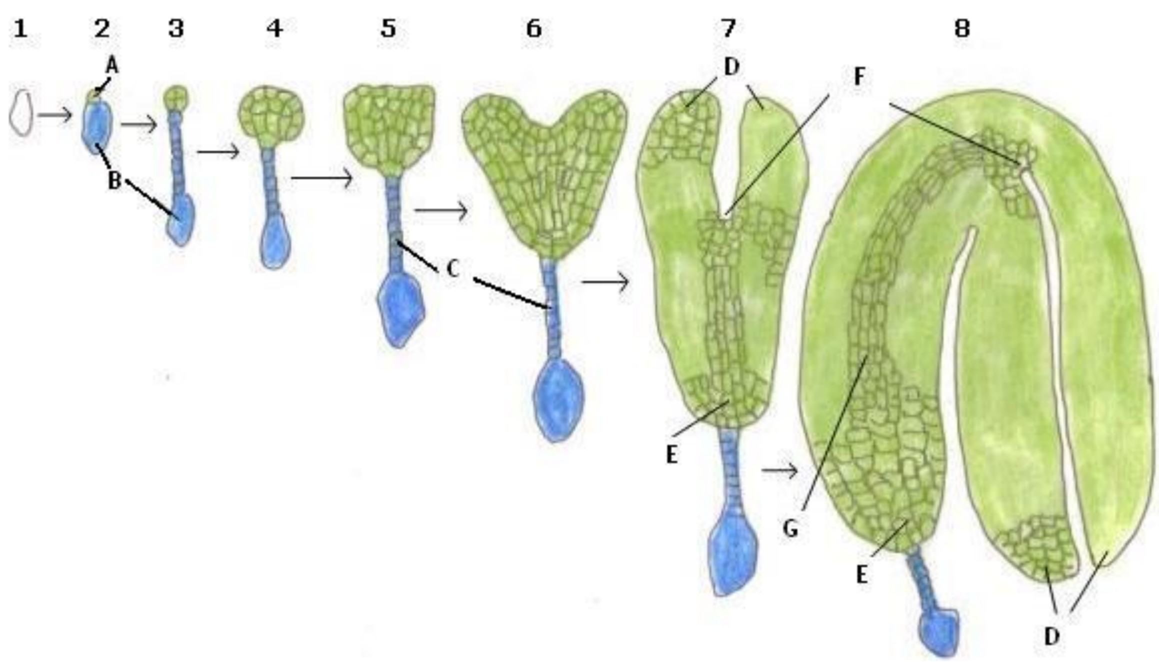


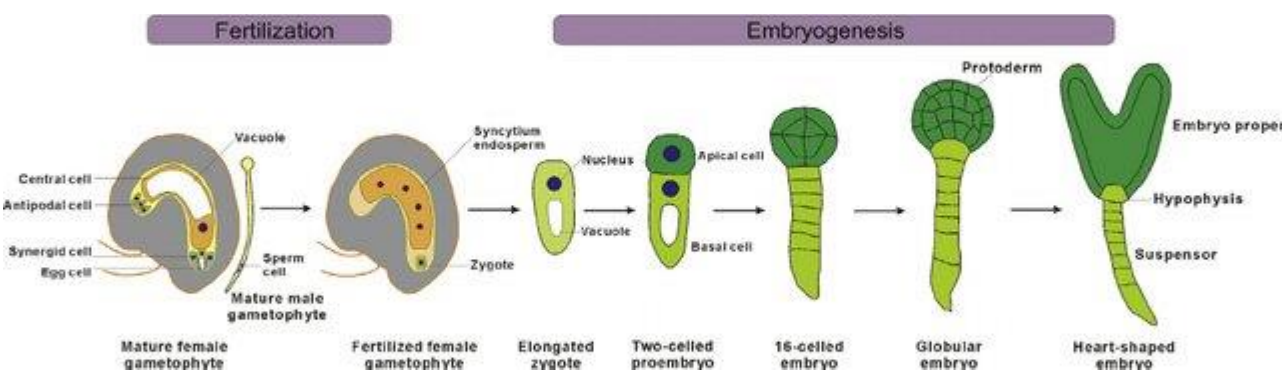
Figure The development of the embryo of the plant

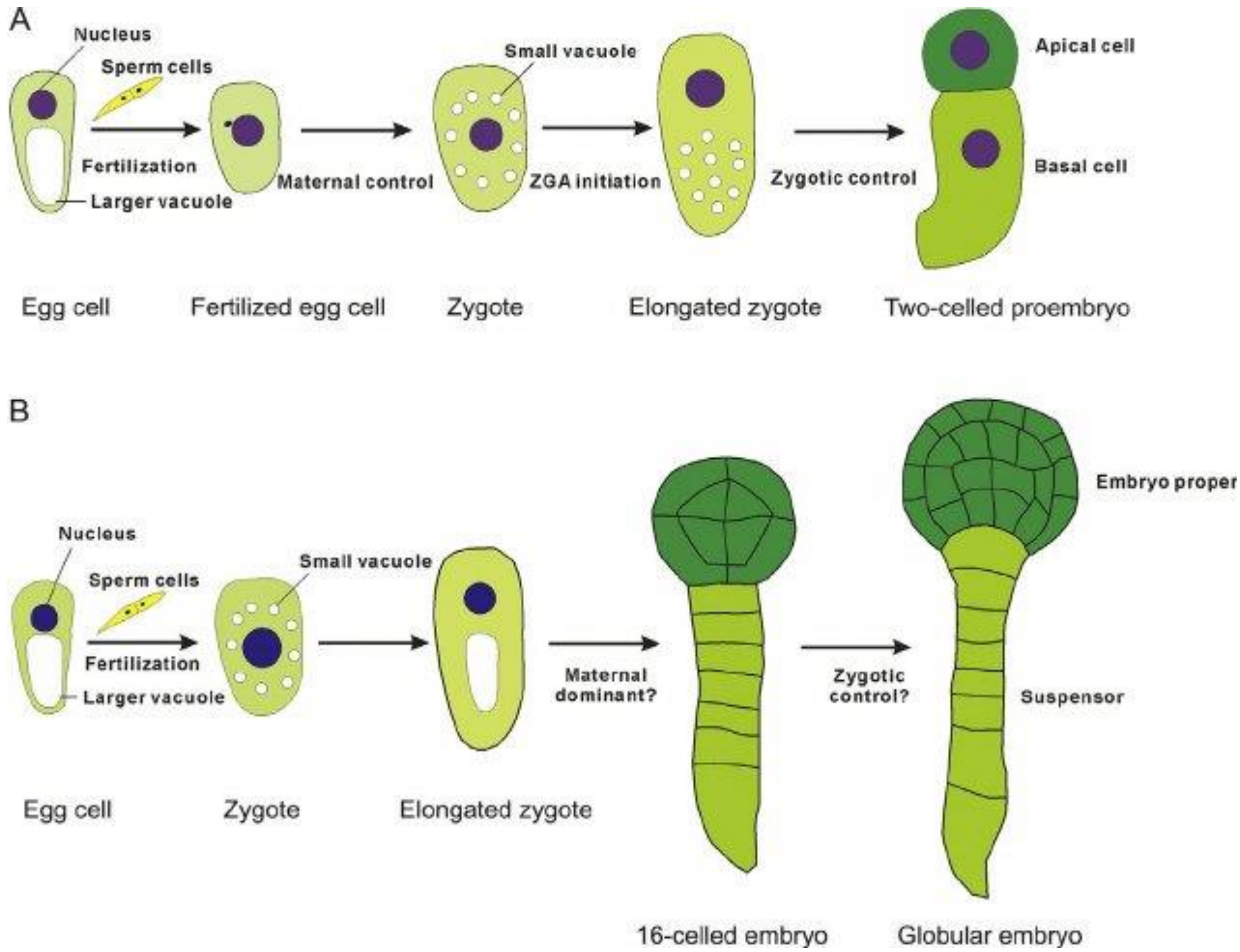
When plants flower, pollen will be carried from the stamens to the stigma of the pistil by wind, insects or other animals. The pollen makes a tube through the style of the pistil to the egg cell in the ovary. Fertilization takes place and then follows the first division (stage 2), by which a small apical cell (A) and a large basal cell (B) are formed. The apical cell divides into four cells and forms a small ball. The basal cell ligates cells at the top (stage 3). The apical clump of cells grows and forms a spherical ball. The lower part with the basal cell stops growing and dividing quite soon (stages 4 and 5). This part is called the suspensor (C). This stage (5) is called the globular stage of the embryo.

The apical tissue grows sidewards (stage 6), the cotyledons (D) are formed from this. At the same time the tissue between the cotyledons and the suspensor differentiates into the growing point of the root (or apical root meristem, E), the growing point of the shoot (or apical shoot meristem, F) and the connective vascular tissue (G), stages 7 and 8. The cotyledons grow and fold out. The seed (e.g. a peanut) is formed.

The seed grows further and goes into rest. It starts to grow again only when it goes into the ground and the conditions are favourable for germination. One might speak of "a double fertilization". First, the pollen fertilizes the egg, then the seed has to fall or be sown into the earth. The seed (male) is received by Mother Earth.

The following processes are visible:
right from the first division the embryo is growing;
immediately there is cell differentiation, the apical and basal cells are different;
the tissue is solid.





Figures show the main embryogenic development stages.

Dormancy

The end of embryogenesis is defined by an arrested development phase, or stop in growth. This phase usually coincides with a necessary component of growth called dormancy. Dormancy is a period in which a seed cannot germinate, even under optimal environmental conditions, until a specific requirement is met. Breaking dormancy, or finding the specific requirement of the seed, can be rather difficult. For example, a seed coat can be extremely thick. According to Evert and Eichhorn, very thick seed coats must undergo a process called scarification, in order to deteriorate the coating. In other cases, seeds must experience stratification. This process exposes the seed to certain environmental conditions, like cold or smoke, to break dormancy and initiate germination.

The role of auxin

Auxin is a hormone related to the elongation and regulation of plants. It also plays an important role in the establishment polarity with the plant embryo. Research has shown that the hypocotyl from both gymnosperms and angiosperms show auxin transport to the root end of the embryo. They hypothesized that the embryonic pattern is regulated by the auxin transport mechanism and the polar positioning of cells within the ovule. The importance of auxin was shown, in their research, when carrot embryos, at different stages, were subjected to auxin transport inhibitors. The inhibitors that these carrots were subjected to made them unable to progress to later stages of embryogenesis. During the globular stage of embryogenesis, the embryos continued spherical expansion. In addition, oblong embryos continued axial growth, without the introduction of cotyledons. During the heart embryo stage of development, there were additional growth axes on hypocotyls. Further auxin transport inhibition research, conducted on Brassica juncea, shows that after germination, the cotyledons were fused and not two separate structures.

Alternative forms of embryogenesis

Somatic embryogenesis

Somatic embryos are formed from plant cells that are not normally involved in the development of embryos, i.e. ordinary plant tissue. No endosperm or seed coat is formed around a somatic embryo. Applications of this process include: clonal propagation of genetically uniform plant material; elimination of viruses; provision of source tissue for genetic transformation; generation of whole plants from single cells called protoplasts; development of synthetic seed technology. Cells derived from competent source tissue are cultured to form an undifferentiated mass of cells called a callus. Plant growth regulators in the tissue culture medium can be manipulated to induce callus formation and subsequently changed to induce embryos to form the callus. The ratio of different plant growth regulators required to induce callus or embryo formation varies with the type of plant. Asymmetrical cell division also seems to be important in the development of somatic embryos, and while failure to form the suspensor cell is lethal to zygotic embryos, it is not lethal for somatic embryos.

Androgenesis

The process of androgenesis allows a mature plant embryo to form from a reduced, or immature, pollen grain. Androgenesis usually occurs under stressful conditions. Embryos that result from this mechanism can germinate into fully functional plants. As mentioned, the embryo results from a single pollen grain.

Plant growth and buds

Embryonic tissue is made up of actively growing cells and the term is normally used to describe the early formation of tissue in the first stages of growth. It can refer to different stages of the sporophyte and gametophyte plant; including the growth of embryos in seedlings, and to meristematic tissues, which are in a persistently embryonic state, to the growth of new buds on stems.

In both gymnosperms and angiosperms, the young plant contained in the seed, begins as a developing egg-cell formed after fertilization (sometimes without fertilization in a process called apomixis which is reproduction by special generative tissues without fertilization.) and becomes a plant embryo. This embryonic condition also occurs in the buds that form on stems. The buds have tissue that has differentiated but not grown into complete structures. They can be in a resting state, lying dormant over winter or when conditions are dry, and then commence growth when conditions become suitable. Before they start growing into stem, leaves, or flowers, the buds are said to be in an embryonic state.