Plant Developmental Biology

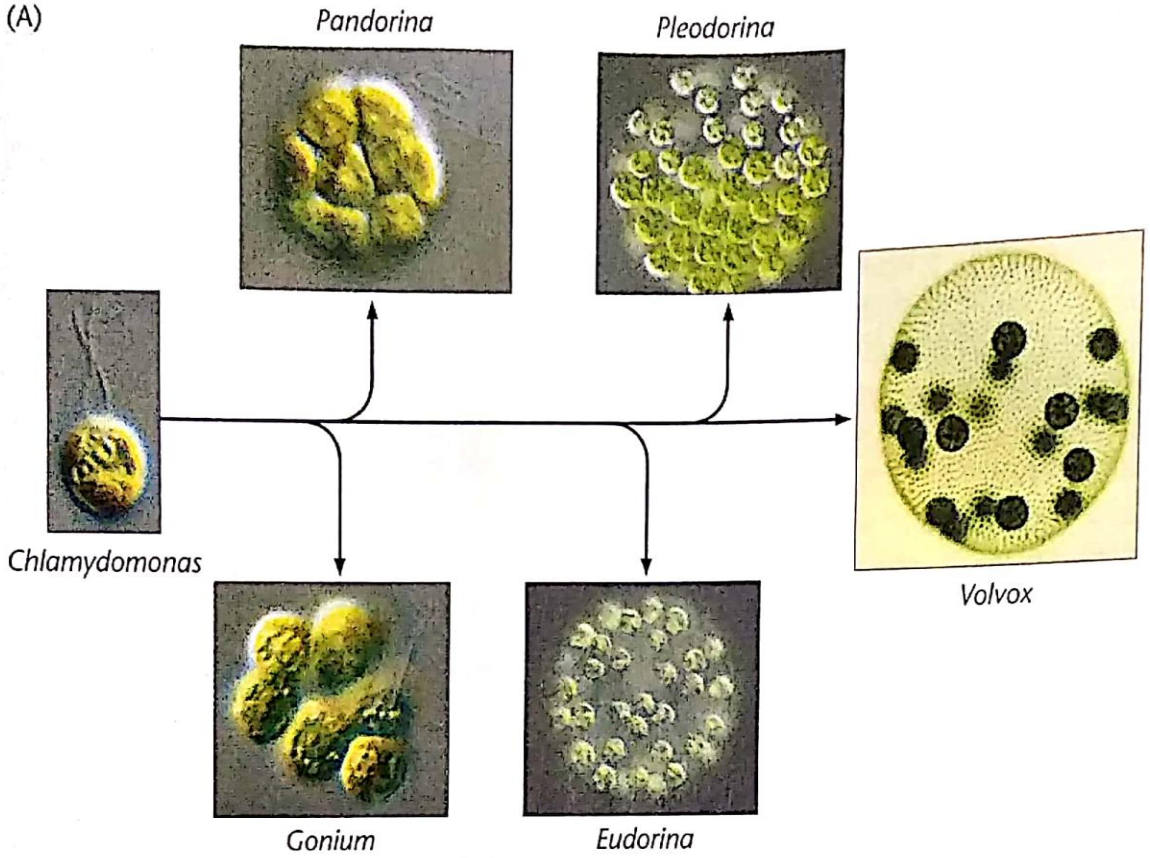
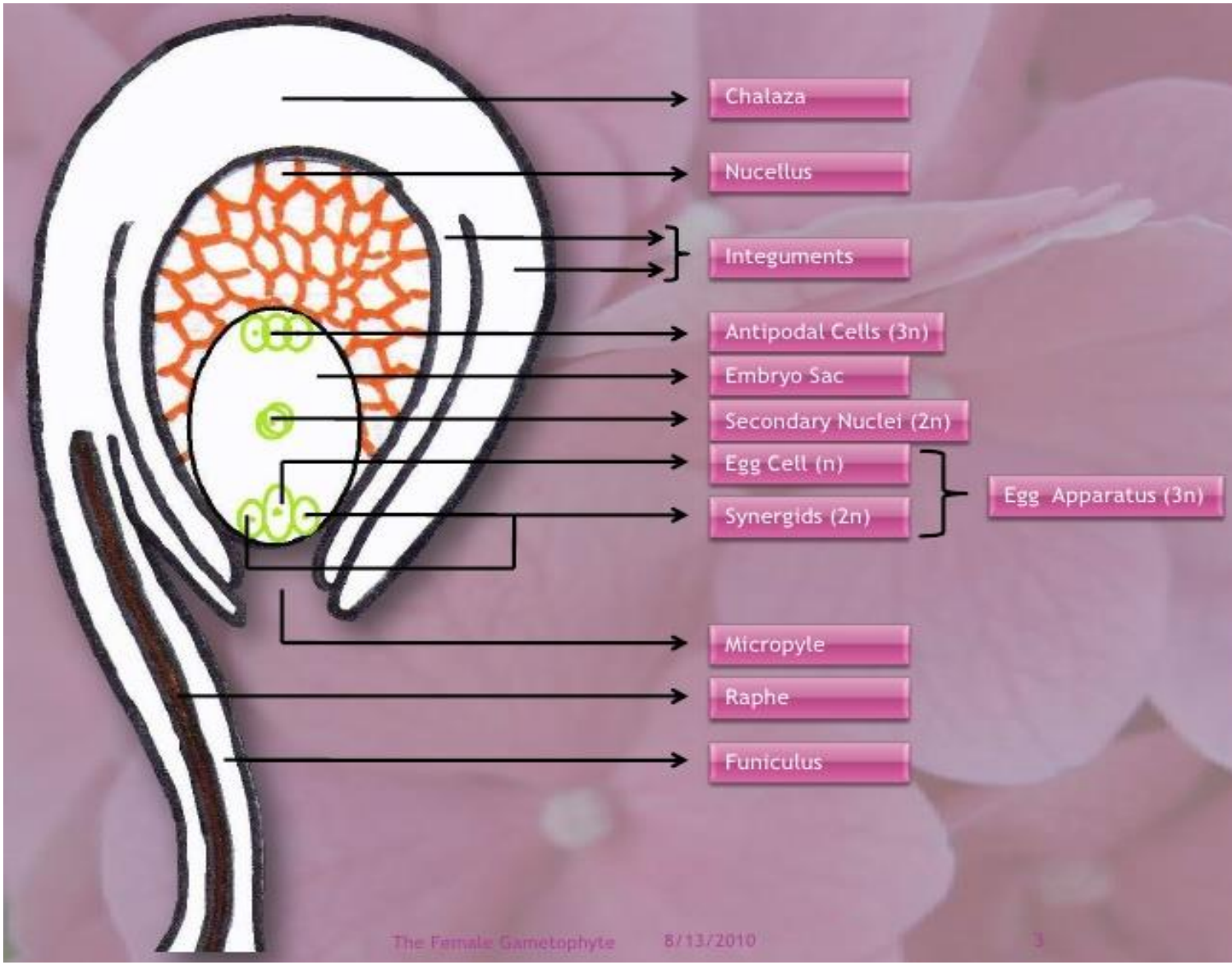


Figure 5–6.
Multicellular and single-celled algae: temporal versus spatial cell specialization. (A) Algae of the Volvocaceae family show different degrees of multicellular development, ranging from free-living single cells (*Chlamydomonas*), through colonial organisms (*Pandorina*, *Gonium*, *Eudorina*, *Pleodorina*), to multicellular organisms with a variety of cell types (*Volvox*). (B) In *Volvox*, spatial specialization results from expression of regulatory genes such as *LATE GONIDIA* (*lag*) and *SOMATIC REGENERATOR* (*regA*) in different cells of a single organism. (C) In *Chlamydomonas*, similar regulatory genes function sequentially to direct cell specialization at different stages of the life cycle. (A, courtesy of David Kirk.)

THE FEMALE GAMETOPHYTE



Embryo and Seed Development

In higher plants i.e., pea the mature embryo contains two different populations of cells in opposite ends.

The apical or top develops as cotyledons. The basal or bottom end develops into roots.

An unfertilized *Fucus* (Brown algae) egg lacks cell wall. After fertilization the cell wall develops around the **zygote**.

The first division is asymmetrical; it forms larger apical cell and a smaller basal cell.

The larger apical cell gives rise to thallus whereas the smaller basal cell give rise to the rhizoids that divides and develops to holdfast.

Impact of environmental cues on embryo Development of *Fucus*

In the brown alga *Fucus* the zygote gets **polarized** within 12 hours of fertilization even before the first cell division.

It is called polar becase top and bottom of the single celled zygote are different.

Some cellular components in one end and are not present in the other end.

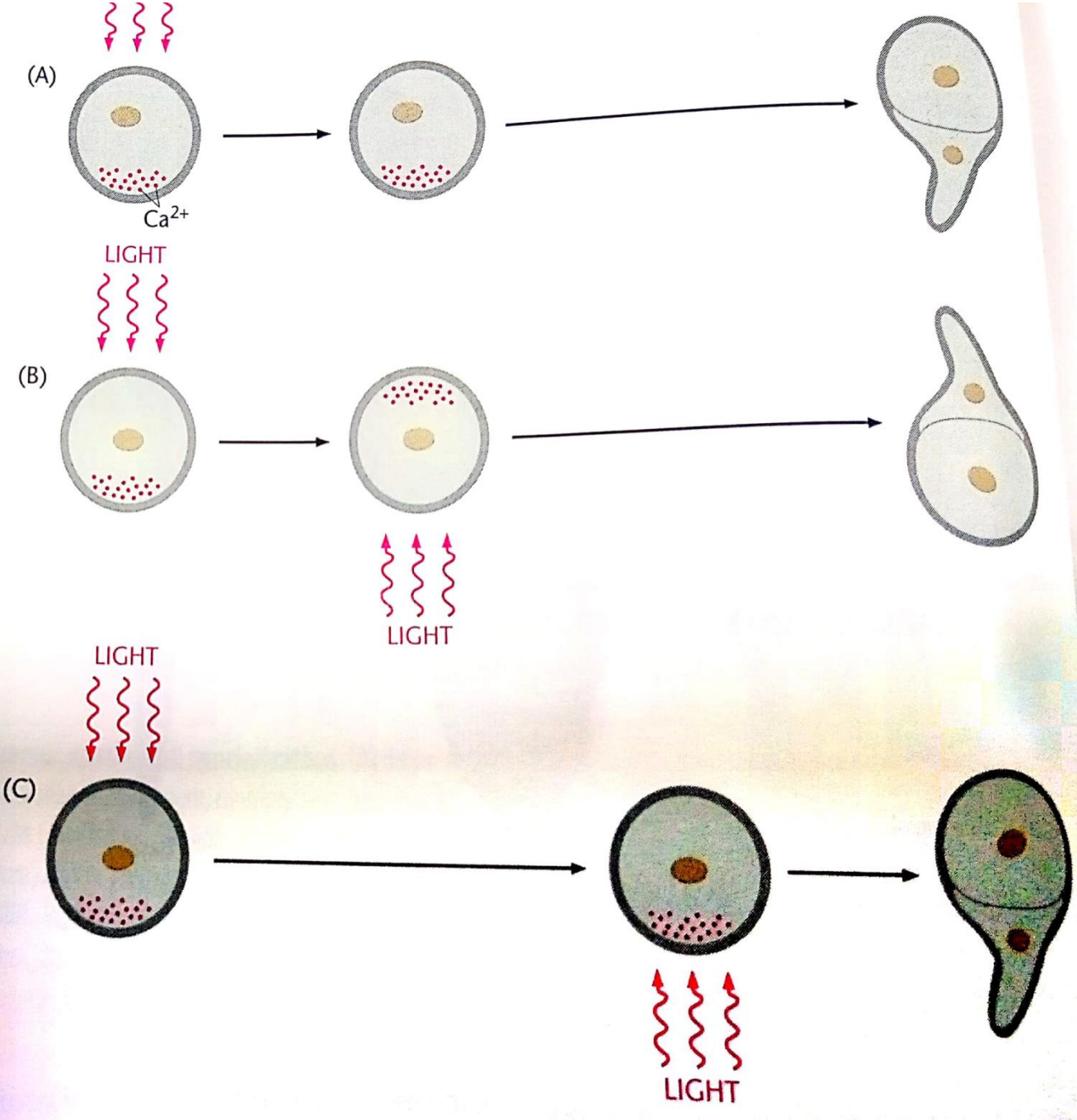
Thus the apical-basal axis is established very early.

When the zygote is exposed to light from the top, Ca^{2+} ions accumulate in the bottom i.e.,in the non-illuminated side due to localized activation calcium ion channels in the plasma membrane that allows influx of Ca2+ into the cell.

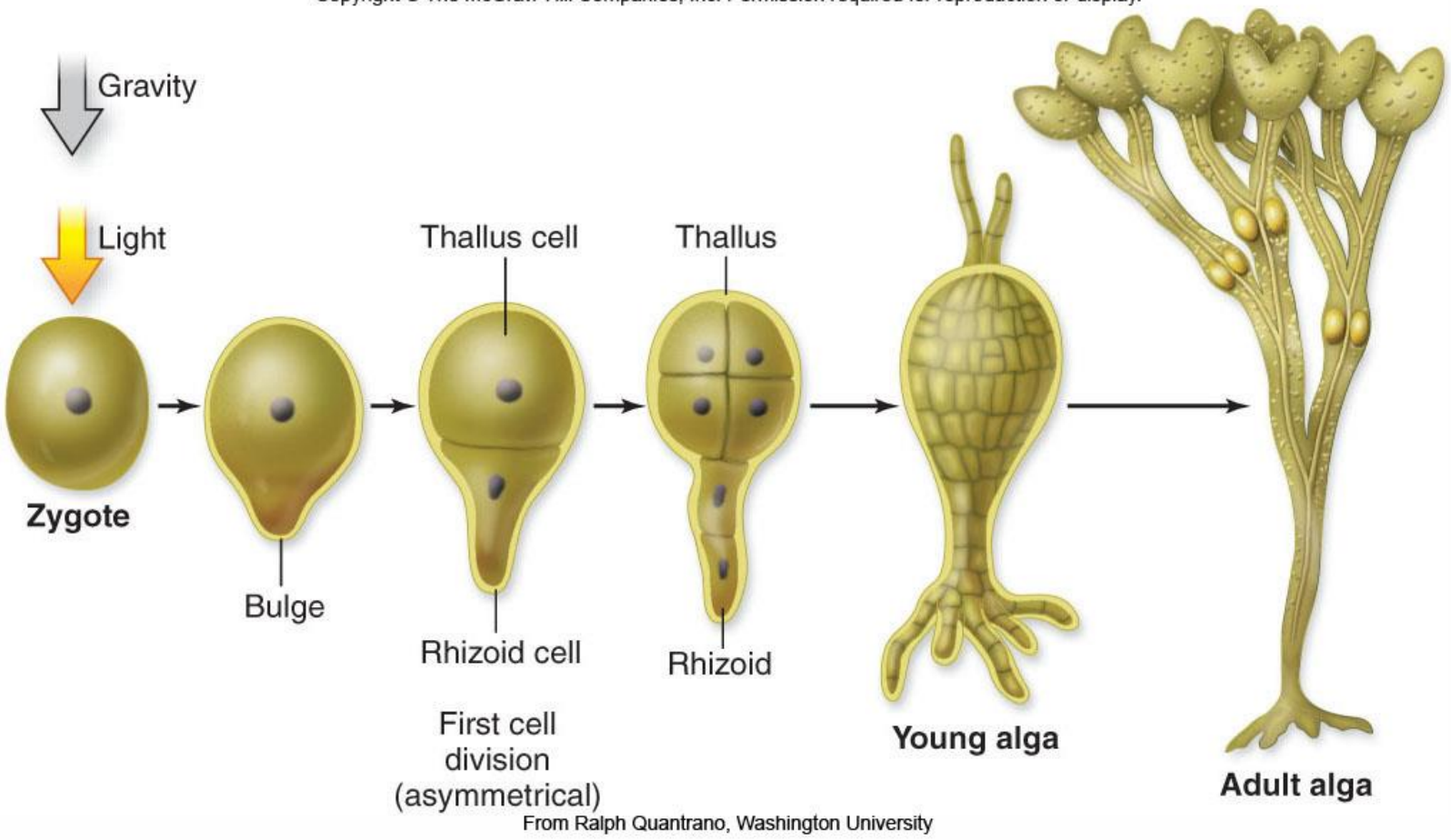
The Ca2+-rich side develops to rhizoids whereas Ca2+-deficient top side develops to thallus.

If the polarized zygote is exposed to a second light pulse from a different direction i.e., from the bottom, then the polarity changes and the rhizoid develops in the non-illumanated Ca2+-rich top end.

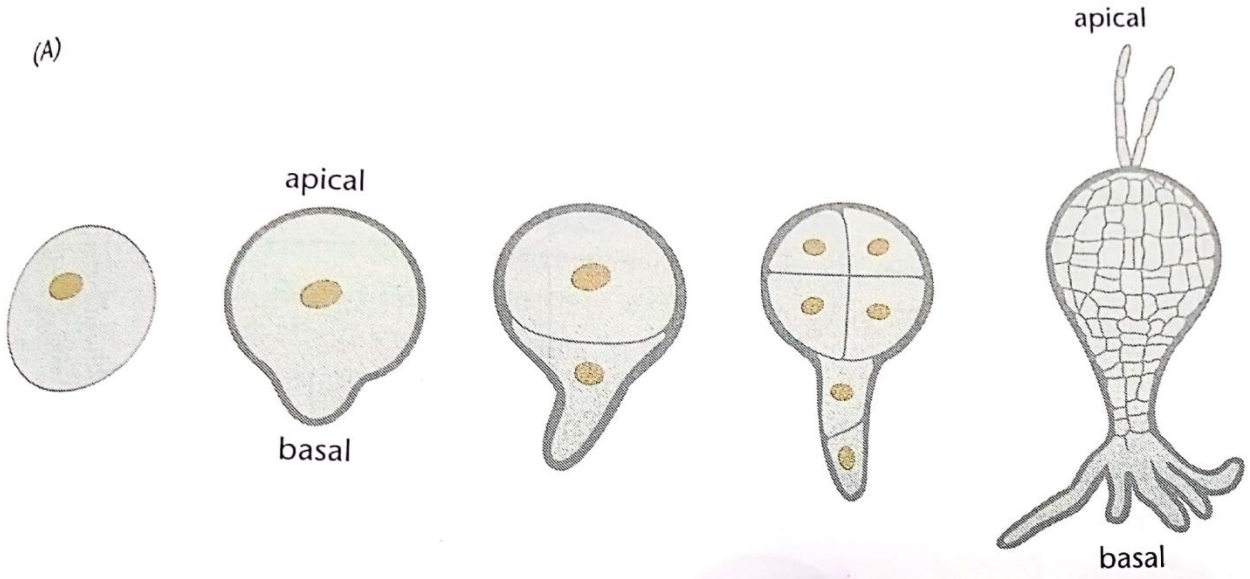
Fucus. (A) In the first 4 hours after fertilization, Ca^{2+} accumulates on the side of the cell facing away from light. The area with high Ca^{2+} becomes the basal pole and eventually develops rhizoids. (B) If the direction of light is changed during this early period, the Ca^{2+} ion distribution and thus the basal pole shift accordingly. (C) By 12 hours after fertilization, however, the Ca^{2+} ion distribution no longer responds to a change in the direction of light and the basal pole is fixed.



Embryo Development



From Ralph Quantrano, Washington University



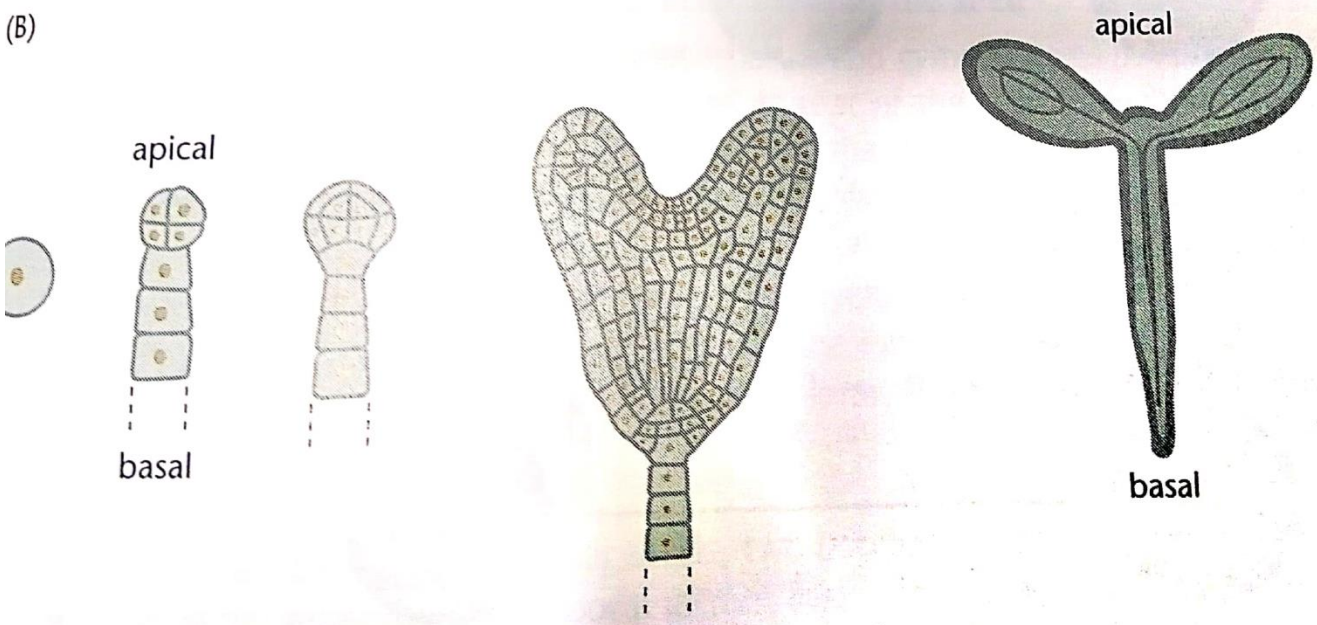


Figure 5–7.
Formation of the apical-basal axis in early embryo development. (A) *Fucus*, a brown alga. (B) Arabidopsis, an angiosperm Note the early appearance of differences between the apical and basal poles—in *Fucus*, occurring at the single-cell stage.

larger basal cell. The apical cell will form [illegible]
basal cell will form a filamentous structure called the **suspensor**. The apical cell

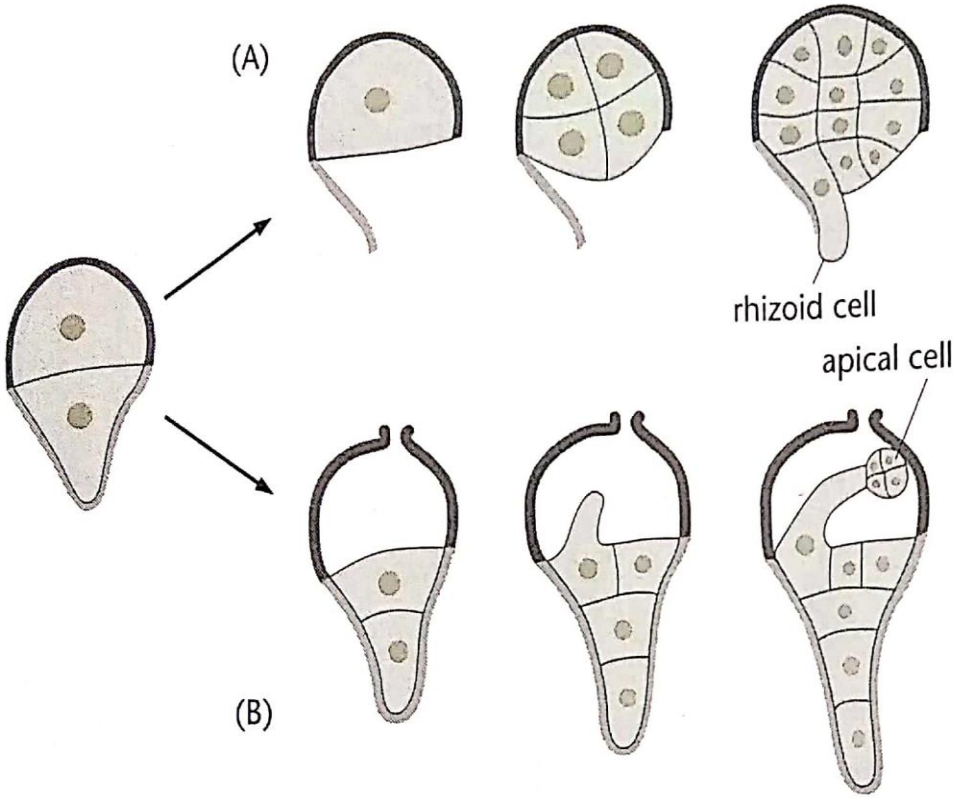


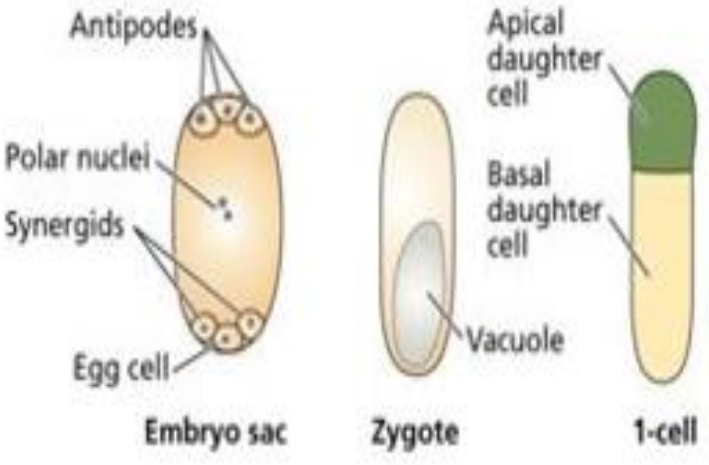
Figure 5–9.
The cell wall carries information about apical-basal polarity in *Fucus*. (A) When the basal cell is destroyed by a laser beam (ablated) at the two-cell stage, if a descendant of the apical cell eventually touches the remaining basal cell wall, this descendant cell develops as a rhizoid cell. (B) Conversely, when the apical cell is destroyed, descendants of the basal cell acquire apical cell features if they touch the remnants of the apical cell wall. (From F. Berger et al., *Science* 263:1421–1423, 1994. With permission of AAAS.)

Embryo development in higher plants occurs within the seed

Unlike *Fucus* Zygote, in gymnosperms and angiosperms the zygote develops within the seed.

In modern literature, *Arabidopsis thaliana* is taken as a model organism to study embryogenesis.

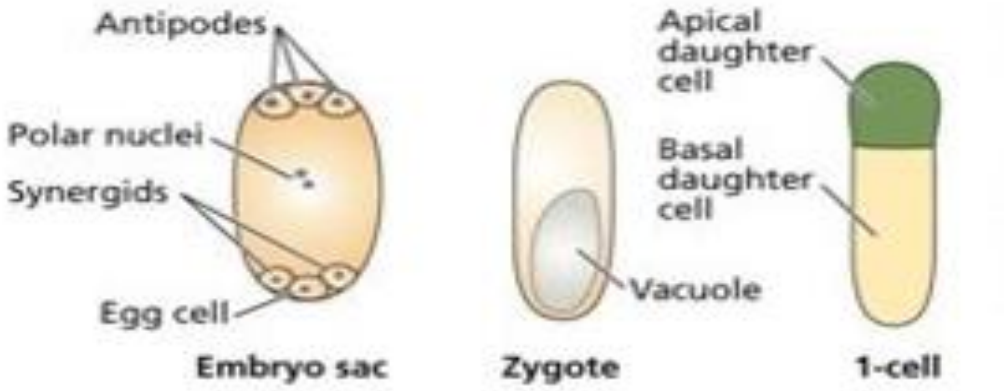
The first division in Arabidopsis zygote is assymetric i.e., a polarity along the apical-basal axis is established as the zygote divides to form a small apical cell and a larger basal cell.



Embryo genesis occurs naturally as a result of **single, or double fertilzation,** of the ovule, giving rise to two distinct structures: the plant embryo and the endosperm

The zygote goes through various cellular divisions and differentiations in order to produce a mature embryo.

The following morphogenic events are only particular to dicots and not monocots.

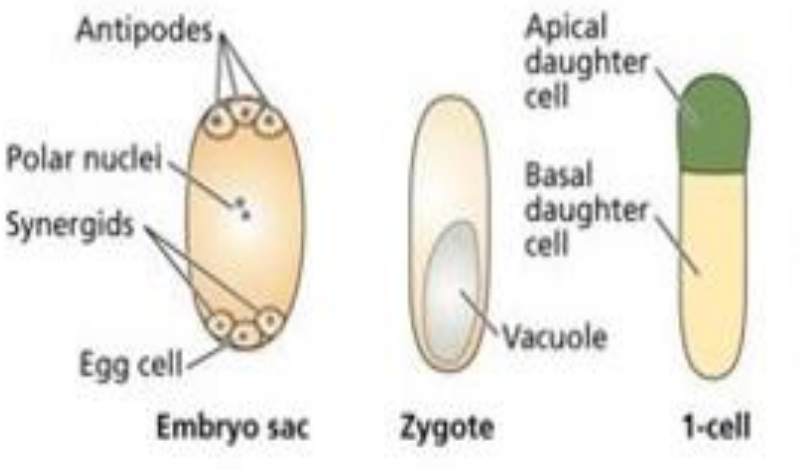


Two cell stage

Following fertilization, the zygote and endosperm are present within the ovule, (Stage 1).

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.



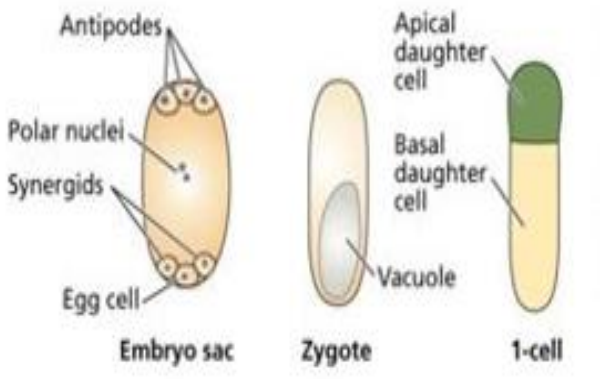
The apical cell

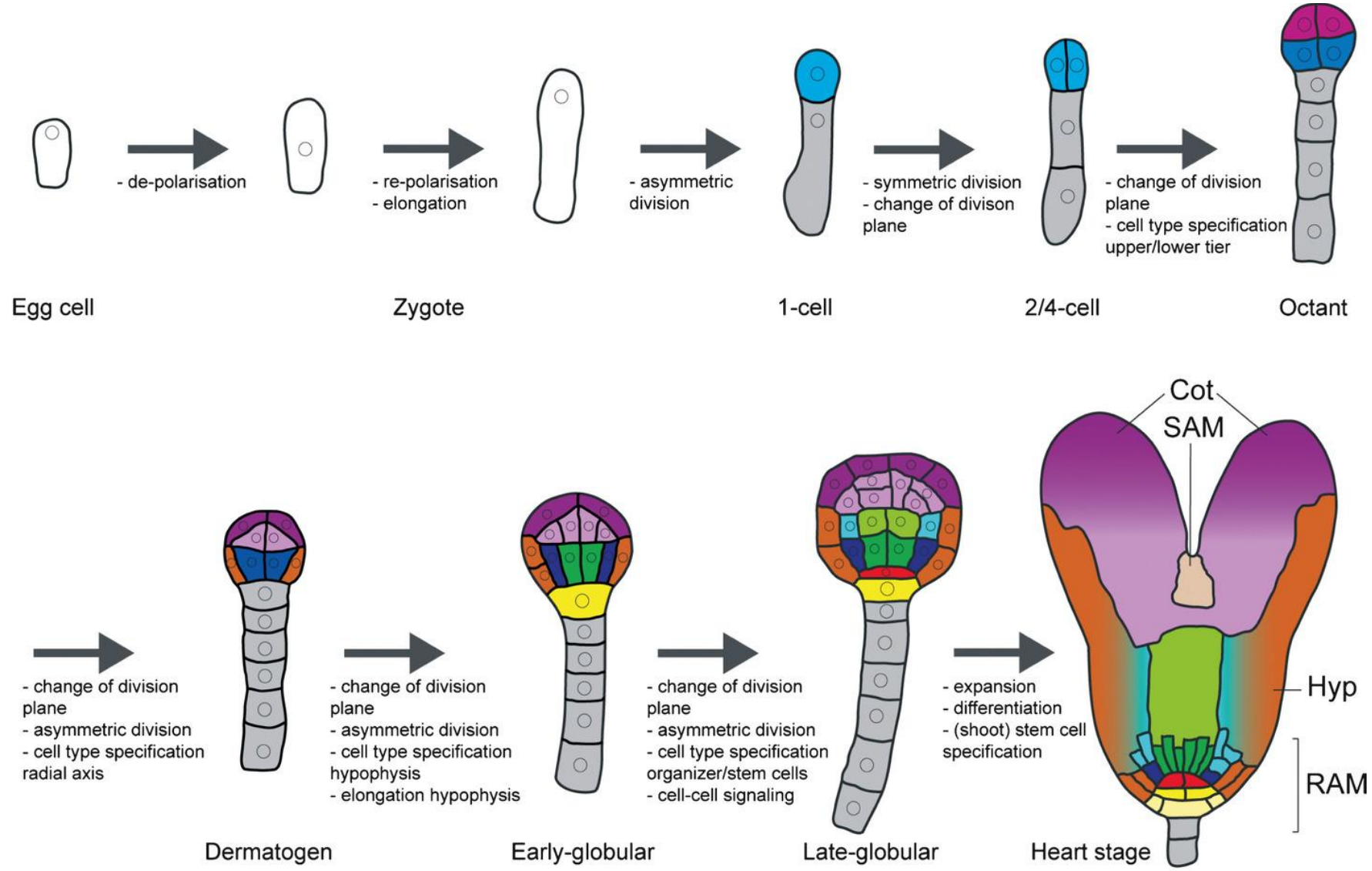
The small apical cell is on the top and contains most of the cytoplasm from the original zygote.

The apical cell forms the majority of proper embryo. It gives rise to the **hypocotyl**, **shoot apical meristem**, and **cotyledons**.

The basal cell

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

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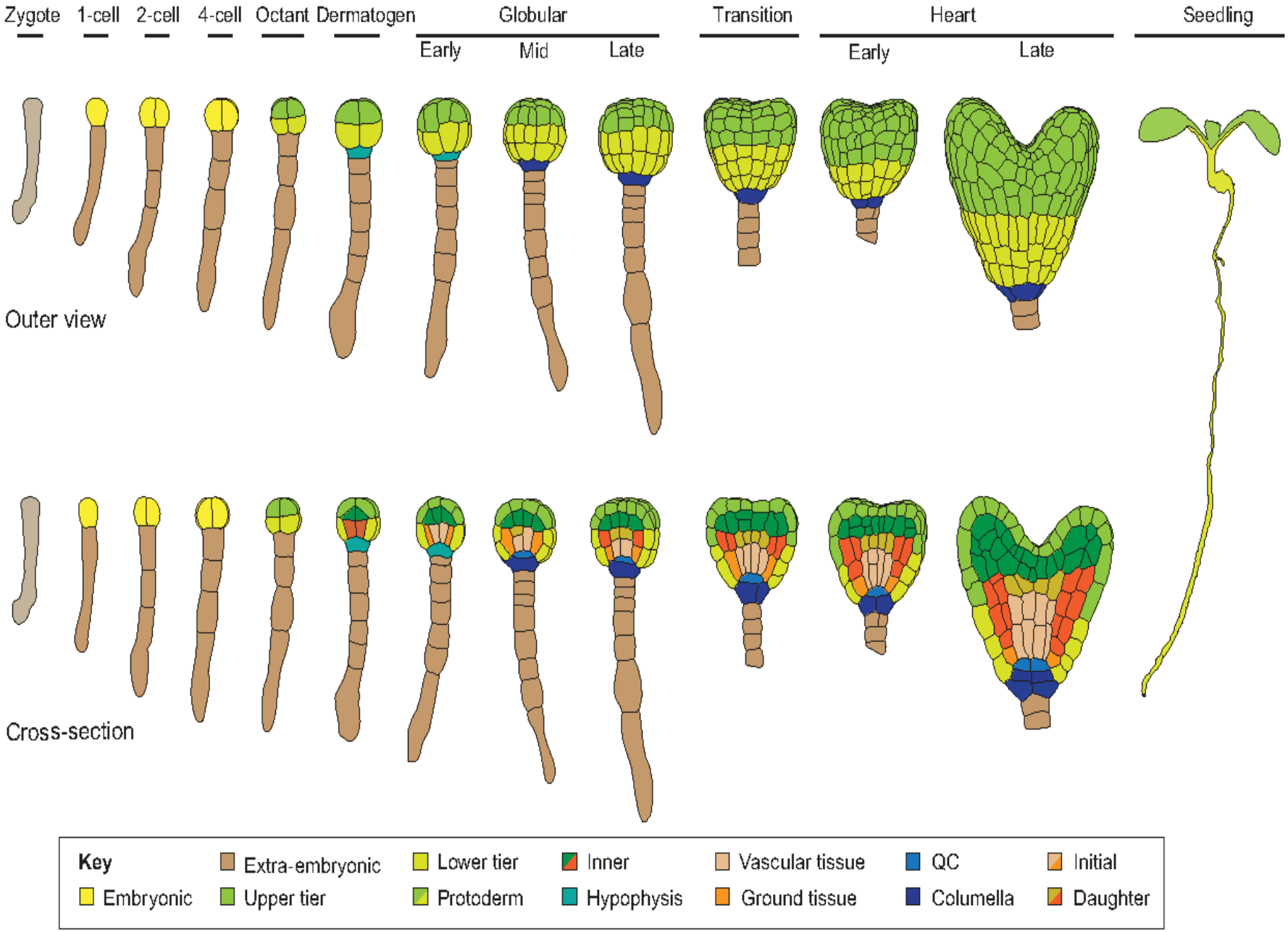
Columella cell
Shoot apical meristem

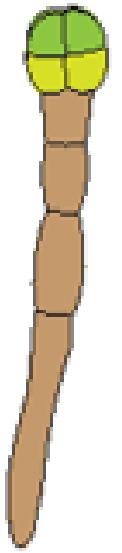


***Arabidopsis* embryo development.** Surface view and longitudinal cross-sections of a developing *Arabidopsis* embryo. Cells are coloured acco

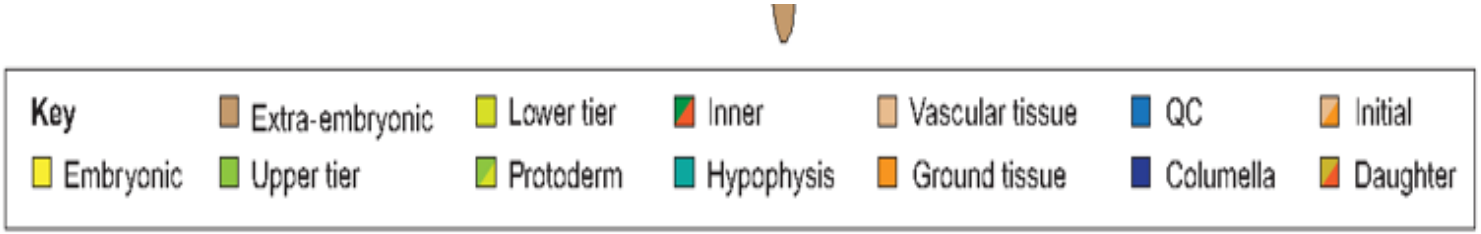
Eight cell stage

After longitudinal and transverse divisions, an eight-celled embryo results (Stage II).

According to Laux et al., there are four distinct domains during the eight cell stage.



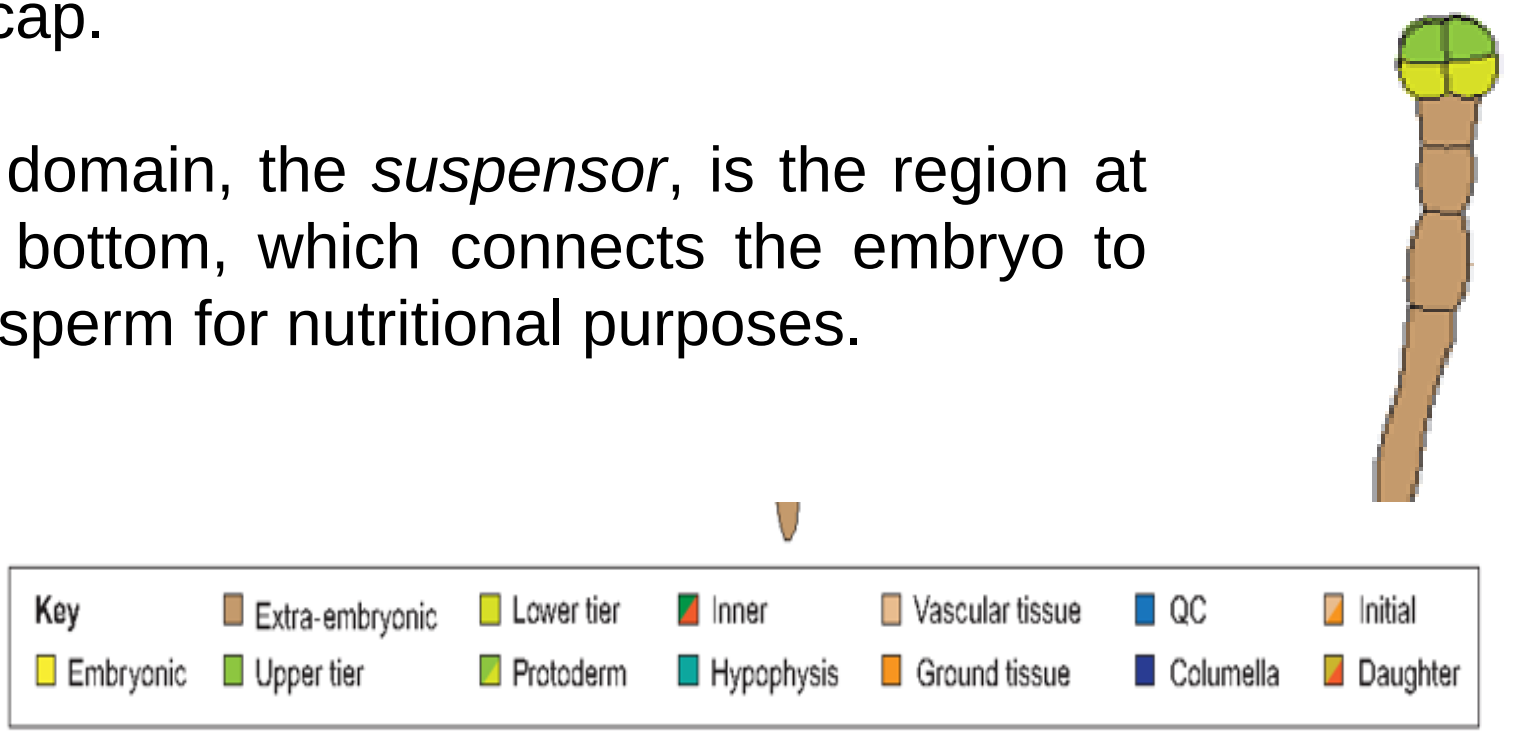
The first two domains contribute to the embryo proper. The *apical embryo domain*, gives rise to the shoot apical meristem and cotyledons.

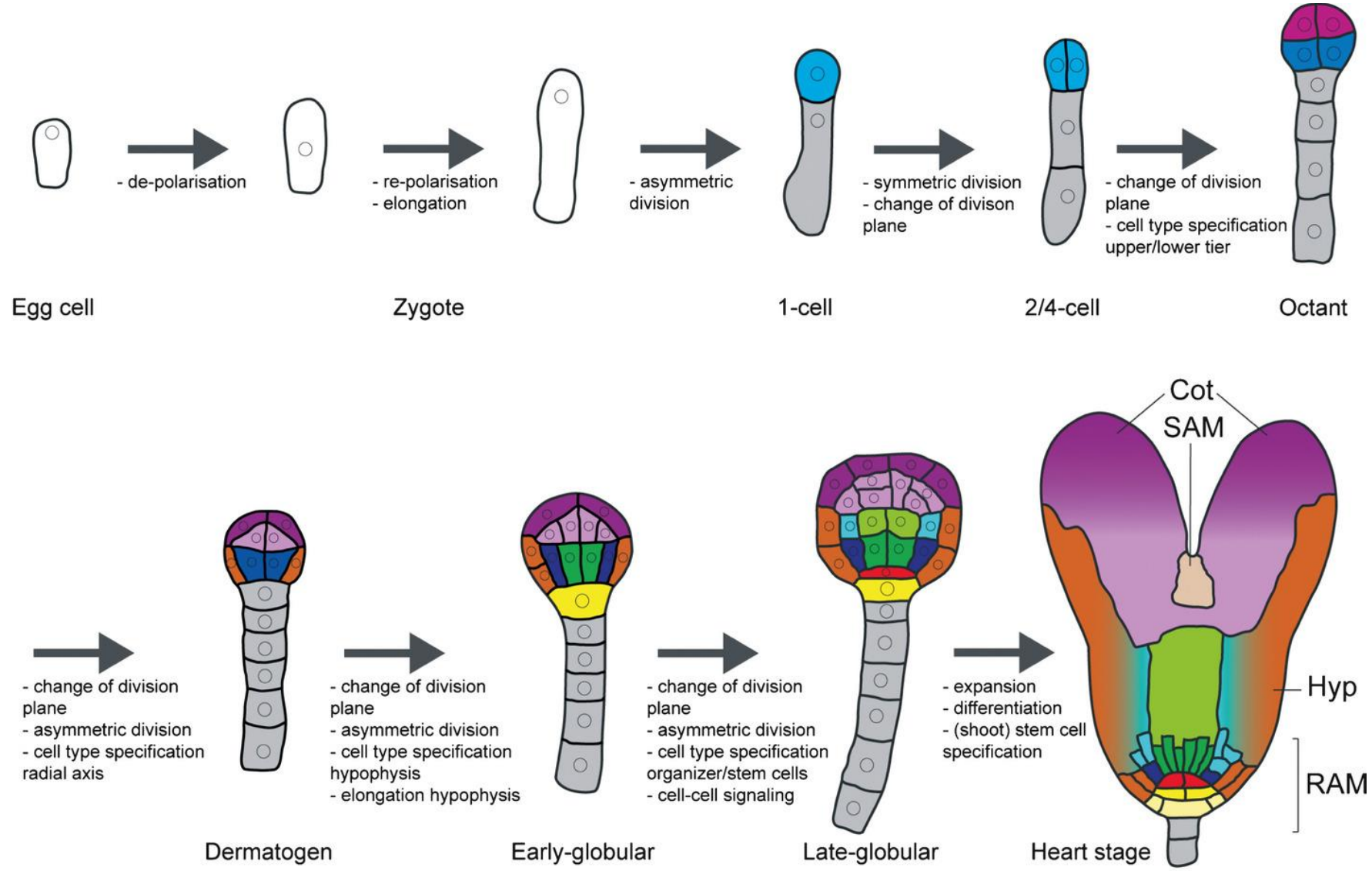


The second domain, the *central embryo domain*, gives rise to the hypocotyl, root apical meristem, and parts of the cotyledons.

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.

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Lower tier inner
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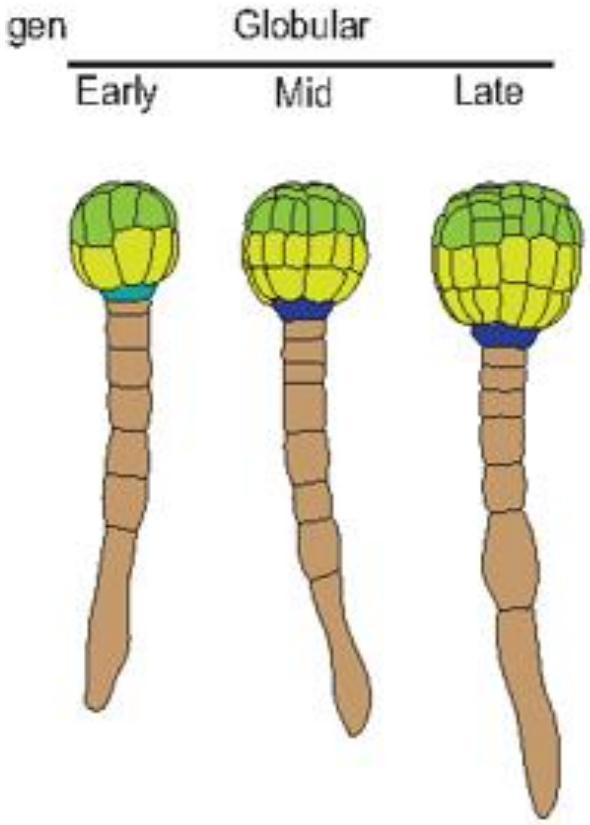
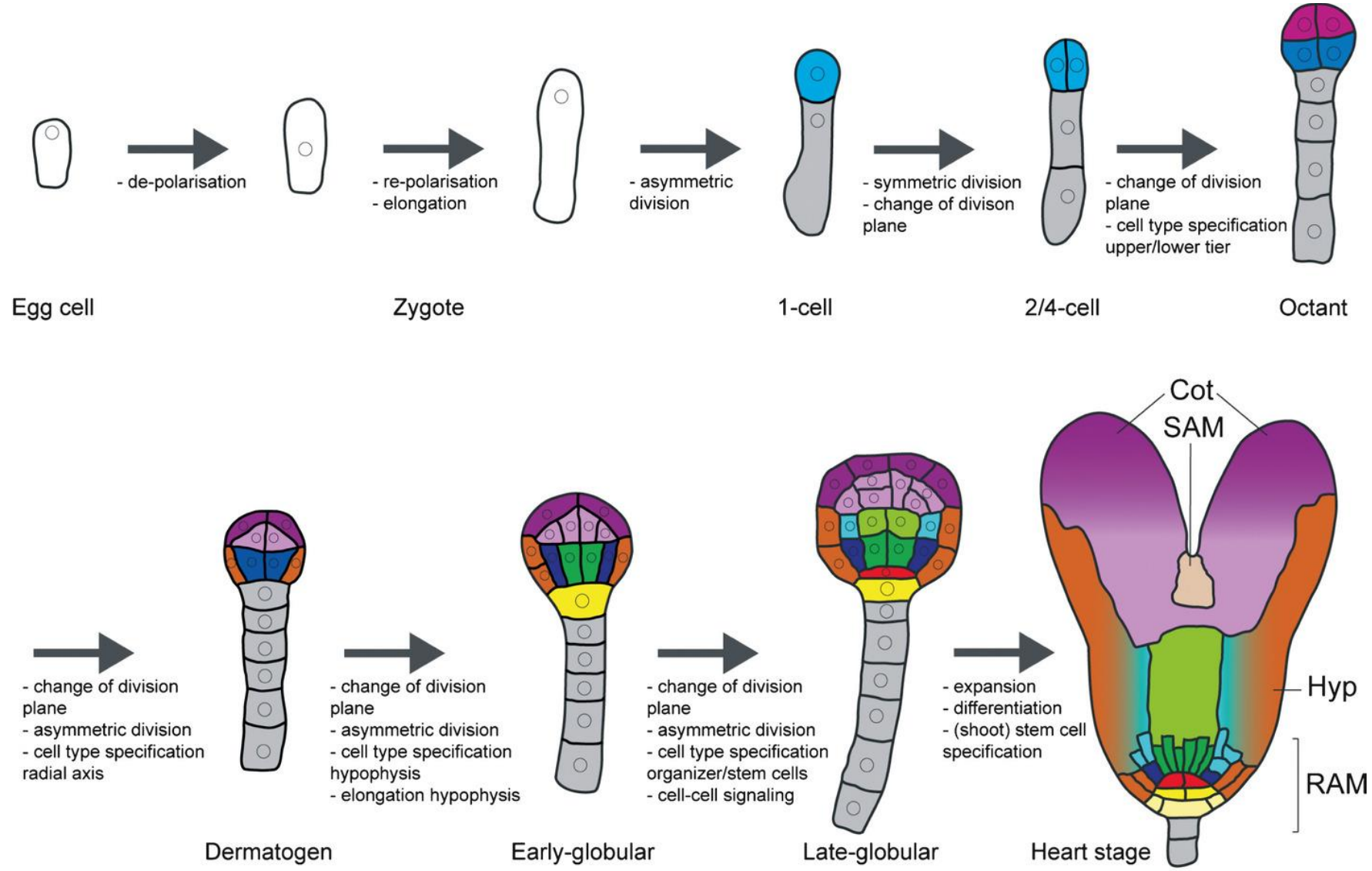
Vascular precusor
Hypophysis
Ground tissue daughter cell
Vascular daughter
Organizer cell
Columella cell
Shoot apical meristem

Sixteen cell stage

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.

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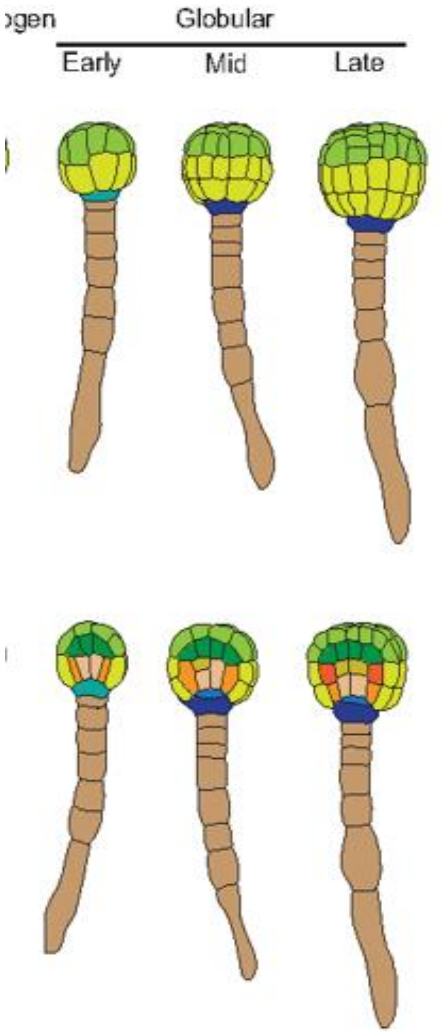
Shoot apical meristem

Globular stage

The name of this stage is indicative of the embryo's appearance at this point in embryo-
genesis; it is spherical or globular (Stage III).

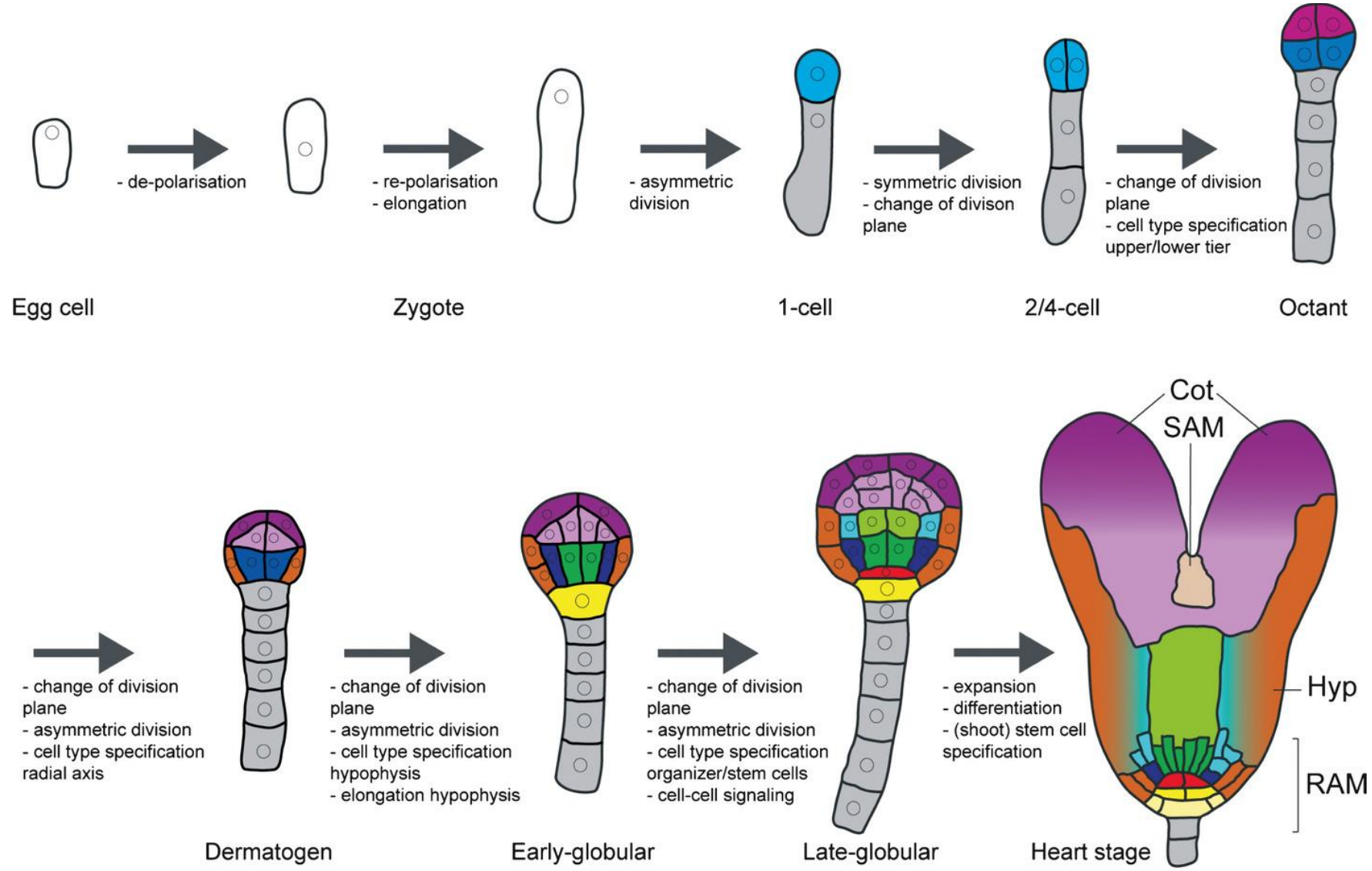
The important component of the globular phase is
the introduction of the rest of the primary meristematic tissue. The protoderm was already introduced during the sixteen cell stage.

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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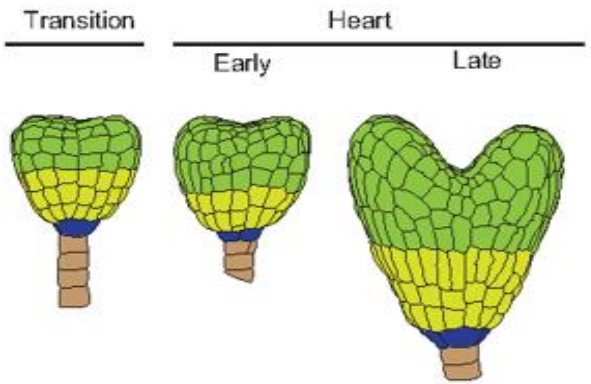
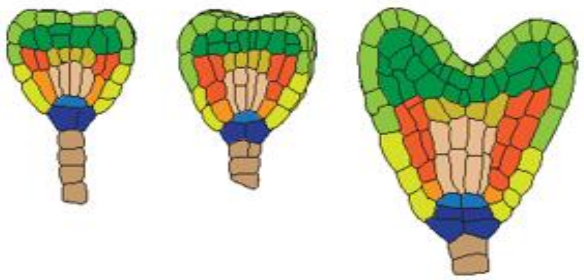
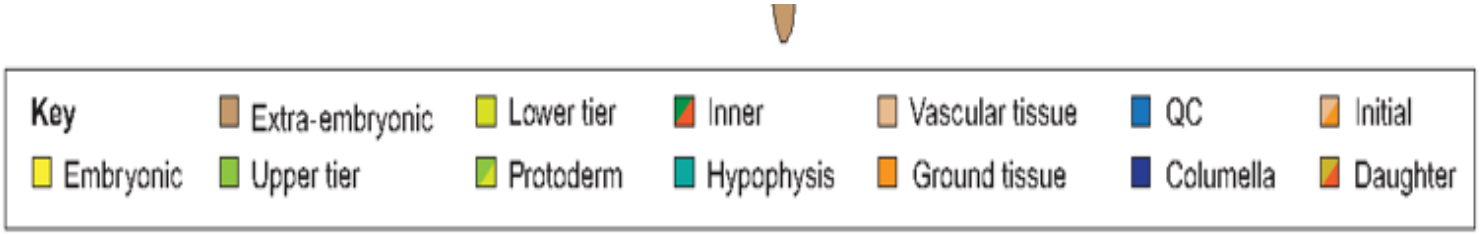
Heart stage

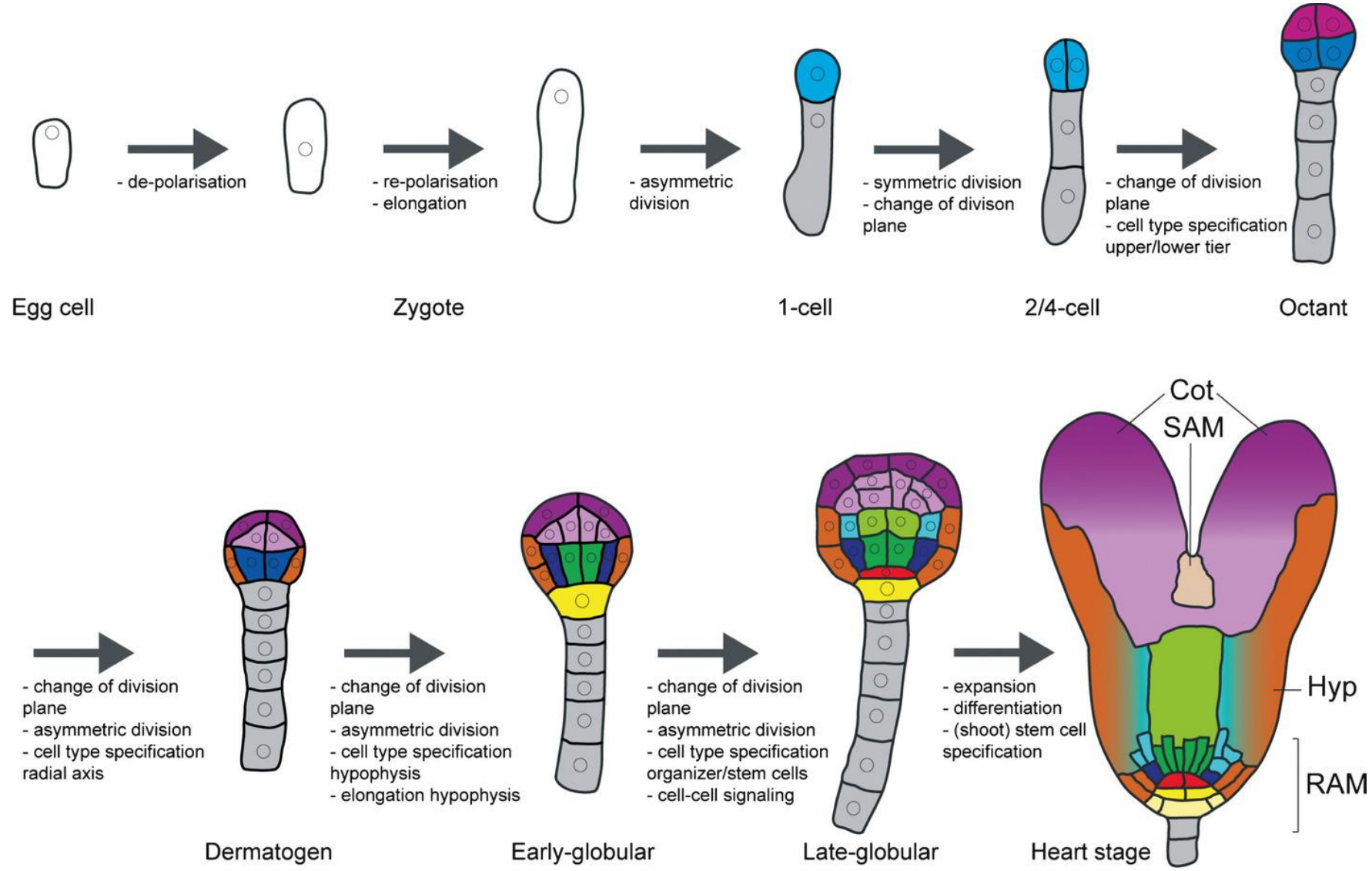
The heart stage is a transition period where the cotyledons finally start to form and elongate. It is given this name in dicots because most plants from this group have two cotyledons, giving the embryo a heart shaped appearance.



The shoot apical meristem is between the cotyledons (Stage IV)



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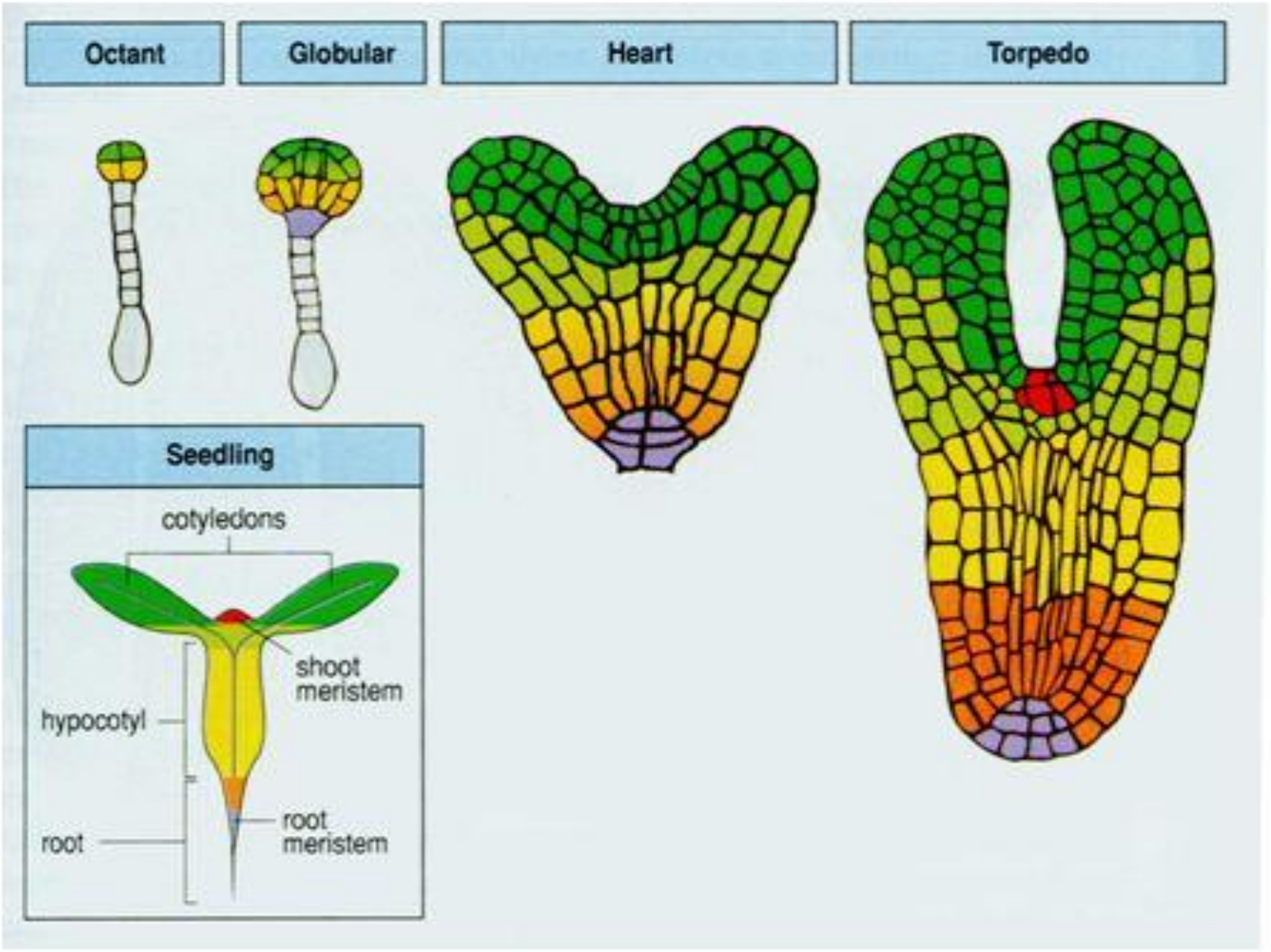
Shoot apical meristem

Torpedo stage

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.


Octant
Globular
Heart
Torpedo
Seedling
cotyledons
shoot meristem
hypocotyl
root
root meristem

During the torpedo stage 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 to grow.

After the suspensor complex is terminated by programmed cell death, the embryo is fully developed, indicates what the embryo looks like at this point in development.

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).