Biology 340
Comparative Embryology
Lecture 3
Dr. Stuart Sumida

Overview of Plant Development

Focus Primarily on Green Plants and Angiosperms (Flowering Plants)

FUNDAMENTAL DIFFERENCES BETWEEN DEVELOPMENT OF PLANTS VS. DEVELOPMENT OF ANIMALS

1. Plant cells don't migrate. No migration of cells to create a gut (gastrulation). No migration of cells like neural crest. (Apositional growth)

2. Meiosis in plants produces spores, not gametes. Plant gametes produced by mitotic division after meiosis.

3. Life cycle of land plants has both diploid and haploid multicellular stages. No multicellular haploid in animals (normally).

4. Plant germ cells not set aside early in development.

5. Plants undergo extended morphogenesis. Meristems (similar to stem cells) persist long after maturity and continue to give rise to new structures (morphogenesis). (i.e. plant cells remain "***totipotent***" much longer.)

6. Plants have greater developmental plasticity.

GAMETE PRODUCTION IN PLANTS

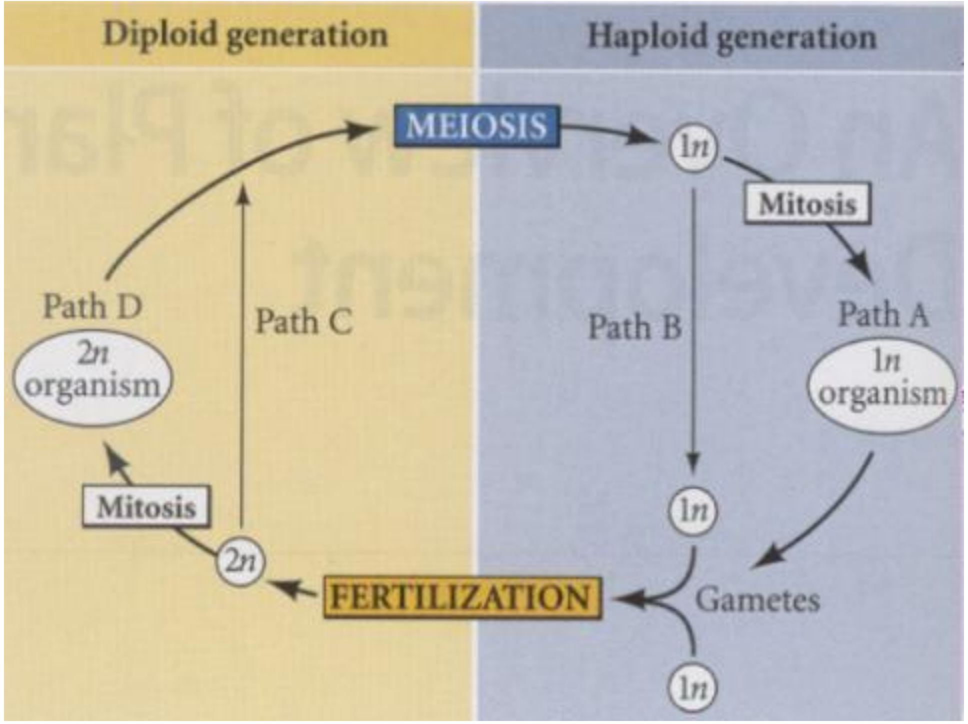
Plants have multicellular organisms in both haploid and diploid stages.

Gametes develop in the multicellular haploid GAMETOPHYTE.

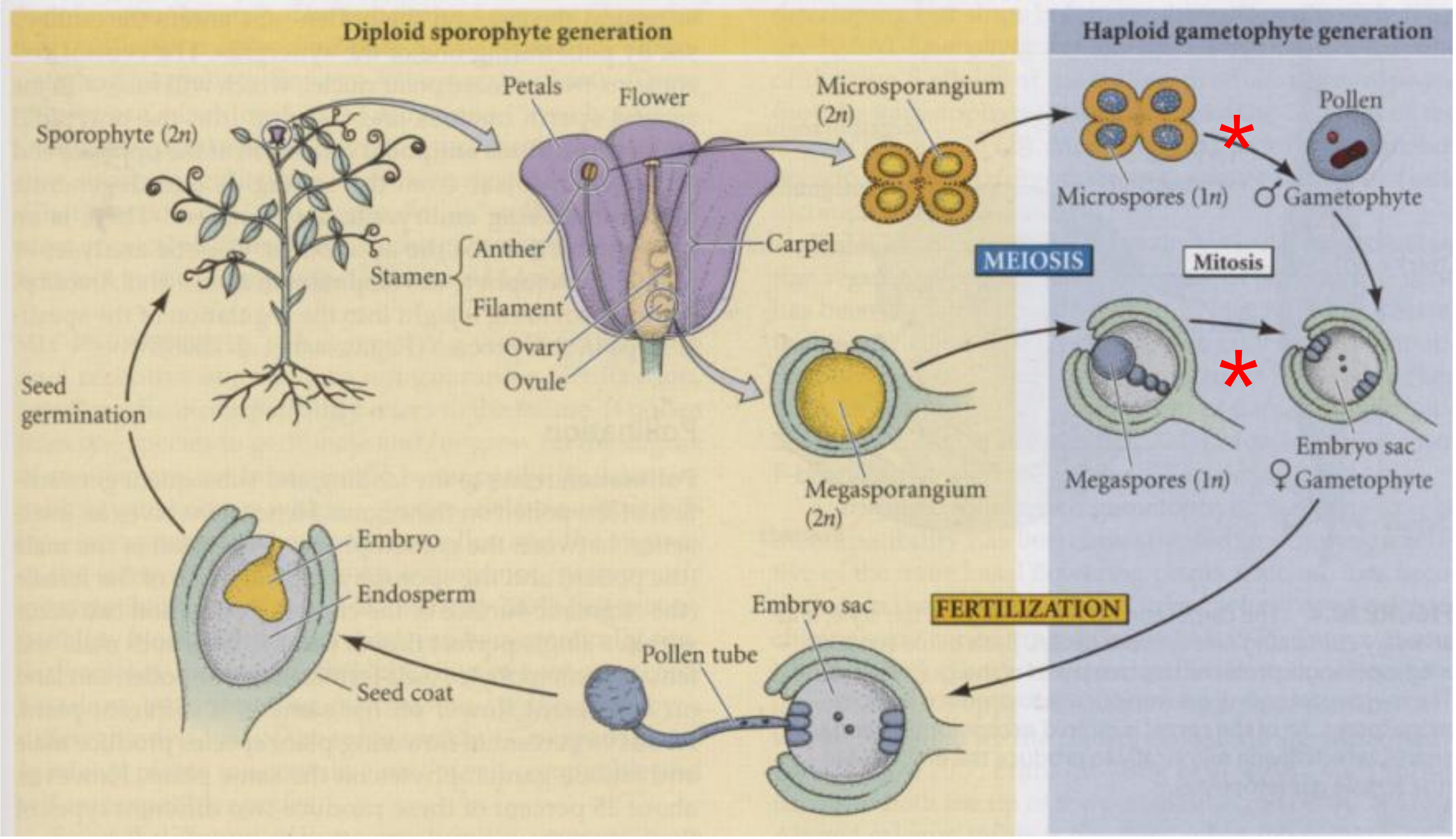
Fertilization gives rise to a multicellular SPOROPHYTE stage.

This strategy is referred to as HAPLODIPLONTIC, or “alternation of generations”.

SPOROPHYTE
(spore producing)

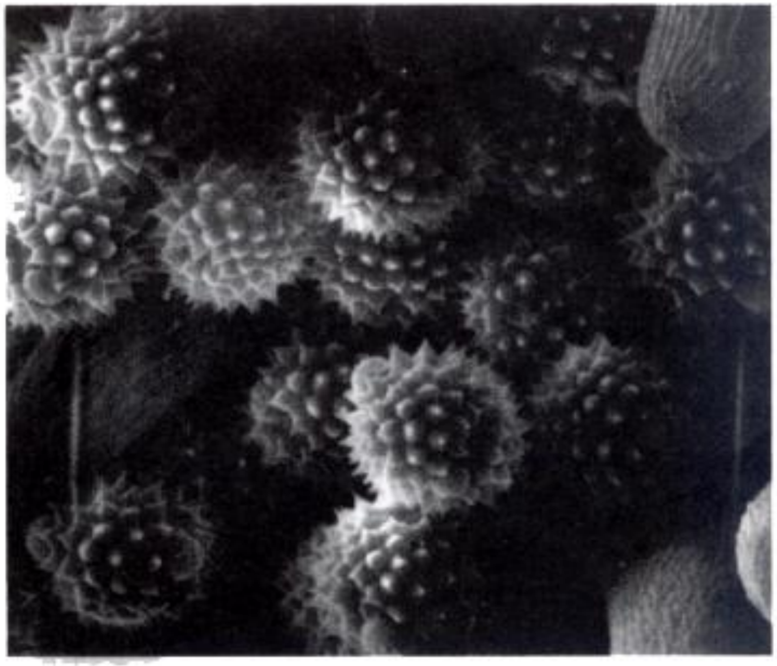


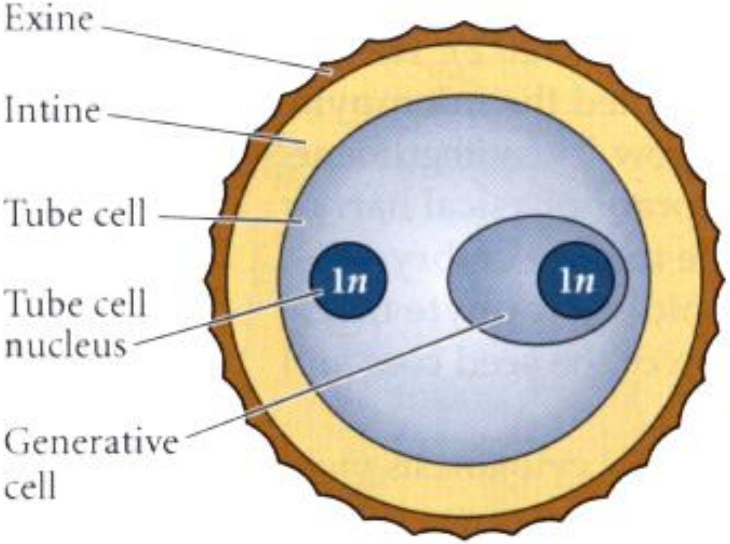
GAMETOPHYTE
(gamete producing)



In ANGIOSPERMS, the multicellular haploid gametophyte stage is much reduced.

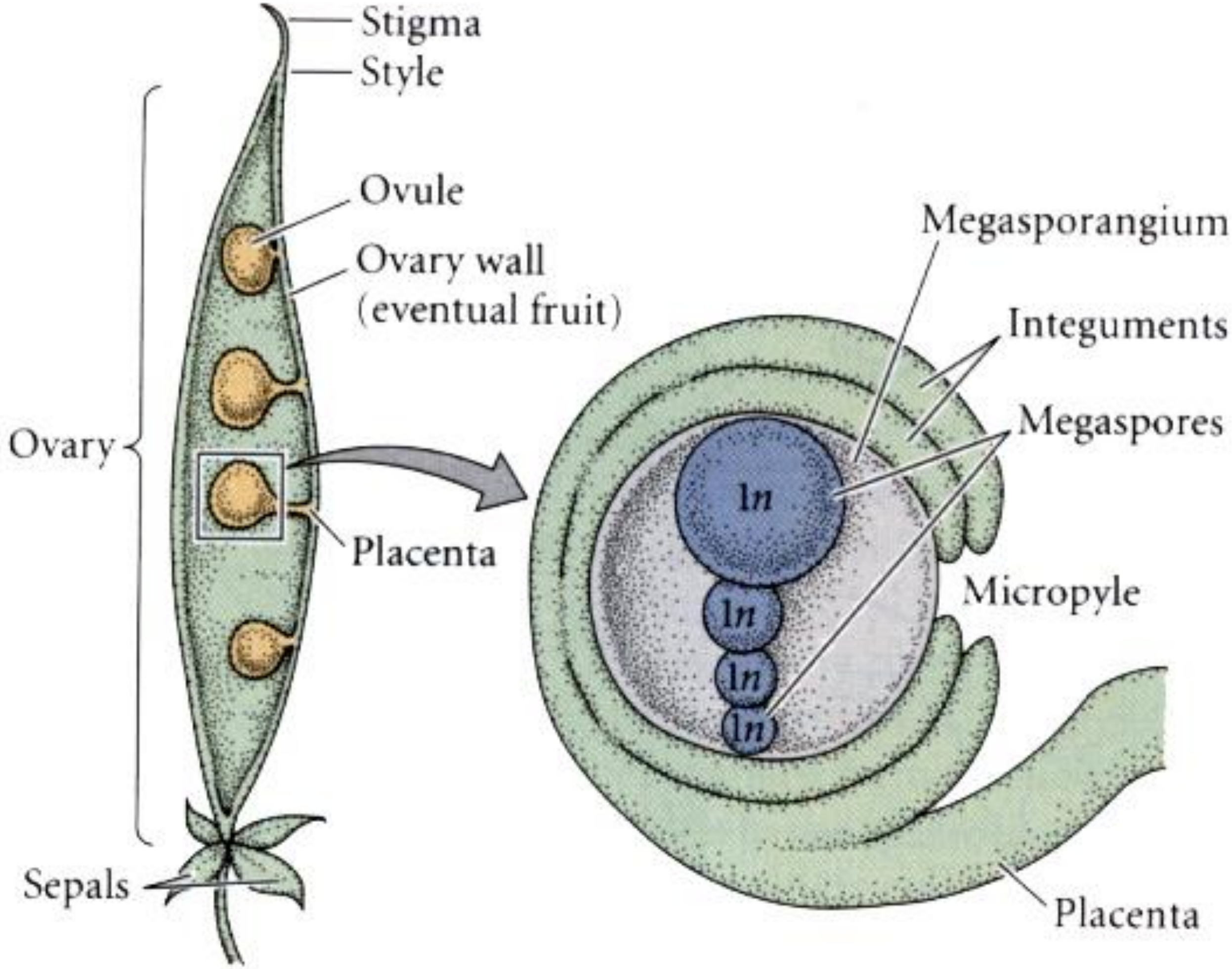
Mitotic division follows meiosis in the sporophyte (*) resulting in small, but multicellular gametophyte – which produces eggs (in embryo sac) or sperm (in pollen grain).



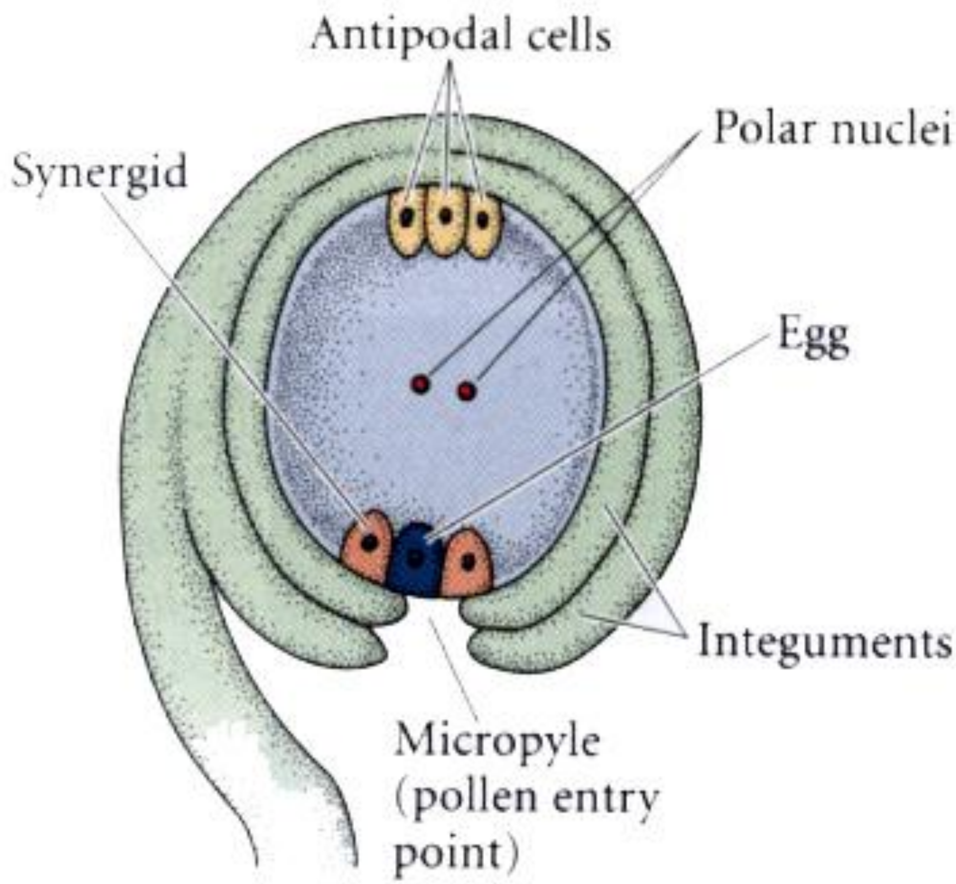


Pollen grain is very simple, but multicellular structure. TWO [haploid] cells:

1. Tube cell
2. Generative cell WITHIN the tube cell (which later divides to produce two sperm).
    A. One generative cell will fertilize embryo.
    B. Other will contribute to triploid tissue called endosperm which nourishes embryo.



•OVARY = carpal of flower, consisting of ovary, style, and stigma (where pollen lands).
•One or more ovules are attaches to ovary wall via the placenta.
•Recall that megaspores were produced via mitosis AFTER meiosis.



Within ovule, largest of four megaspores go through three mitotic divisions giving 8 cells, one of which will be egg.

POLLINATION – landing and subsequent germination of pollen grain on stigma. Pollen grain enters via one of the two synergids and fertilizes egg.

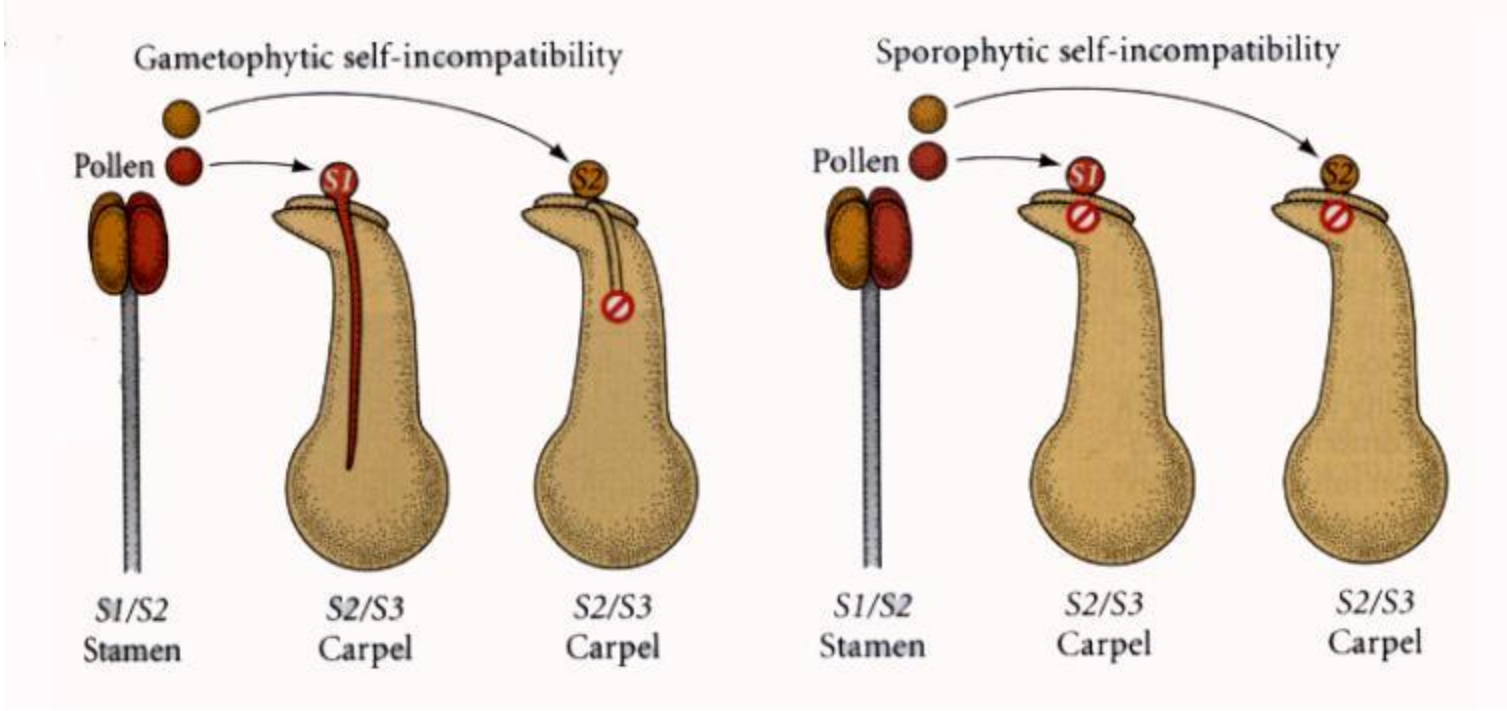
INCOMPATIBILITY:

- ***Interspecific Incompatibility*** – different species (often because of inappropriate chromosome number, and other such things).

- ***Intraspecific Incompatibility (2 types)***

    - ***Gametophytic Incompatibility*** pollen tube elongation is halted when it has proceeded approximately one third of the way through the style. The female component ribonuclease (termed **S-Nase)** probably causes degradation of the ribosomal RNA inside the pollen tube, in the case of identical male and female S alleles, and consequently pollen tube elongation is arrested, and the pollen grain dies.

    - ***Sporophytic Self Incompatibility*** – blocks fertilization between genetically similar gametes. Probably due to exine (outer shell) of pollen grain. Occurs when one of the two alleles at the (S) Self Incompatibility locus match. (This promotes gene mixing within a population.)



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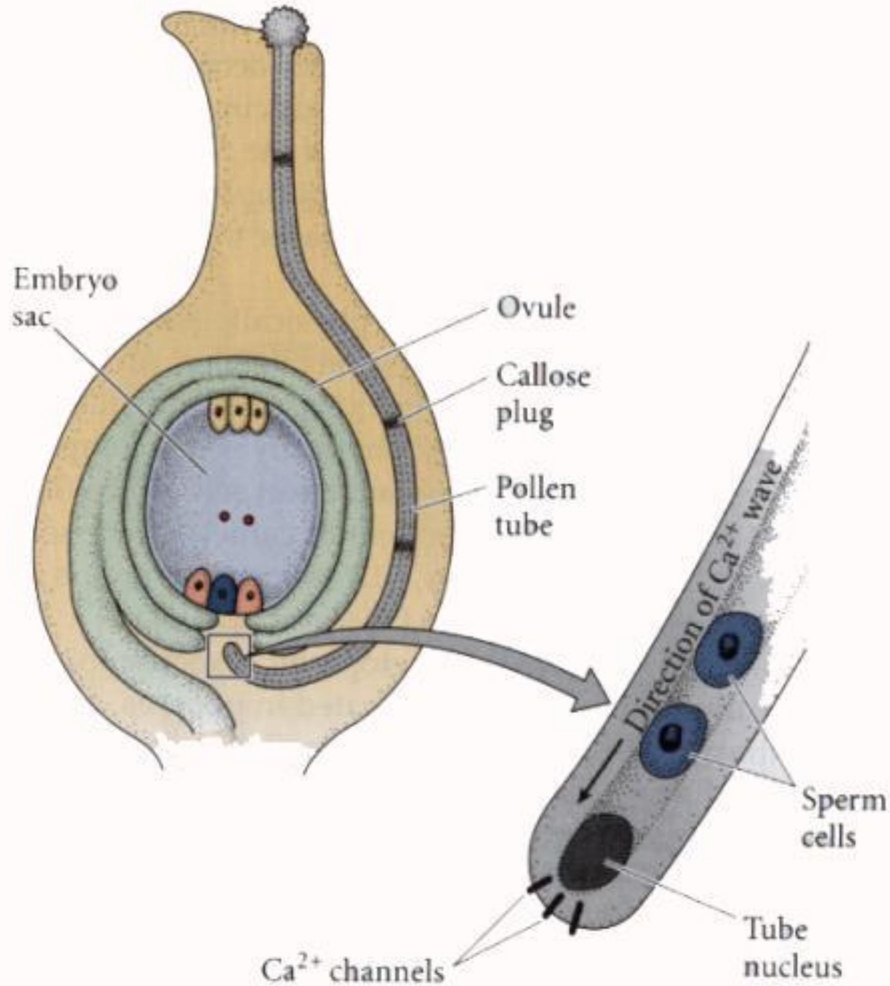
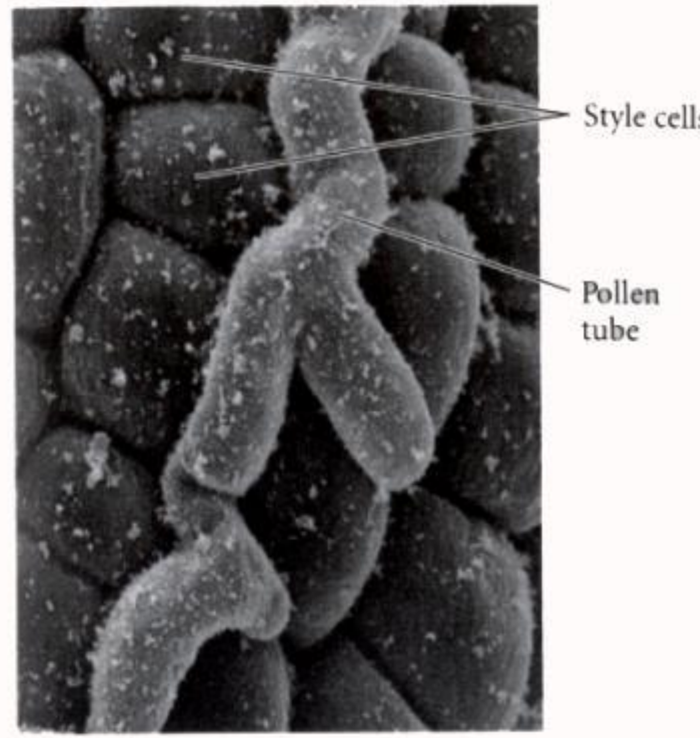




When pollen tube germination does work, pollen grain takes up water, and pollen tube grows down style, followed by sperm cells.

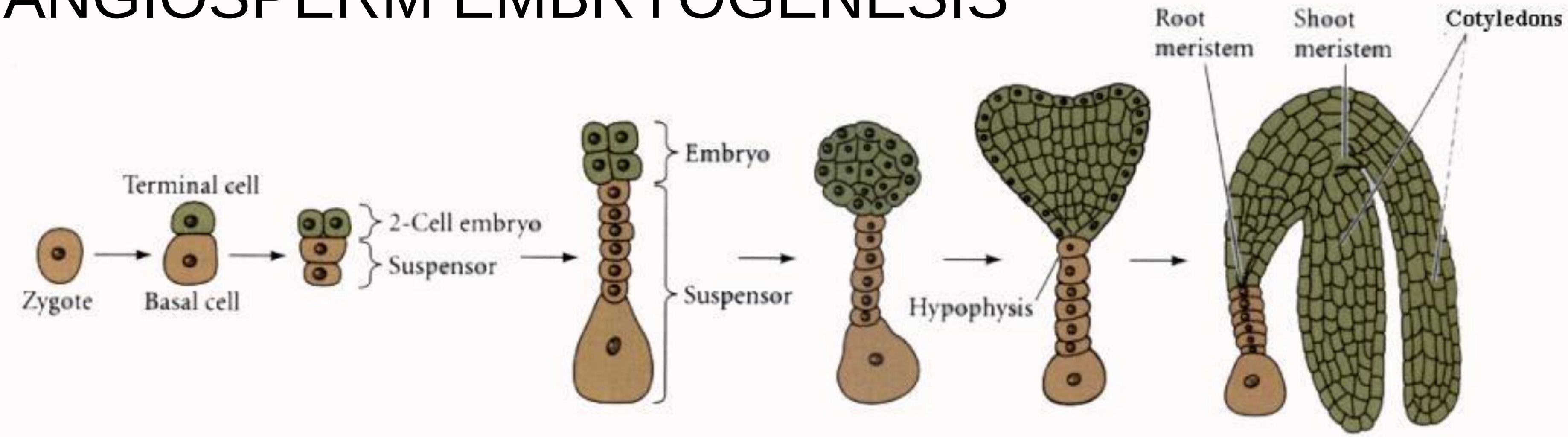
It appears that Calcium ions are necessary for proper pollen tube growth.

DOUBLE FERTILIZATION

One sperm cell fuses with egg.

Other sperm cell fuses with binucleate or multinucleate cell to generate triploid endosperm that provided nutrition for embryo.

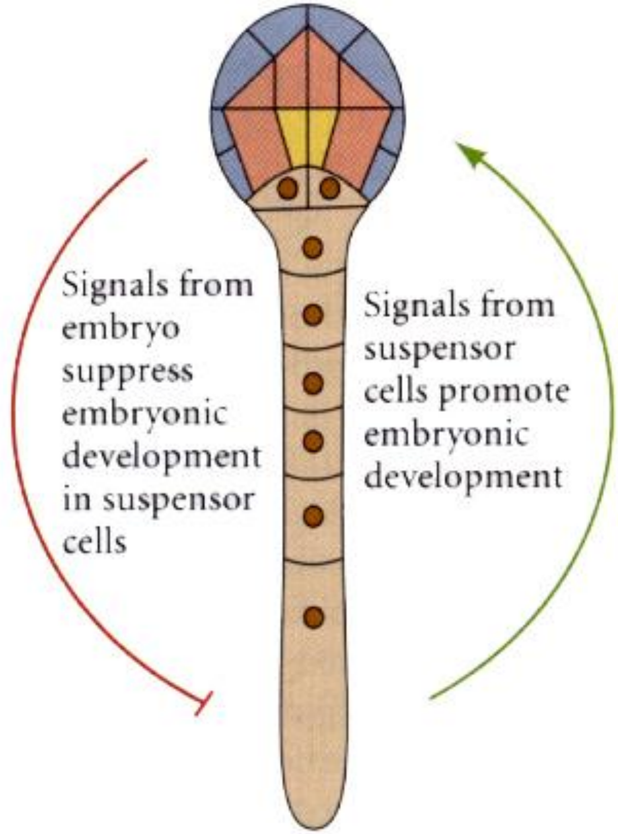
ANGIOSPERM EMBRYOGENESIS

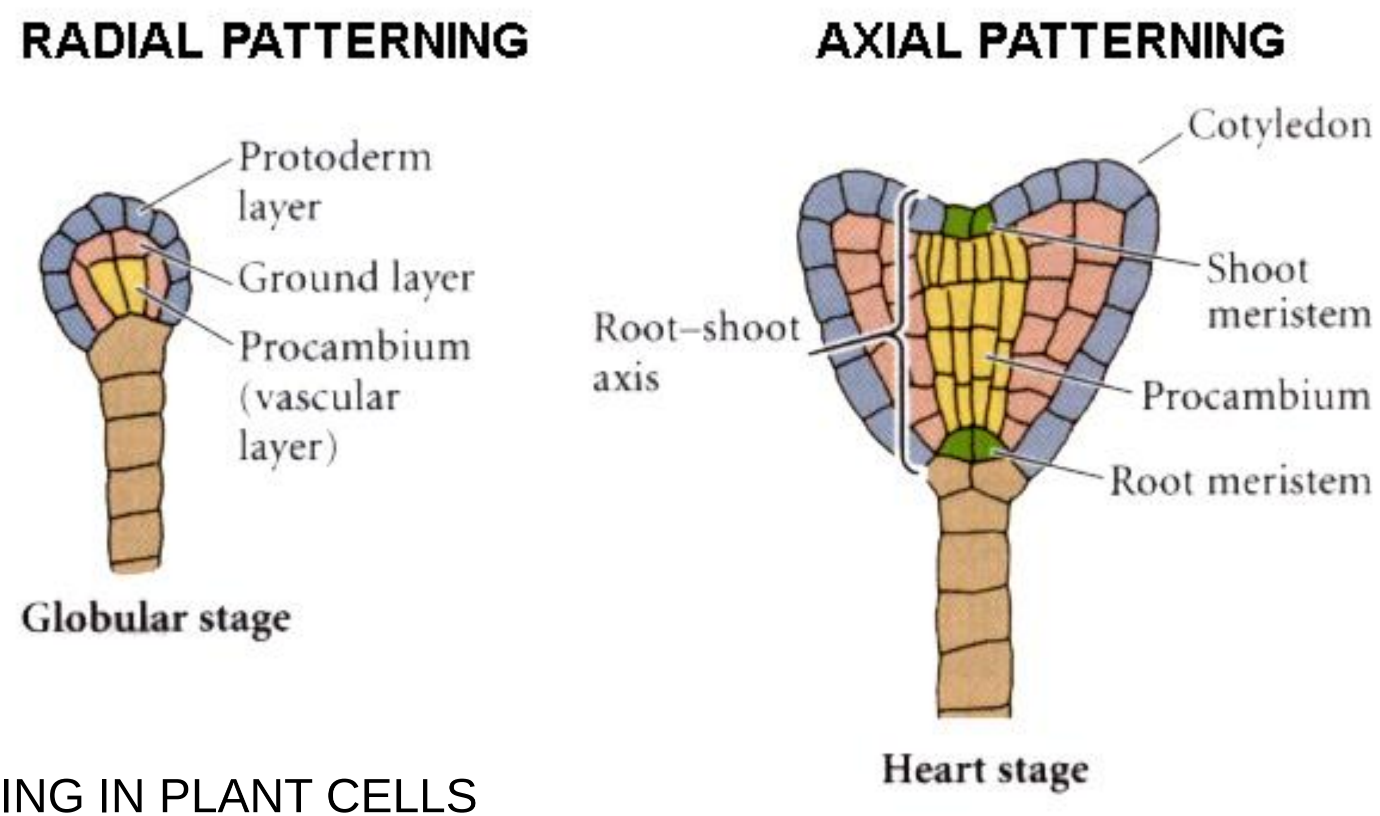


MONOCOTS vs. DICOTS – refers to number of embryonic leaves (cotyledons).

First cell division is asymmetric, resulting in basal cell and terminal cell. Mitotic divisions of terminal cell will generate eventual embryo.

Basal cell mitotic divisions generates suspensor cells and eventually hypophysis – “extra-embryonic” structures. Serves embryo by orienting absorbtive surface toward food source. (We will see many examples of extra-embryonic structures in animals.)


Signals from embryo suppress embryonic development in suspensor cells
Signals from suspensor cells promote embryonic development

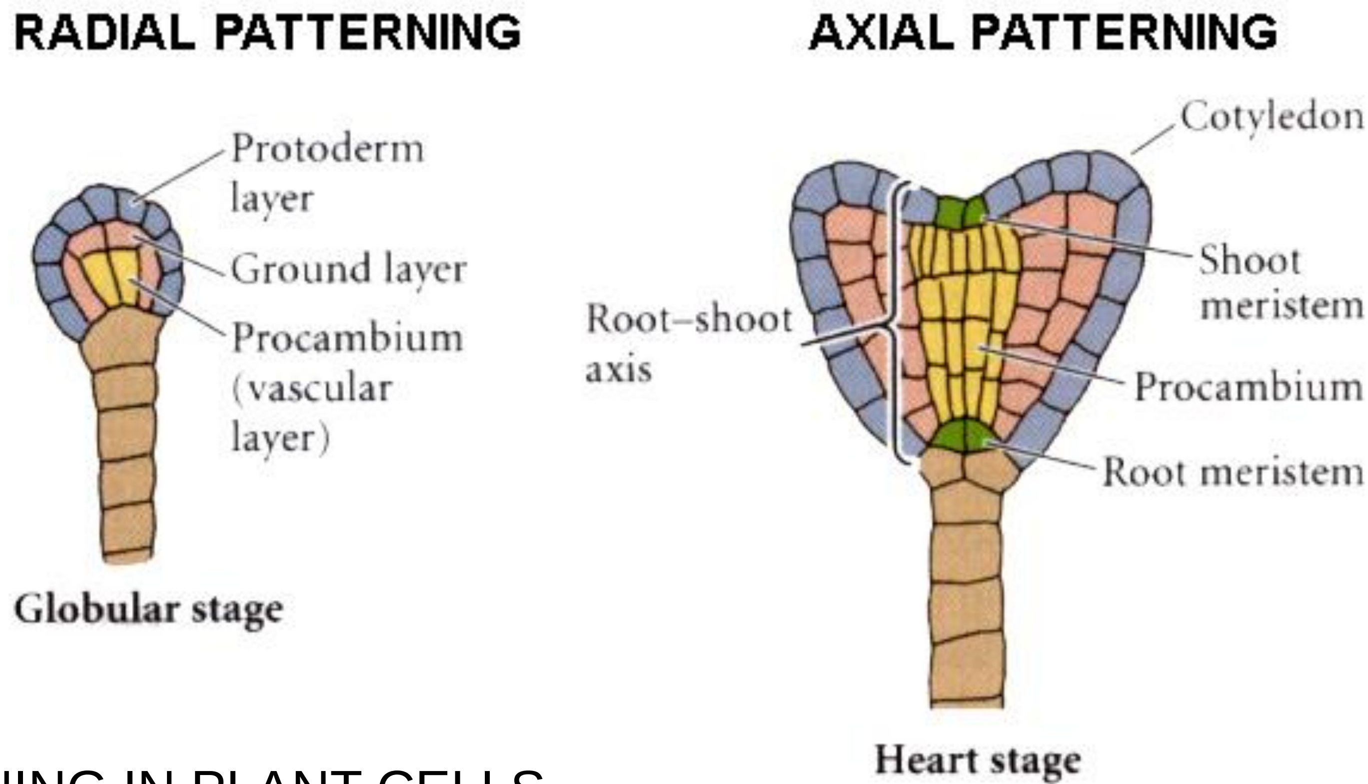


PATERNING IN PLANT CELLS

Initially, patterning is radial, much like that in animals cells initially. At this point, three tissue systems are present: dermal tissue, ground tissue, and vascular tissue.

- Dermal tissue gives rise to epidermal protective layers.
- Ground tissue give rise to cortex and pith.
- Vascular tissue gives rise to xylem and phloem.

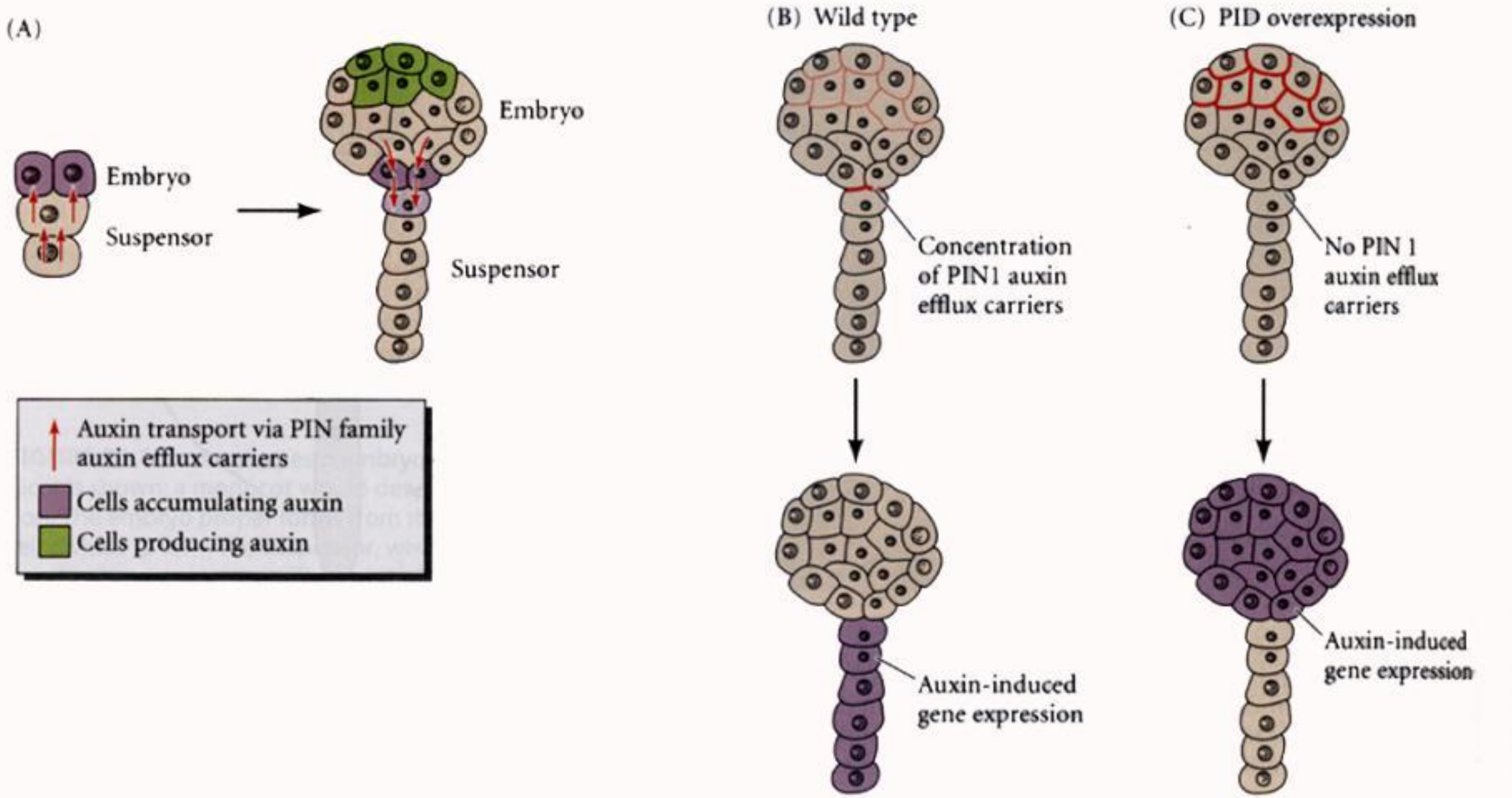
This is probably the closest plant tissues come to approximating "germ tissues" of animals.



PATERNING IN PLANT CELLS

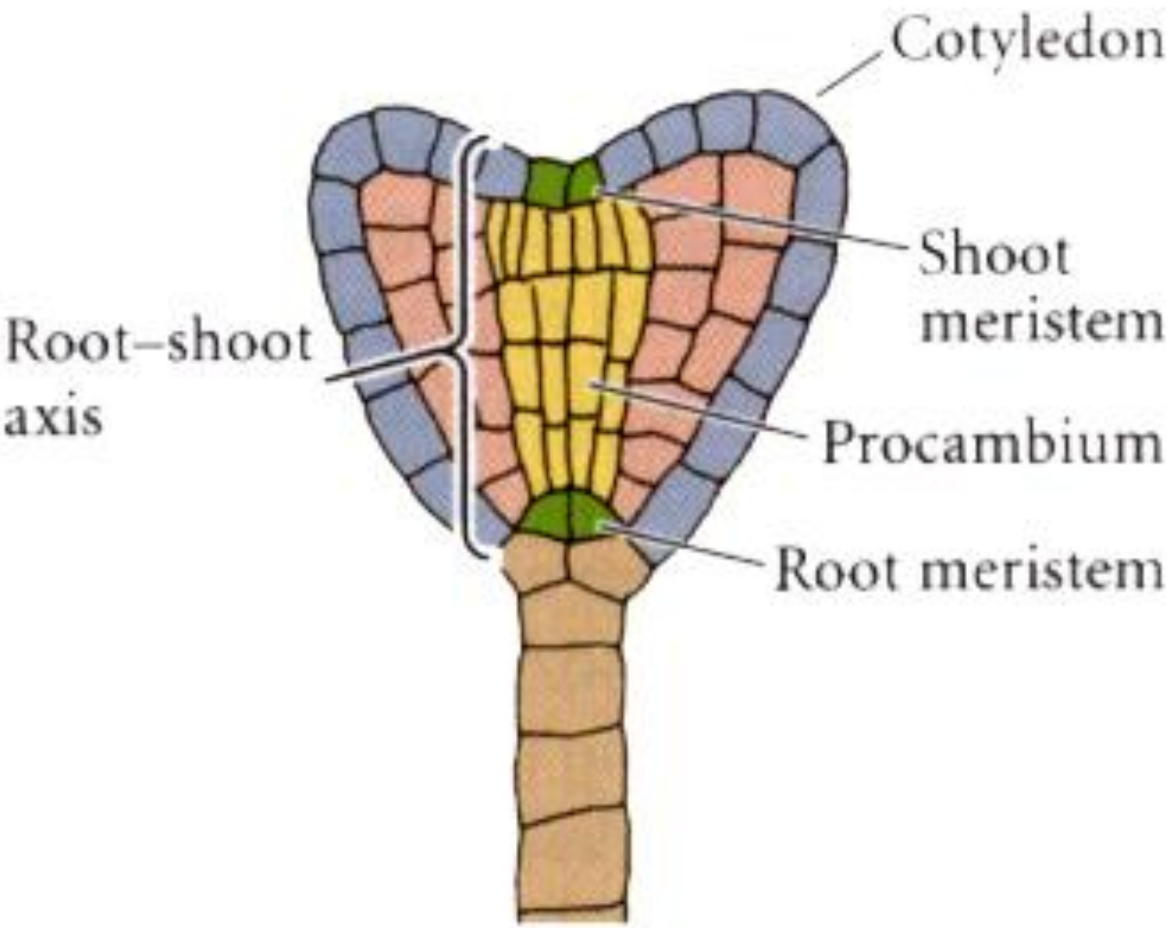
Later stages, as two embryonic leaves develop in dicots, the radial symmetry of the plant is lost, and a “heart stage” shows bilateral symmetry.

Probably a result of hormones – auxins.

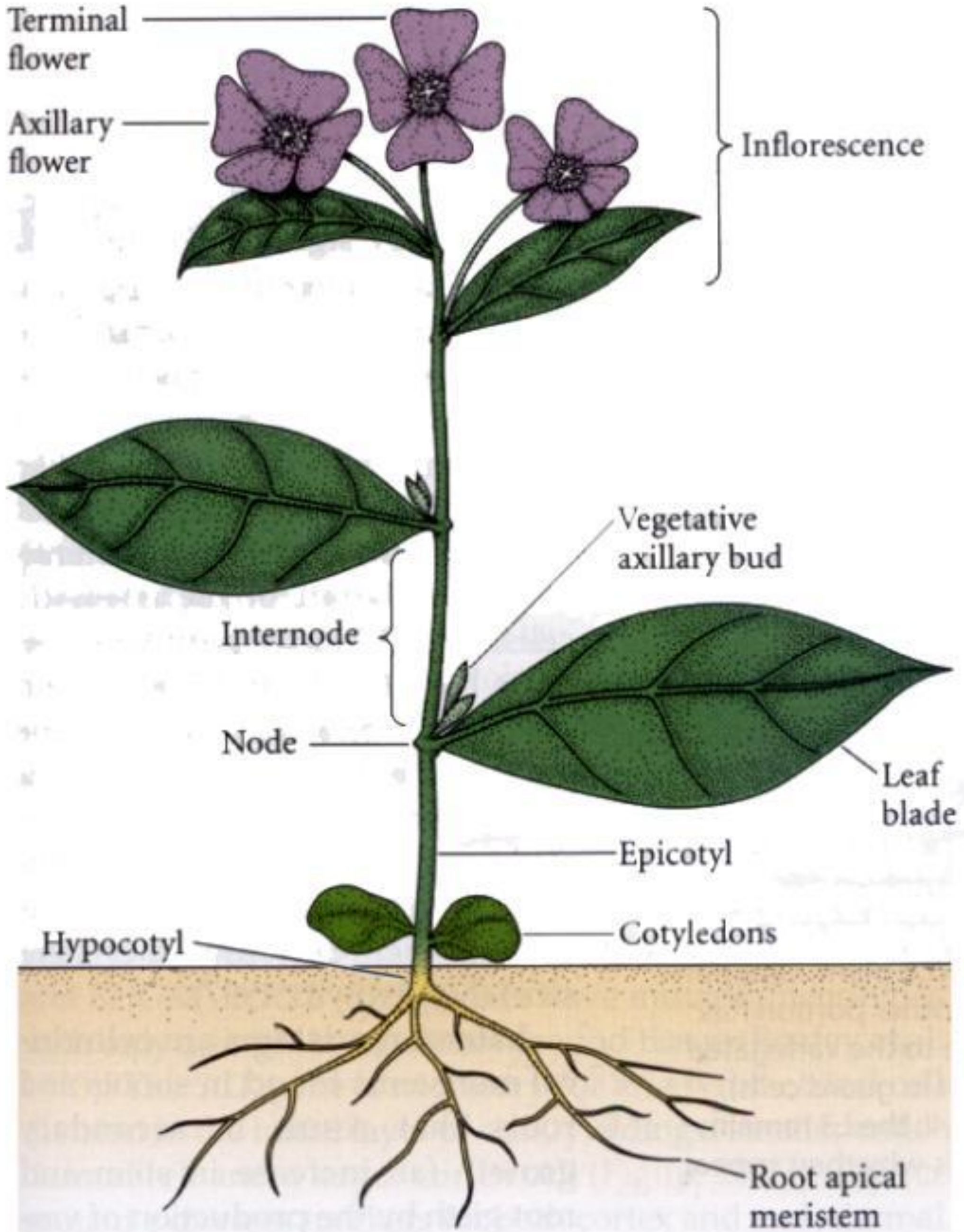


As in change from radial to heart-shaped condition, auxins contribute to development of basal to apical (bottom to top) or root to shoot axis.

Note that embryo is increasing in size!


Cotyledon
Shoot
meristem
Root–shoot
axis
Procambium
Root meristem

Heart stage


Terminal flower
Axillary flower
Inflorescence
Vegetative axillary bud
Internode
Node
Leaf blade
Epicotyl
Cotyledons
Hypocotyl
Root apical meristem

Recall that plant germ cells not set aside early in development and plants undergo extended morphogenesis.

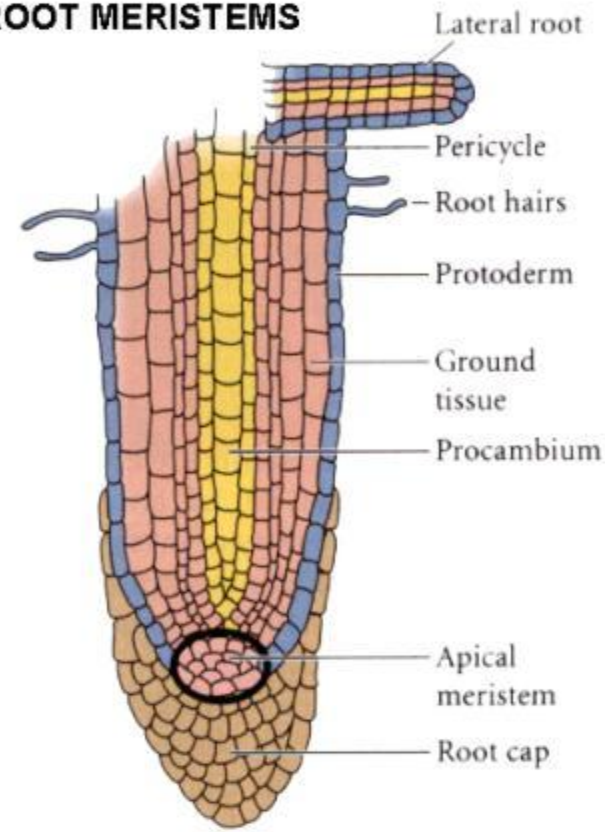
MERISTEMS are clusters of cells that allow the basic body pattern established during embryogenesis to continue to be reiterated and extended into adult life of the plant.

Normally, when they divide, they give rise to two daughter cells, one of which differentiates, and one of which retains its meristematic potential.

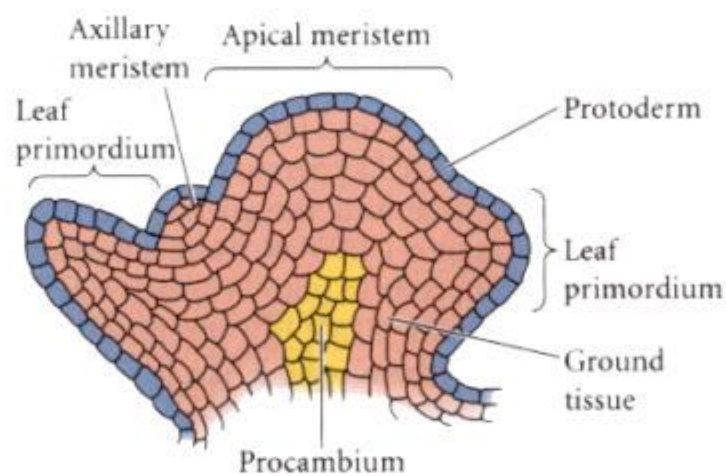
APICAL MERISTEMS occur at shoot and root tips.

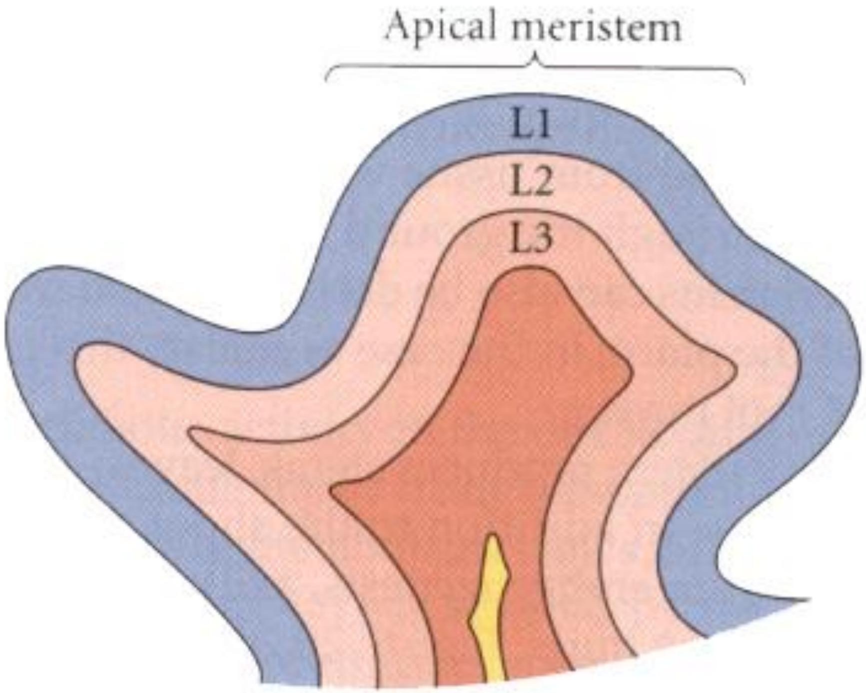
SHOOT MERISTEMS occur at lateral organs of plant – leaves and axillary branches.

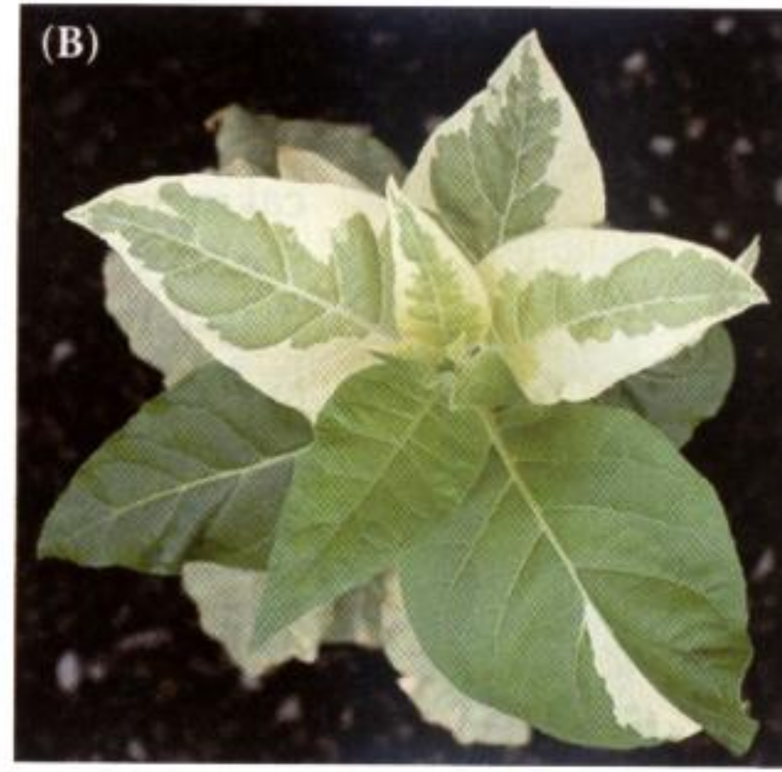
ROOT MERISTEMS



SHOOT MERISTEMS







Normally, apical meristems in angiosperms have up to three layers of cells:

Each of these layers can be histologically and genetically different (as seen in the colors of the leaves at right, each of which is derived from a different meristematic layer.

LEAF DEVELOPMENT

(involves three aspects)

1. Cells' commitment to become a leaf.

2. Establishment of leaf axis.

3. Morphogenesis giving rise to leaf shape (sometimes involving apoptosis [programmed cell death]).

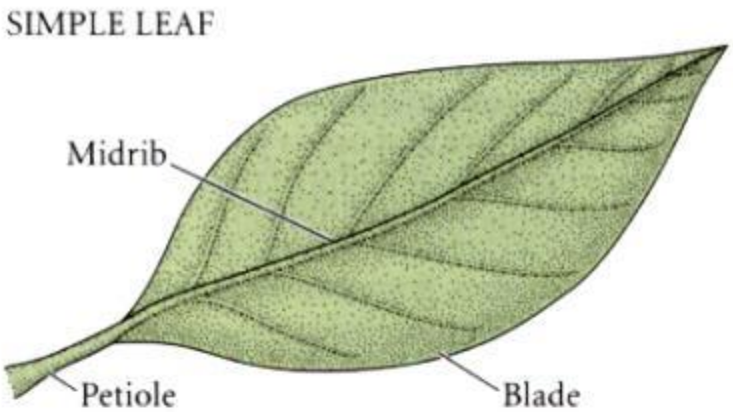
SIMPLE LEAF: single midrib with branching veins at end of single petiole.

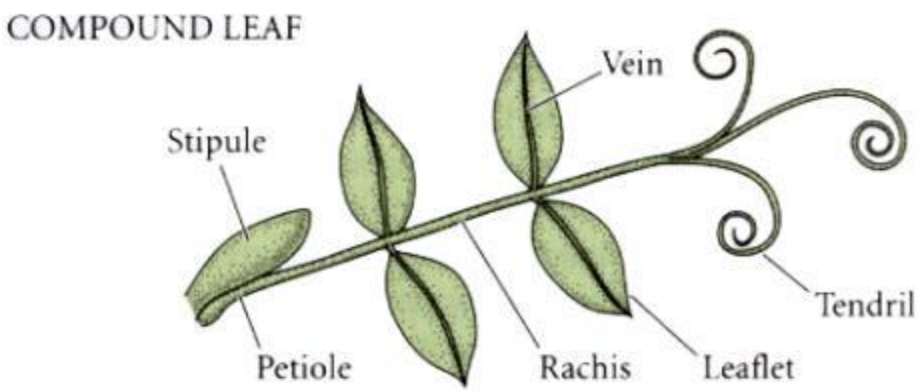
COMPOUND LEAVES: individual leaflets branching off of a single petiole.

How they develop is debated. Because they both have a single petiole, some feel that compound leaves are actually highly lobed simple leaves and their veins are equivalent to those branching from the midrib of a simple leaf.

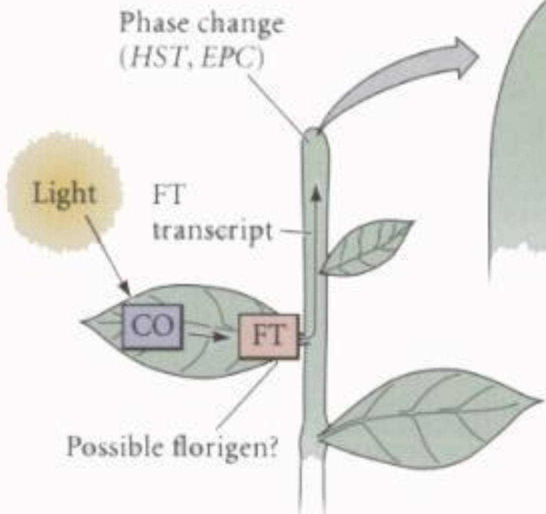
Others feel leaflets are highly modified lateral shoots.

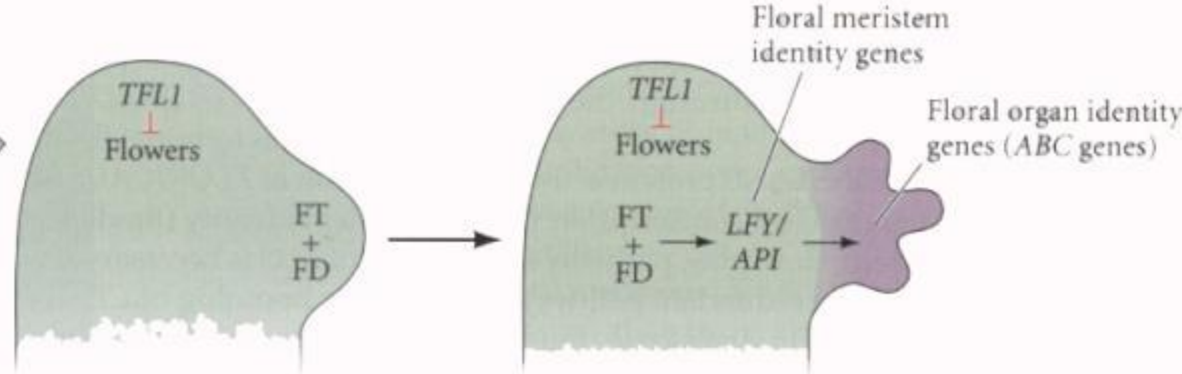
* Primitive state for seed plants is compound, whereas, slightly more derived angiosperms have simple leaves as their ancestral condition. So, it isn't clear if compound leaves demonstrate a reversion to the basal (primitive) ancestral state.



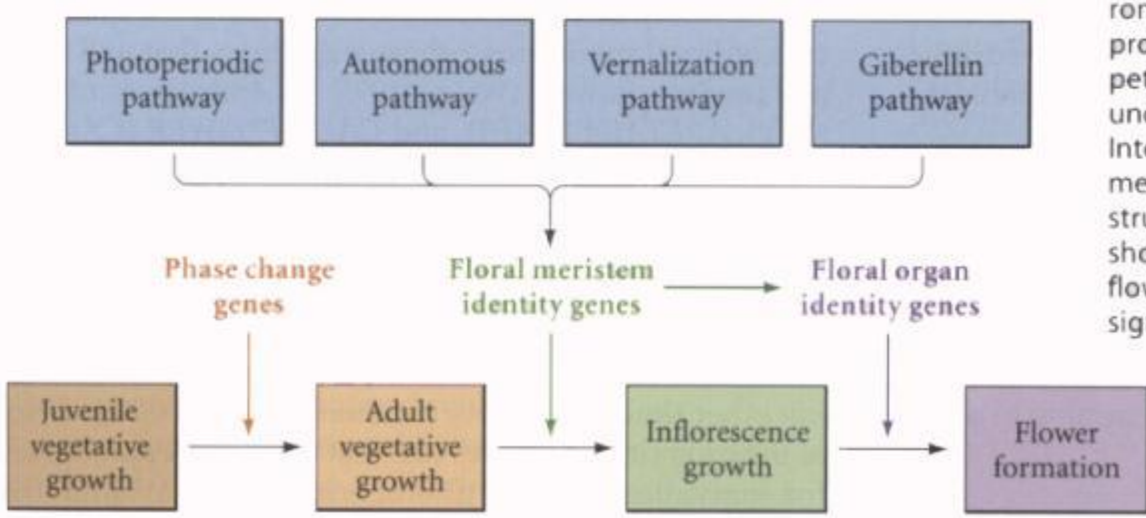


(A)





(B)



The vegetative-to-reproductive transition. (A) Signals promoting or inhibiting flowering can move from the roots, cotyledons, or leaves to the shoot apex, where meristem competence determines whether or not the plant will respond to the signals. Leaves may also need to develop competence to respond to environmental signals before they can produce floral promoters. Leaves and meristems that are competent to respond to flowering signals have undergone a juvenile-to-adult phase change. (B) Internal and external factors regulate whether a meristem produces vegetative or reproductive structures. Not all of the regulatory mechanisms shown are used in all species, and some species flower independently of external environmental signals.

Note that plant embryos – which are connected to other supporting “extra-embryonic” structures have access to water and nutrients – and thus can grow immediately.

Animal cells, initially constrained by how much yolk is in an egg, can differentiate, but not grow (get larger). This is a condition known as PALINTOMY.