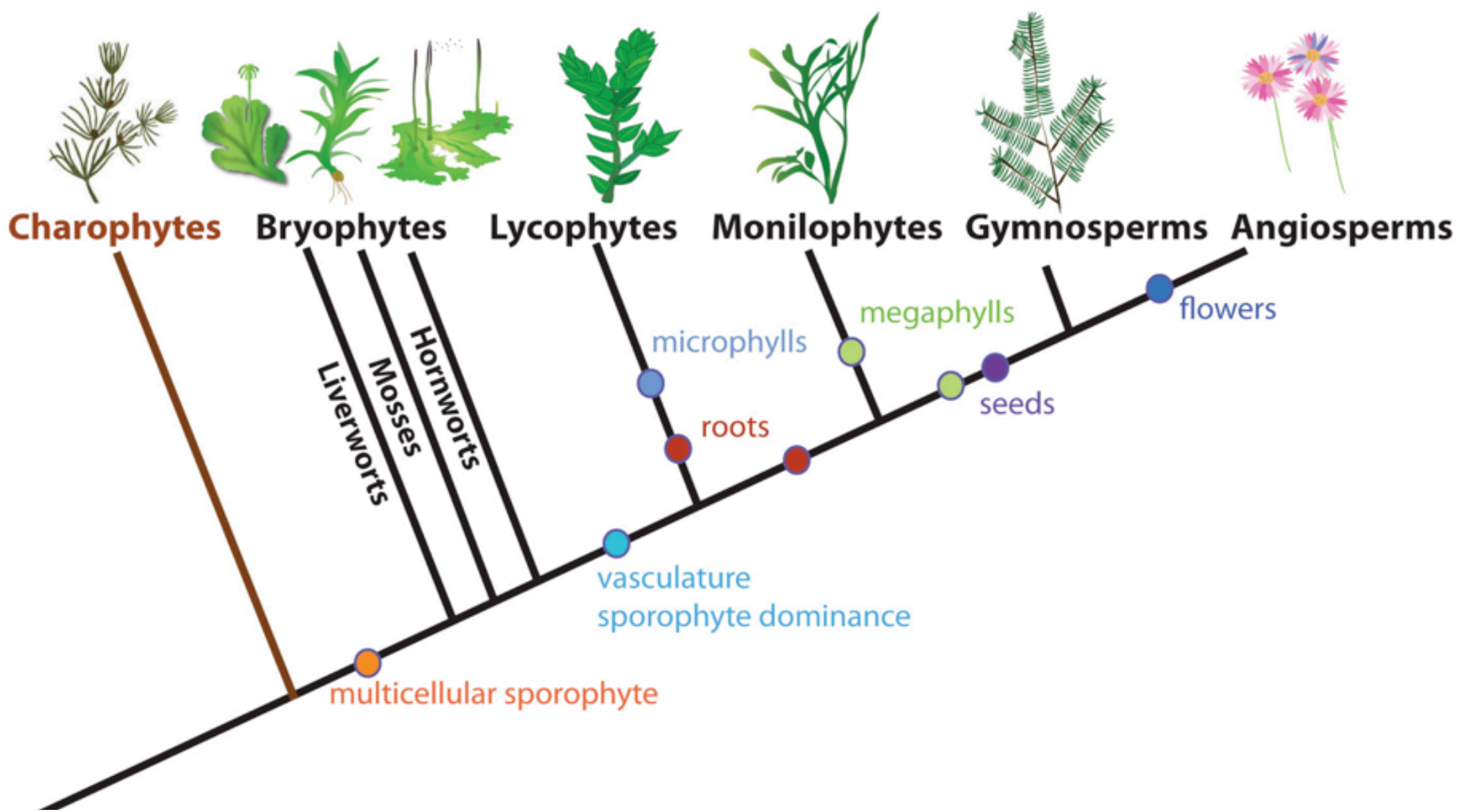
Flower-Producing Plants with Ovules inside Ovaries Evolve from a Subset of Seed-Producing Ovule-Containing Vascular Plants



Flowering plants

- Key reproductive adaptations of seed plants seen in gymnosperms first:
  1. Sporophytes dominates life cycle
  2. Seeds as resistant and dispersible parts of the life cycle
  3. Pollen as the airborne agents bringing gametes together
- Angiosperm: flowering plants evolve after gymnosperms
  - All belong to the phyum Anthophyta *('anthos' meaning flower in Greek)*
    - Vascular tissue
    - Pollen production by microsporagia
    - Heterospory
      - male vs female spores produce microscopic male vs female gametophytes
    - Seeds (formed from ovules) now held within ovaries, which become fruit
    - Life cycle dominated by sporophyte stage
      - Flowering trees & bushes you are familiar with are diploid
      - Have reduced (microscopic) gametophyte held within sporophyte.

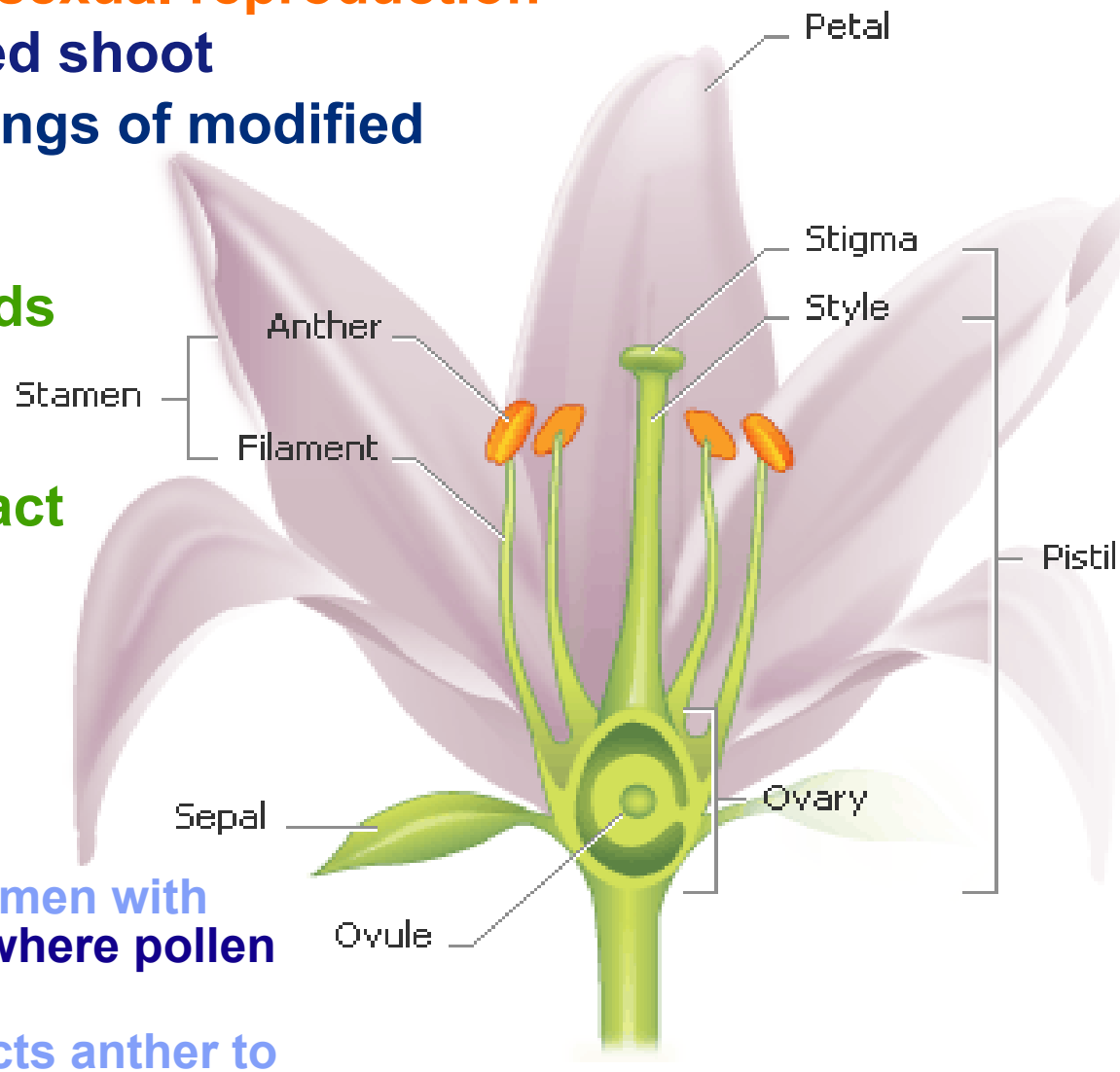
Angiosperm: Flowering Plants (seeds are produced from ovules; seeds not naked like in gymnosperms but surrounded by ovaries which become fruit)

Monocots (plant starts with one cotyledon or embryonic leaf) vs. Eudicots (plant starts with two cotyledons or embryonic leaves)

	Embryos	Leaf venation	Stems	Roots	Flowers
Monocots	 One cotyledon	 Veins usually parallel	 Vascular bundles usually complexly arranged	 Fibrous root system	 Floral parts usually in multiples of three
Dicots	 Two cotyledons	 Veins usually netlike	 Vascular bundles usually arranged in ring	 Taproot usually present	 Floral parts usually in multiples of four or five

Angiosperm Reproductive Organs

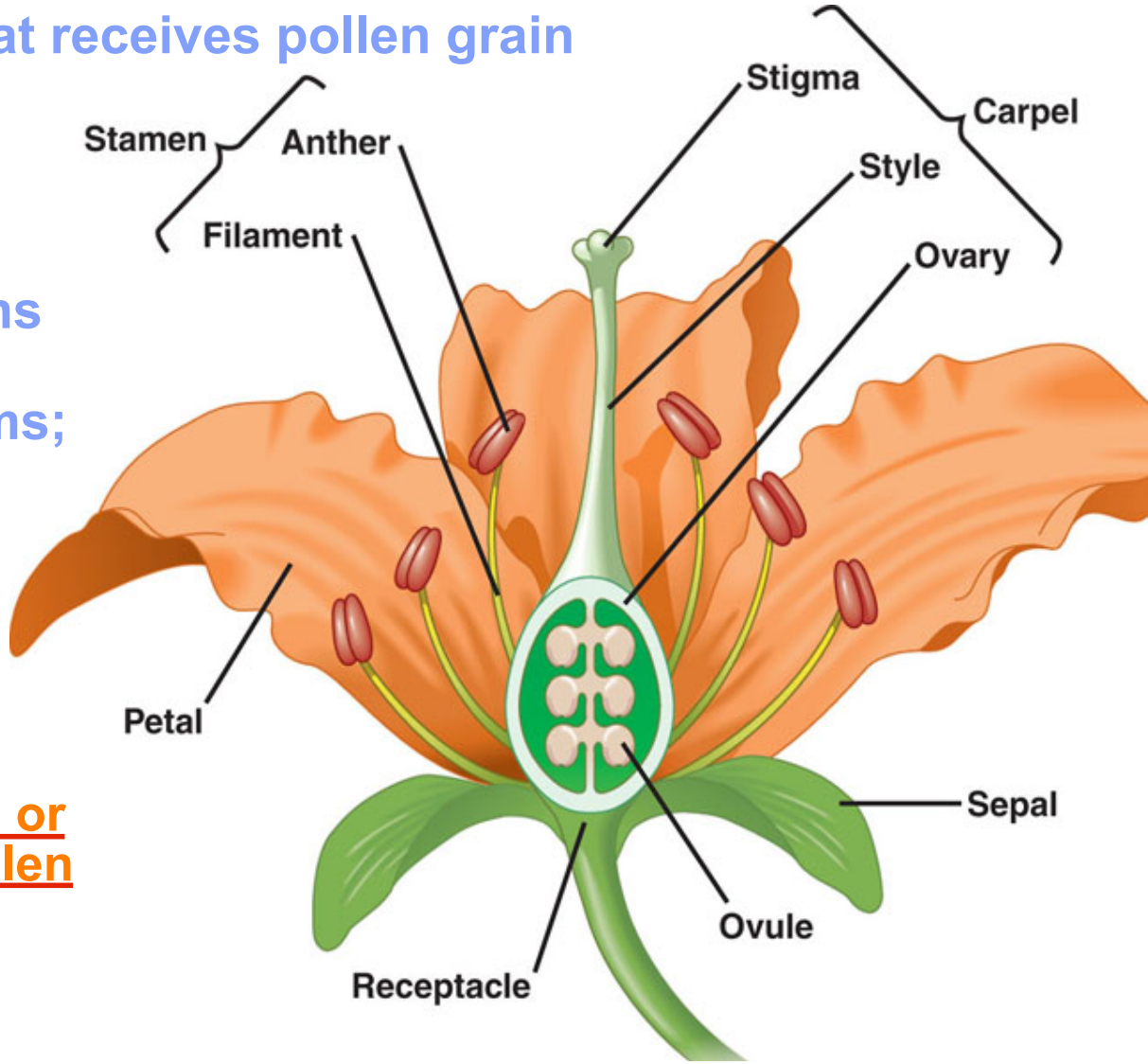
- **Flower production**
  - **Specialized structure for sexual reproduction**
    - A flower is a specialized shoot
    - Flowers have to four rings of modified sporophylls (leaves) called floral organs
      1. **Sepals** = enclose buds and usually green
      2. **Petals** = brightly colored often to attract pollinator
      3. **Stamens** = produce microspores that develop into pollen grains
         a. **Anther** = tip of stamen with microsporangia (where pollen grains made)
         b. **Filament** = connects anther to rest of flower



Angiosperm Reproductive Organs

4. Carpels or Pistil = produce megaspore that becomes the female gametophyte

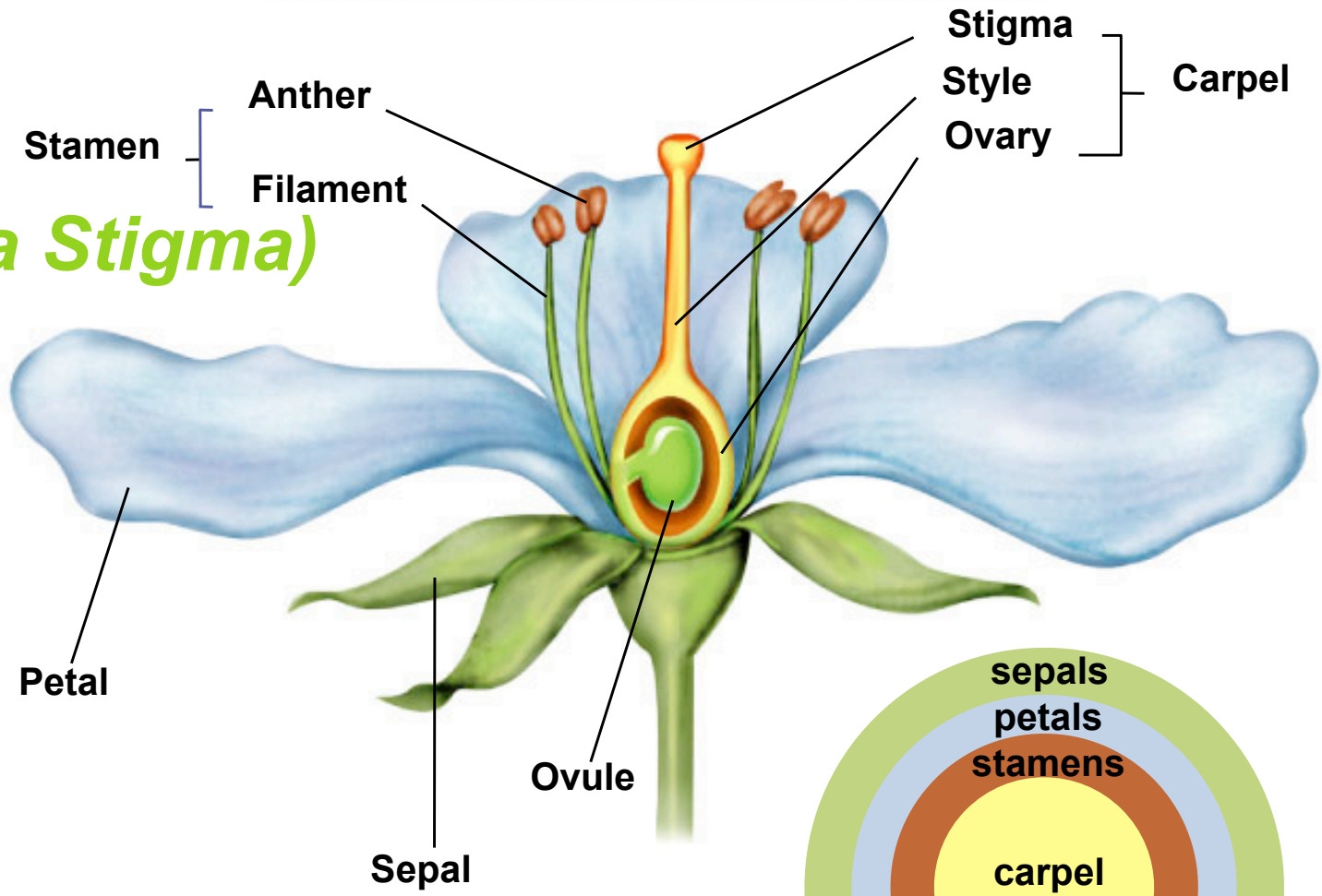
a. Stigma = tip of carpel that receives pollen grain
b. Style = structure that runs from stigma to ovary
c. Ovary = at the base of the carpel and contains one or more ovules
d. Ovules = where egg forms; develops into seed after being fertilized



- Like gymnosperms, some angiosperms rely on the wind for pollination
- Unlike gymnosperms, many angiosperms rely on insects or other animals to transfer pollen from one flower to the sex organs on anther flower

Flower

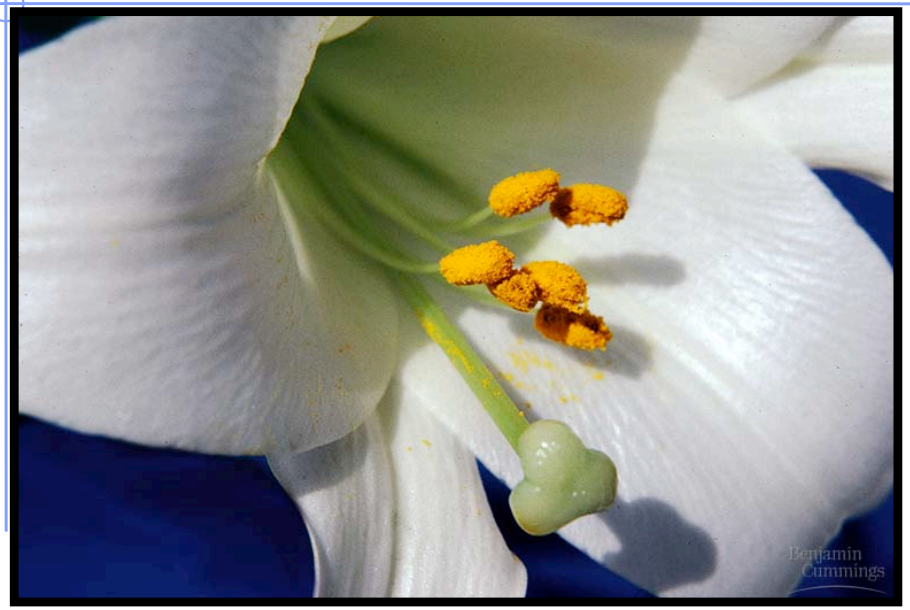
- **stamens**
  - male part
- **carpel** *(aka Stigma)*
  - female part



Four rings of modified leaves:

Adaptations through mutations

Identify the flower structures…



Flower Characteristics

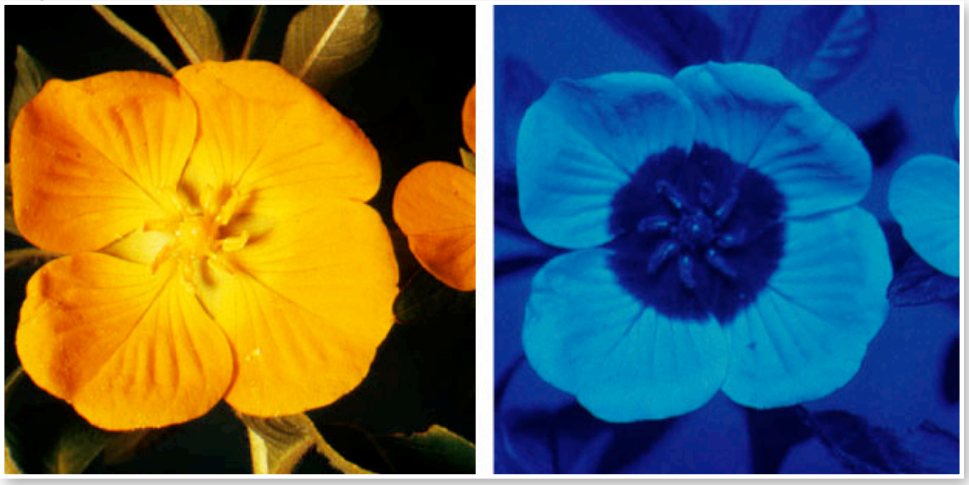
Many flowers in nature have evolved to attract animals or insects (often birds or bees) to pollinate the flower as a means of increasing genetic recombination.

- These flowers commonly have glands called nectaries that attract pollinators.
- Birds and bees can see colors and opt for "colorful" flowers.
- Some flowers have patterns, called nectar guides, that show pollinators where to look for nectar
  - They may be visible to us or only under ultraviolet light, which is visible to bees and some other insects.

Co-evolution: flowers & pollinators

Co-evolution: flowers & pollinators

How a bee sees a flower…some insects see UV light & are attracted to darker colors = *a bulls-eye to the nectar*

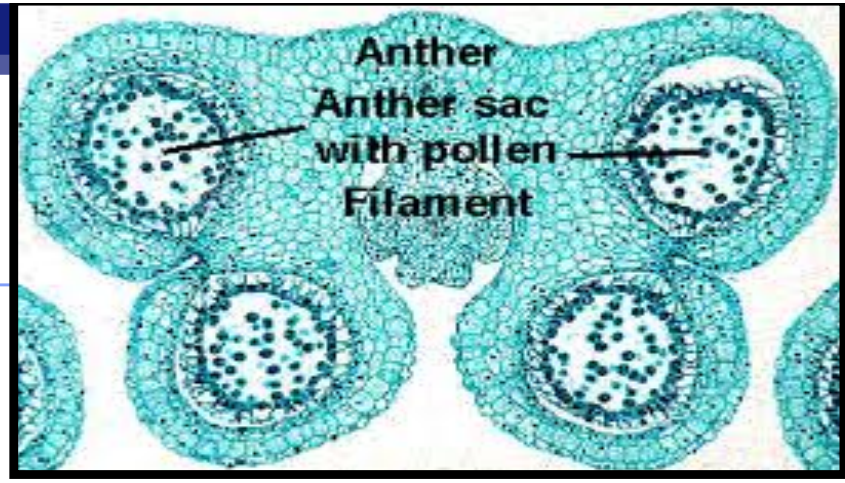


Flower Characteristics

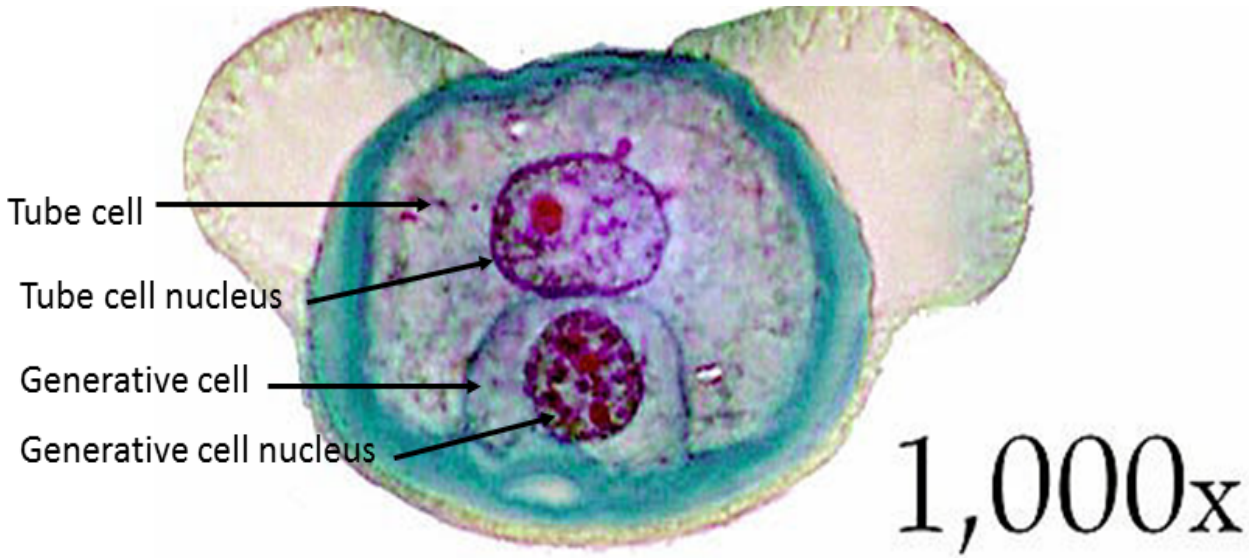
- Flowers also attract pollinators by scent.
  - Many of their scents are pleasant to our sense of smell
  - Some plants are pollinated by flies, so produce a scent imitating rotting meat.

- Still other flowers use mimicry to attract pollinators.
  - Ex: Some orchids, for example, produce flowers resembling female bees in color, shape, and scent to attract male bees by desception

Angiosperm life cycle

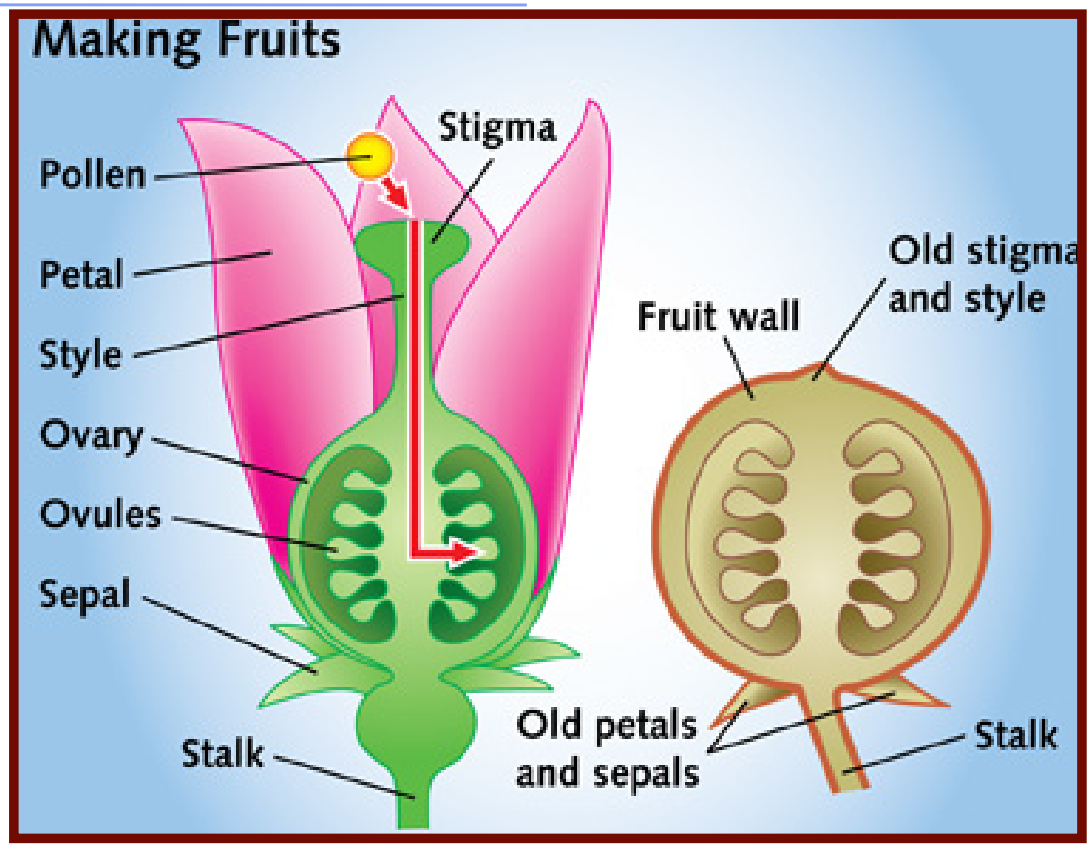


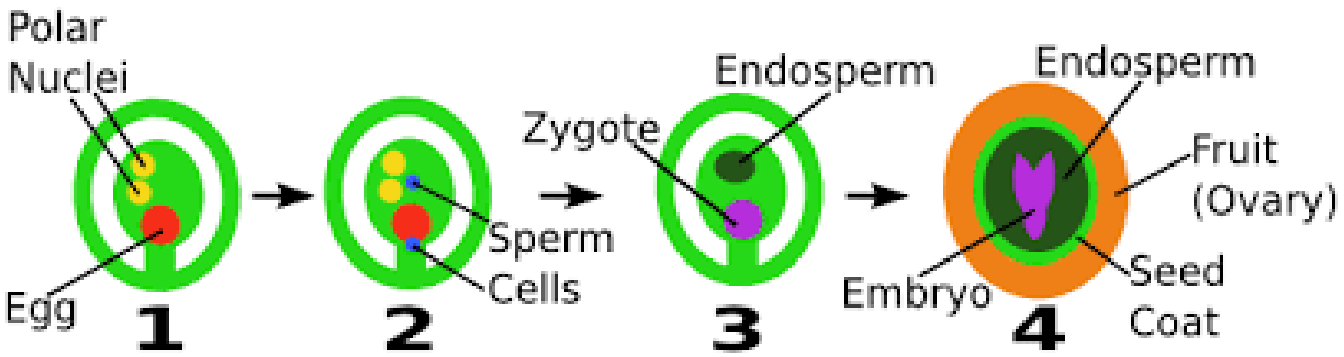
- Stamen have structures called Anthers
  - These contain microsporangia which produce by meiosis microspores which are packaged into into pollen grains
    - These "micro" spores (n) divide by mitosis to form male gametophytes (n) inside pollen grains
  - Male gametophyte has forms haploid cells by mitosis:
    - Generative cells (n) divide to form two sperm by mitosis
    - Tube cell (n) produces pollen tube by mitosis



Angiosperm life cycle

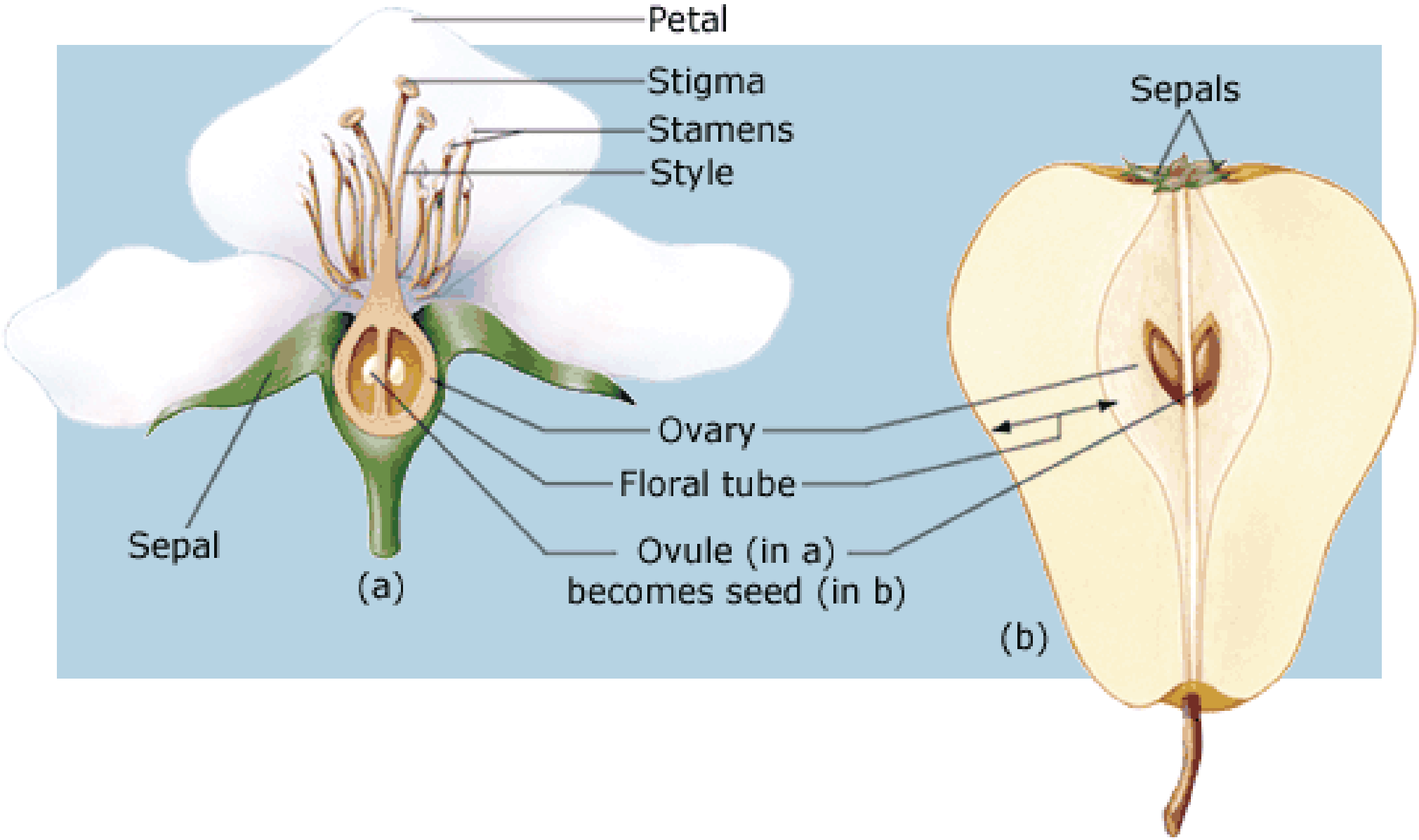
- One or more ovules develop inside an ovary
  - Megaspore made by meiosis inside ovule develops into a female gametophyte called an embryo sac
- This gametophyte (n) will make the eggs (n) by mitosis.
- Egg gets fertilized into a zygote, which forms the sporophyte embryo (2n)
- Ovules will become the sporophyte embryo-containing seeds
- Ovary becomes the surrounding fruit





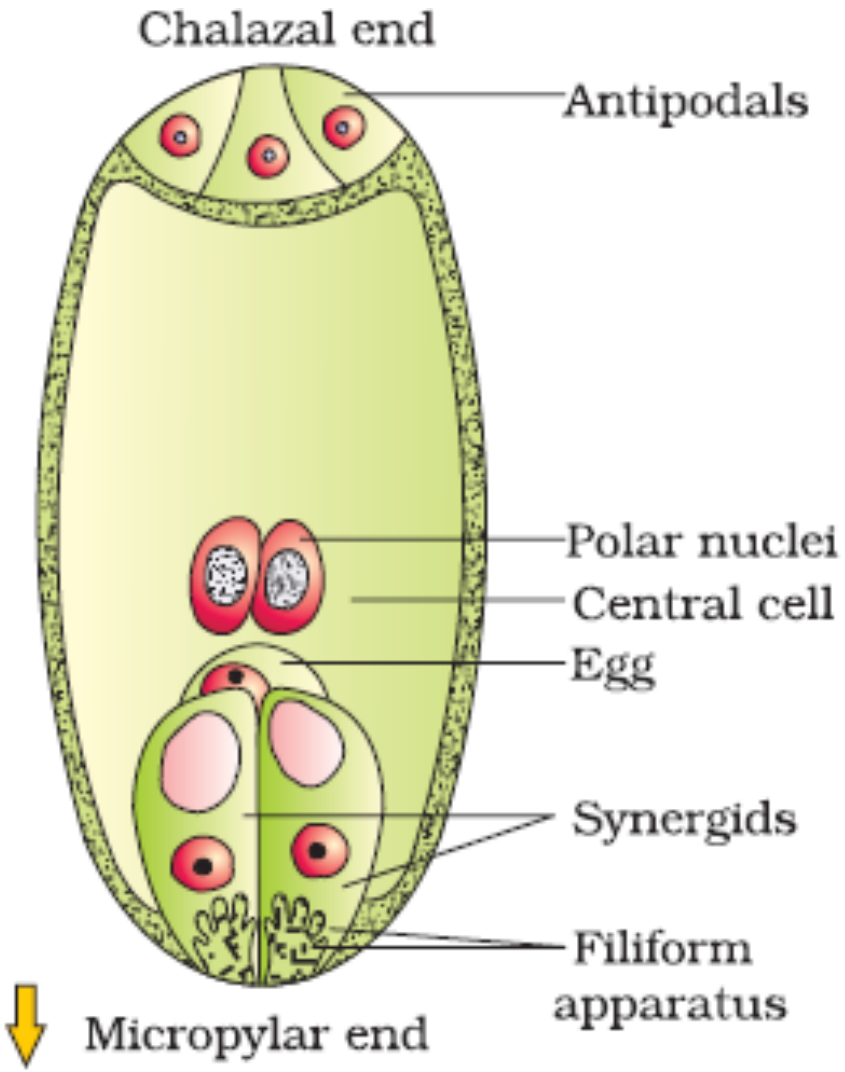
Angiosperm life cycle

- **Relationship between the flower and the fruit**



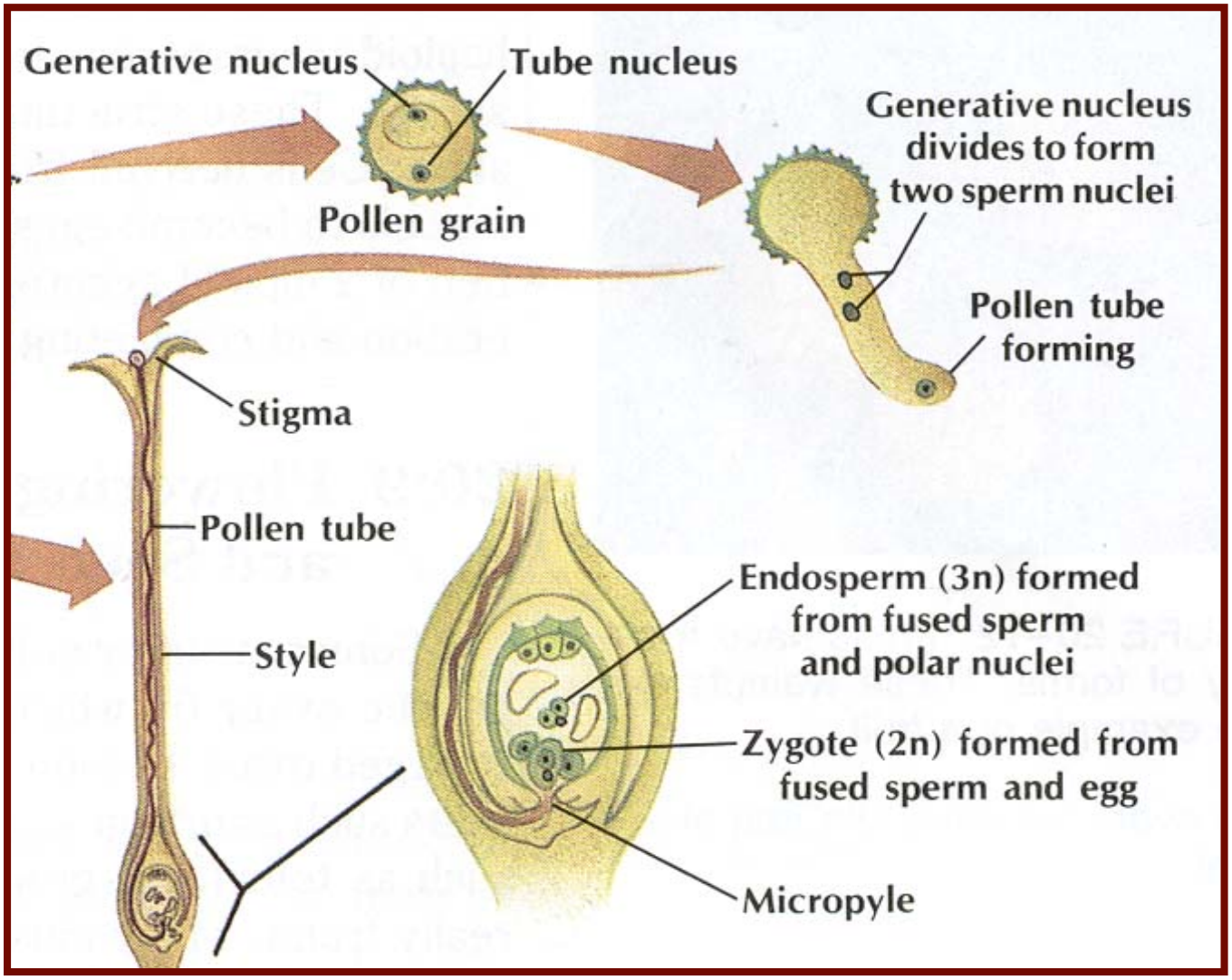
Angiosperm life cycle

- **In the ovule:** the haploid megaspore made by meiosis in the megasporangia of the sporophyte divides by mitosis to form a female gametophyte made up of cells including a haploid egg and a cell called the central cell with two haploid polar nuclei
  - The central cell forms when a haploid female gametophyte cell completes mitosis but doesn't complete cytokinesis leaving two nuclei inside one cell



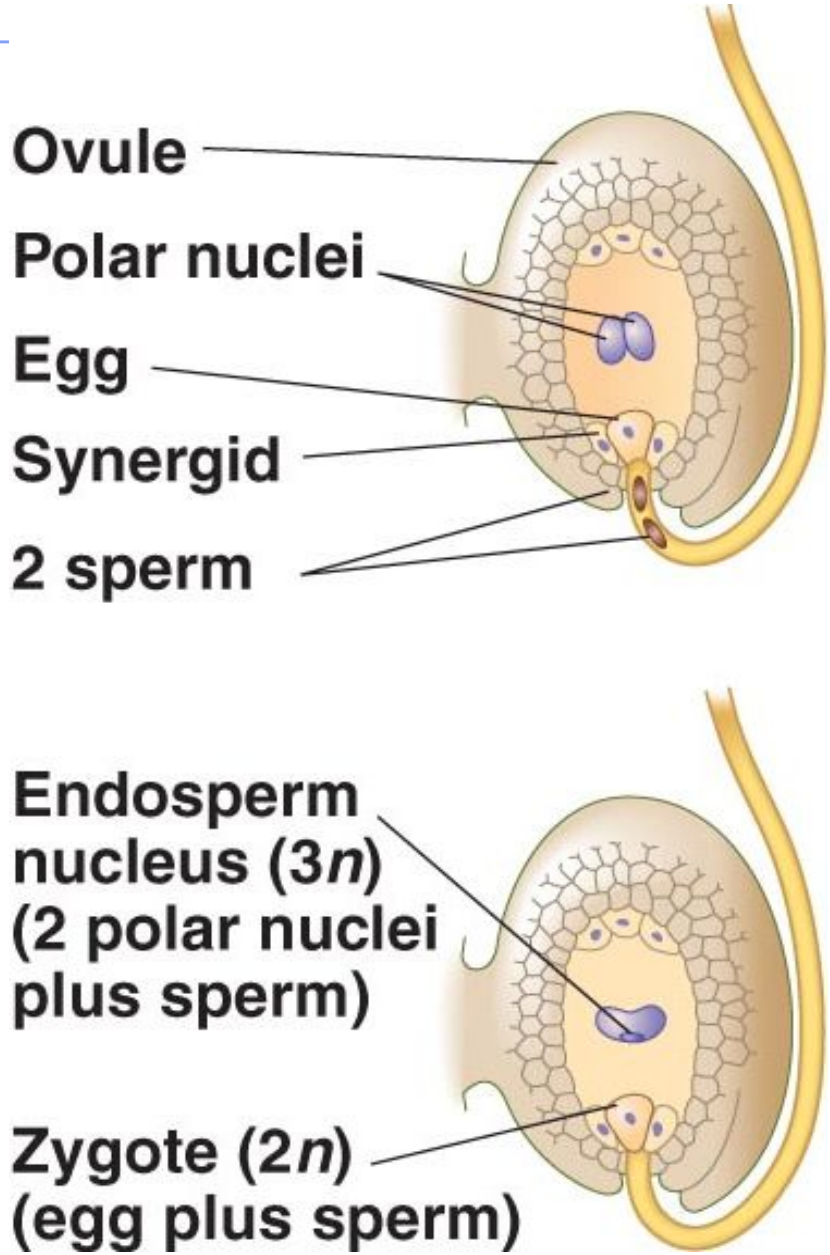
Angiosperm life cycle

- **Pollen travels to sticky stigma at the tip of a carpel**
  - **Male gametophyte grows pollen tube down style of carpel**
  - **Pollen tubes reach ovary & penetrates the micropyle**
    - *a pore in the integuments of the ovule*
  - **Two sperm cells are released into the female gametophyte (aka EMBRYO SAC)**



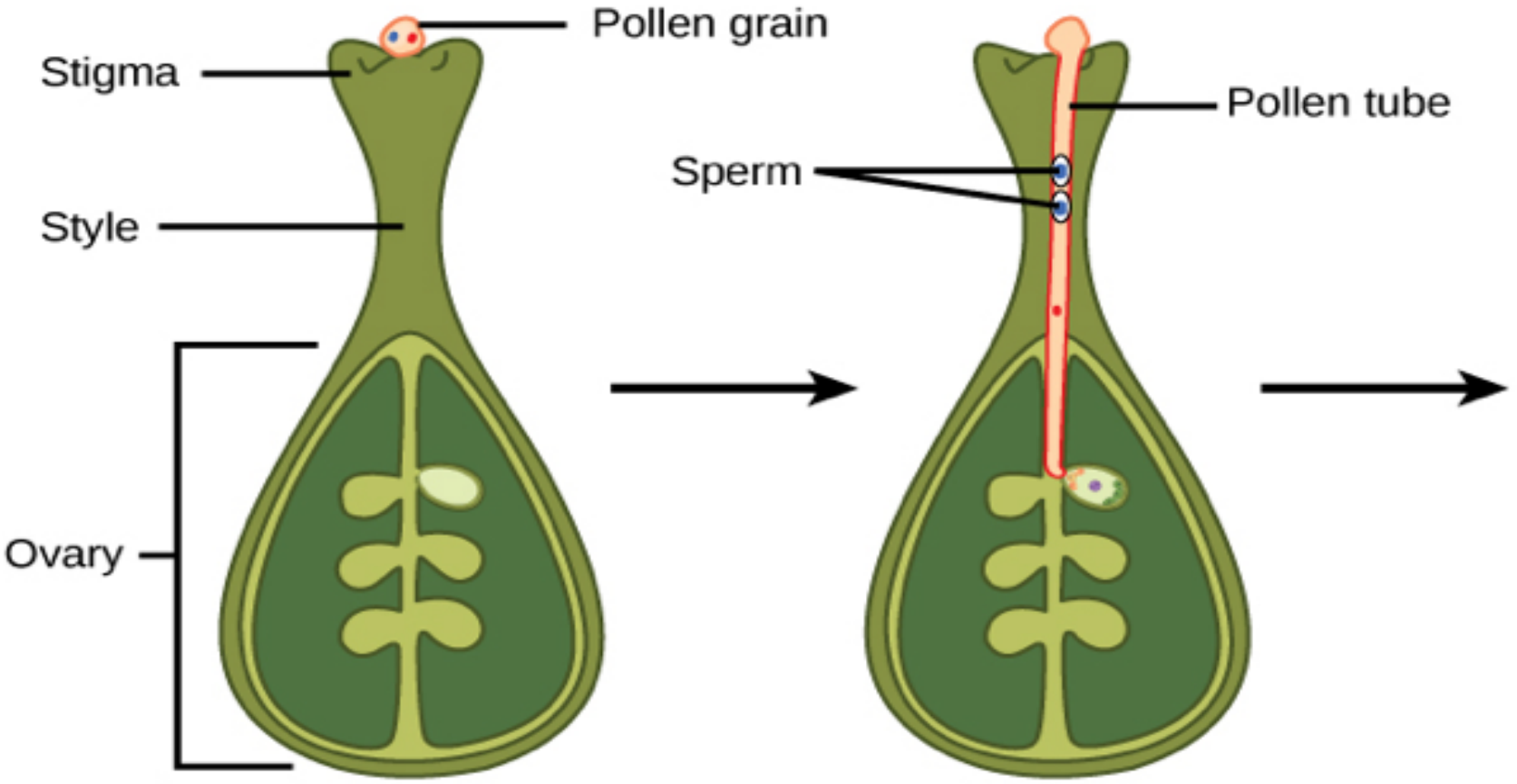
Angiosperm life cycle

- Involves DOUBLE FERTILIZATION
  - UNIQUE TO ANGIOSPERMS!!!
    - One sperm fertilizes the egg made by female gametophyte producing a diploid ZYGOTE which undergoes mitosis to form a sporophyte embryo
    - Second sperm fuses with the two nuclei in the large central cell of the female gametophyte, producing a triploid cell
      - Triploid cells divides by mitosis repeatedly to produce ENDOSPERM
        - Tissue rich in starch and other food reserves that nourishes the developing embryo



Double Fertilization

Two cells of the female gametophyte get fertilized by two sperm cells.

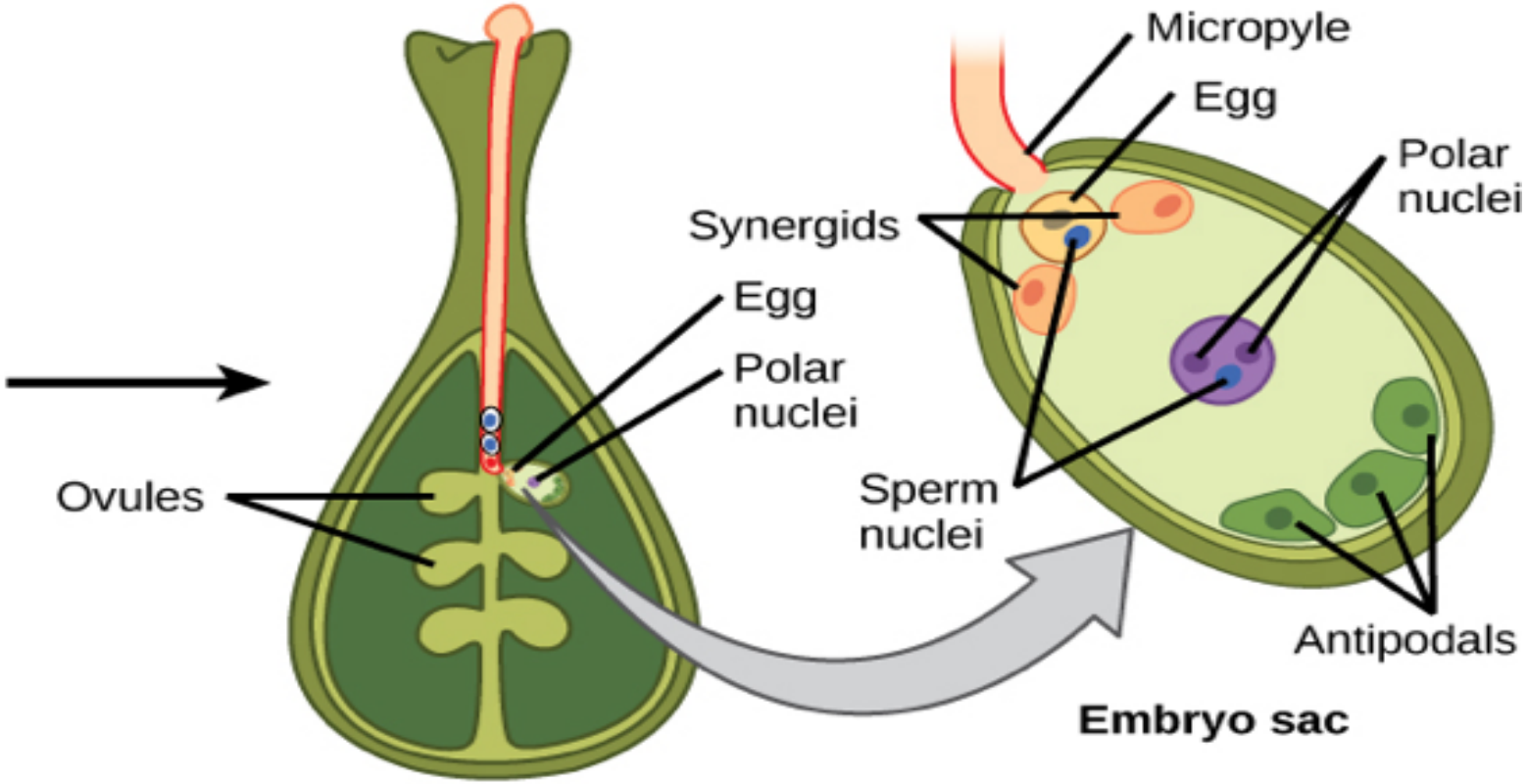


The pollen grain adheres to the stigma, which contains two cells: a generative cell and a tube cell.

The pollen tube cell grows into the style. The generative cell travels inside the pollen tube. It divides to form two sperm.

Double Fertilization

Two cells of the female gametophyte get fertilized by two sperm cells.



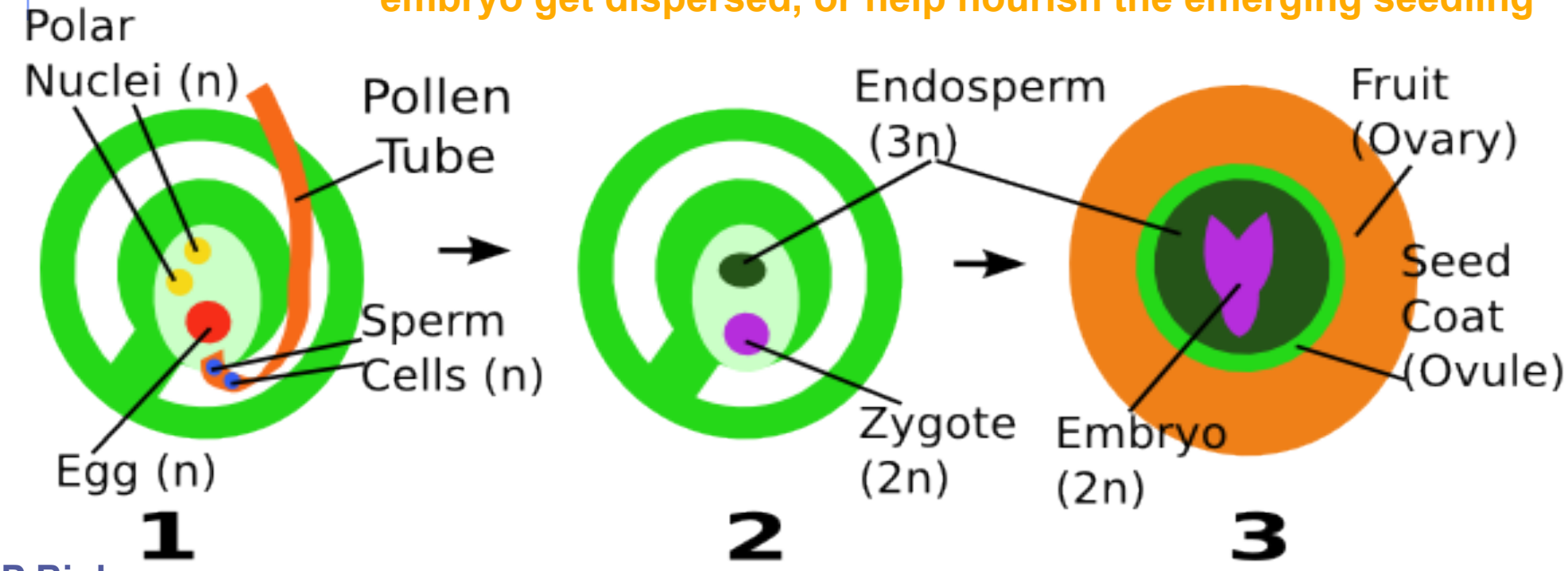
The pollen tube penetrates an opening in the ovule called a micropyle.

One of the sperm fertilizes the egg to form the diploid zygote. The other sperm fertilizes two polar nuclei to form the triploid endosperm, which will become a food source for the growing embryo.

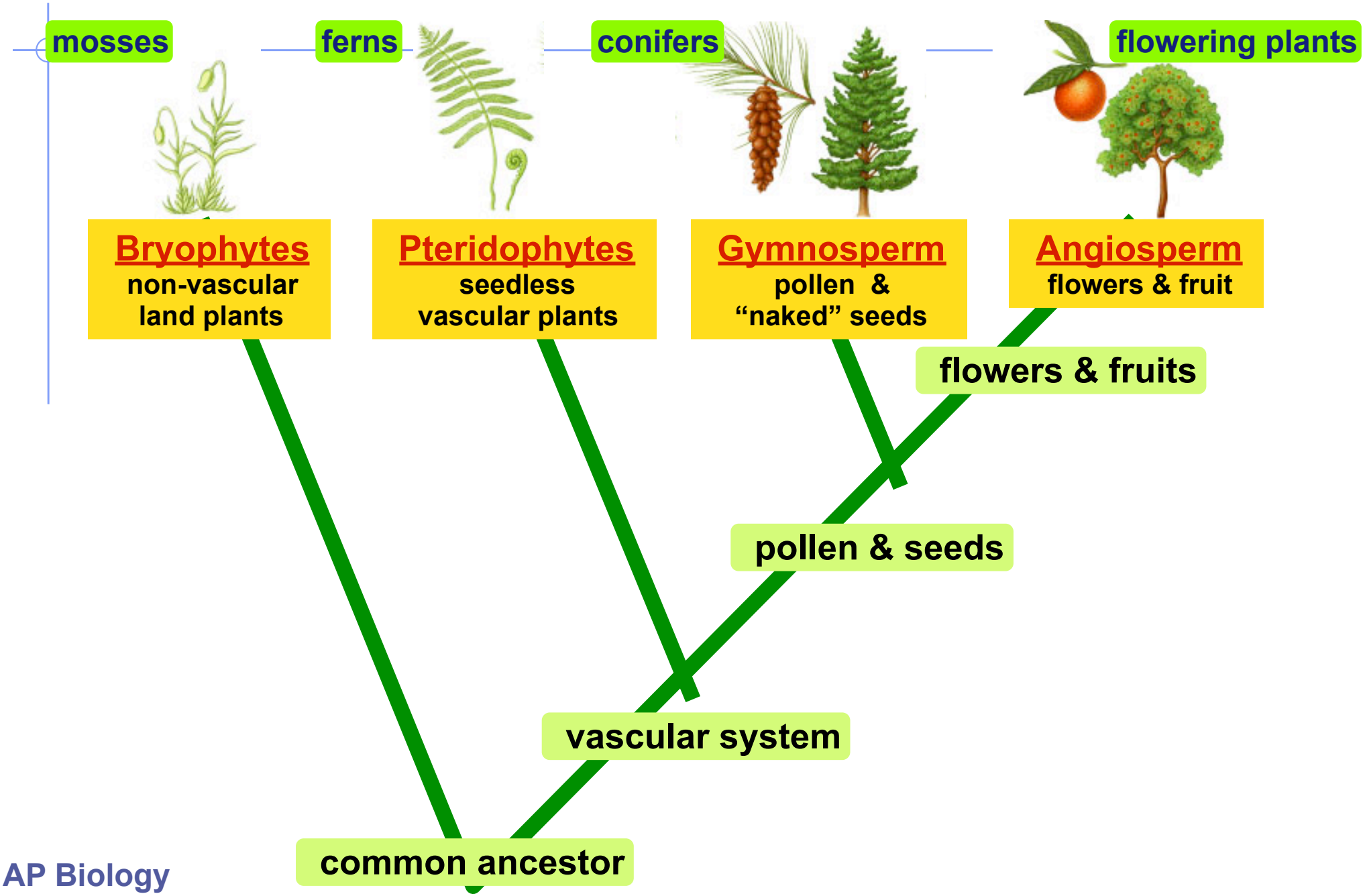
Double Fertilization

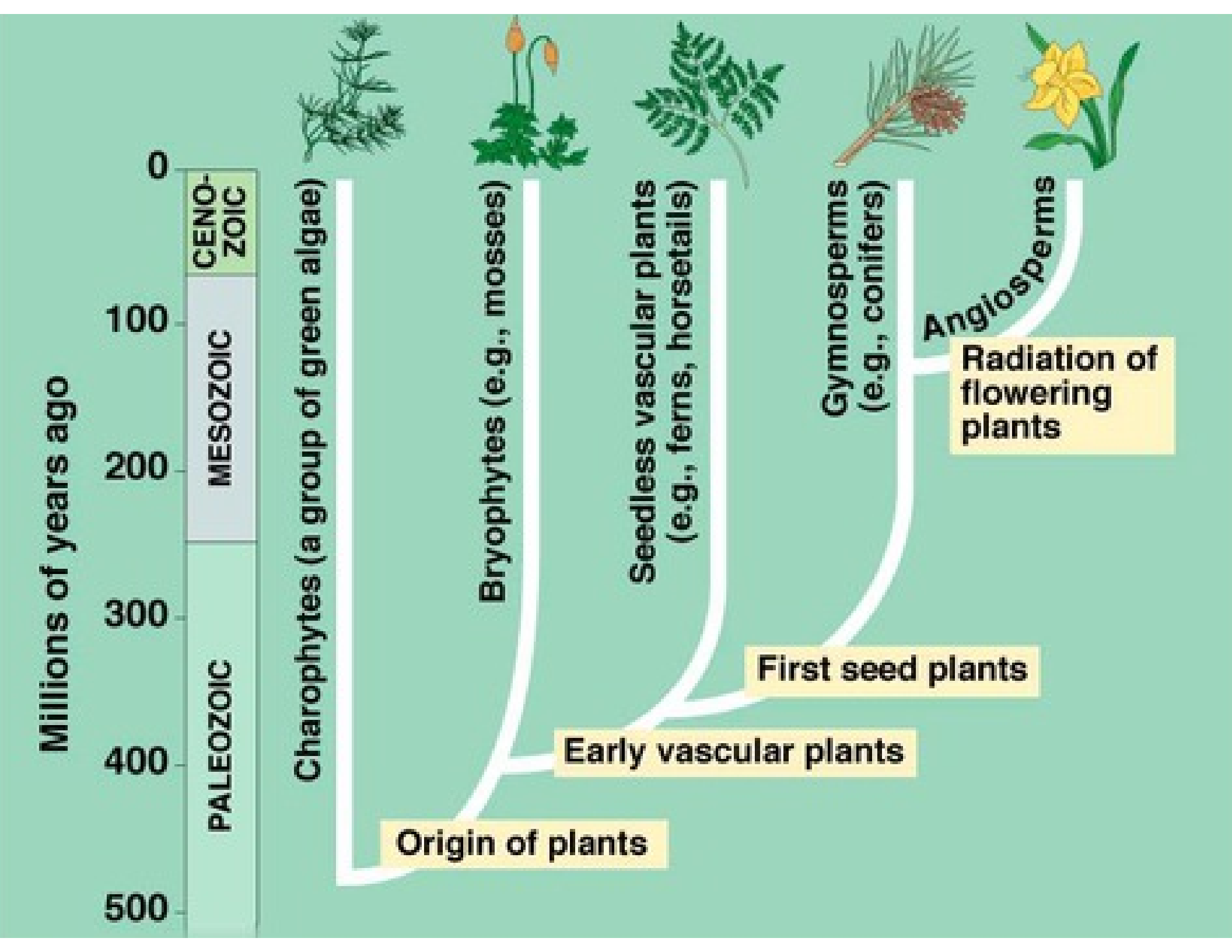
Two cells of the female gametophyte get fertilized by two sperm cells.

- **DOUBLE FERTILIZATION = Synchronizes the development of food storage in the seed with the development of the embryo**
  - **The endosperm forms right as the zygote forms**
    - **The endosperm is a source of nutrients for the growing embryo**
      - **The ovary develops into part of the fruit.**
        - **Fruits help protect the embryo from herbivores, helps the embryo get dispersed, or help nourish the emerging seedling**

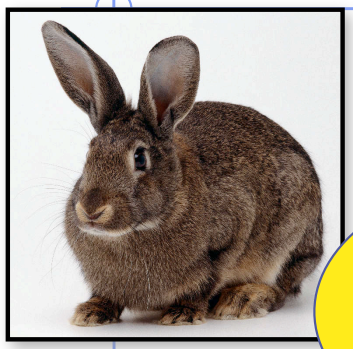


To Recap - Plant Evolution




Millions of years ago
0
100
200
300
400
500
CENO-ZOIC
MESOZOIC
PALEOZOIC
Charophytes (a group of green algae)
Bryophytes (e.g., mosses)
Seedless vascular plants (e.g., ferns, horsetails)
Gymnosperms (e.g., conifers)
Angiosperms
Origin of plants
Early vascular plants
First seed plants
Radiation of flowering plants

Animal vs. Plant life cycle

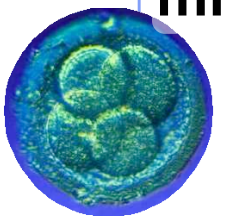


Animal

diploid multicellular organism 2n

mitosis

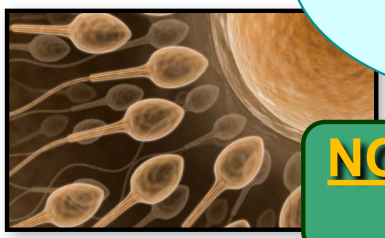
meiosis



zygote 2n

fertilization

haploid unicellular gametes 1n



NO multicellular haploid

mitosis

zygote 2n

fertilization

gametes 1n

mitosis

haploid multicellular gametophyte 1n

Plant

diploid multicellular sporophyte 2n

meiosis

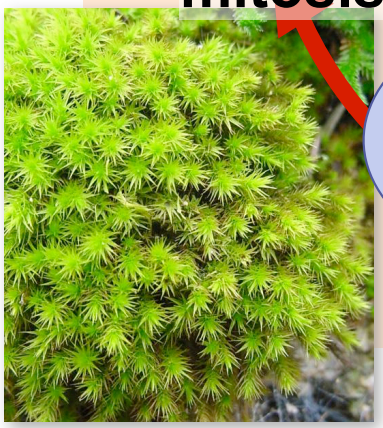
spores 1n

mitosis

alternation of generations

Bryophytes

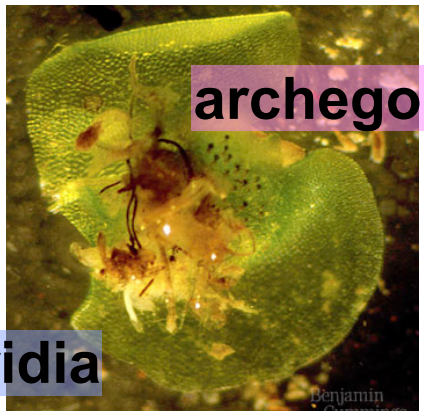
- **Mosses & liverworts**
  - non-vascular
  - swimming sperm
  - dominant haploid gametophyte
  - dependent sporophyte
  - spores for reproduction



alternation of generations

Pteridophytes

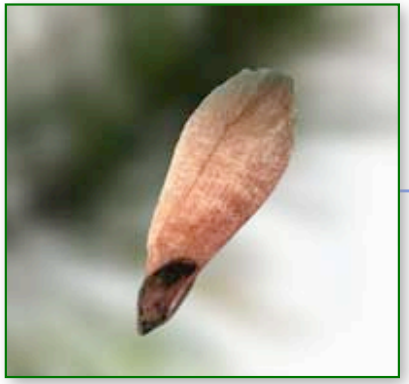
- **Ferns**
  - vascular
  - swimming sperm
  - dominant sporophyte
  - independent gametophyte
    - fragile
  - spores for reproduction

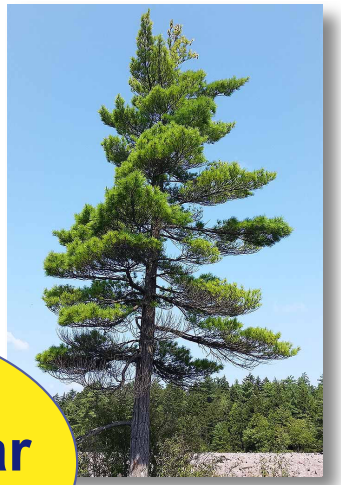


alternation of generations

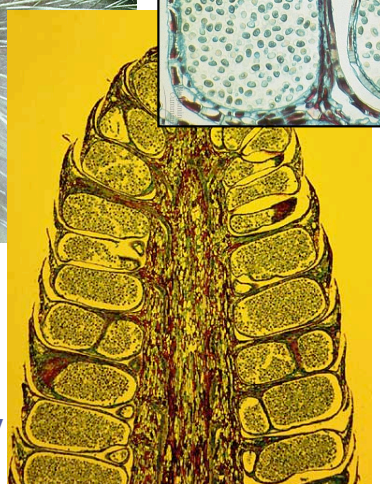
Gymnosperm

- **Conifers**
  - vascular
  - pollen (non-flagellated sperm carried often by wind)
  - dominant sporophyte
  - dependent reduced gametophyte
  - cones, seeds for reproduction

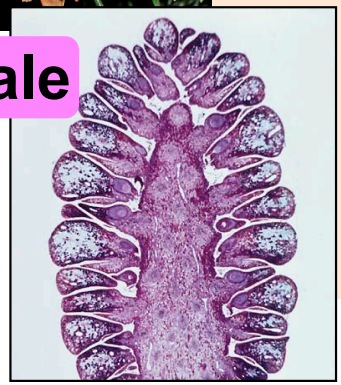


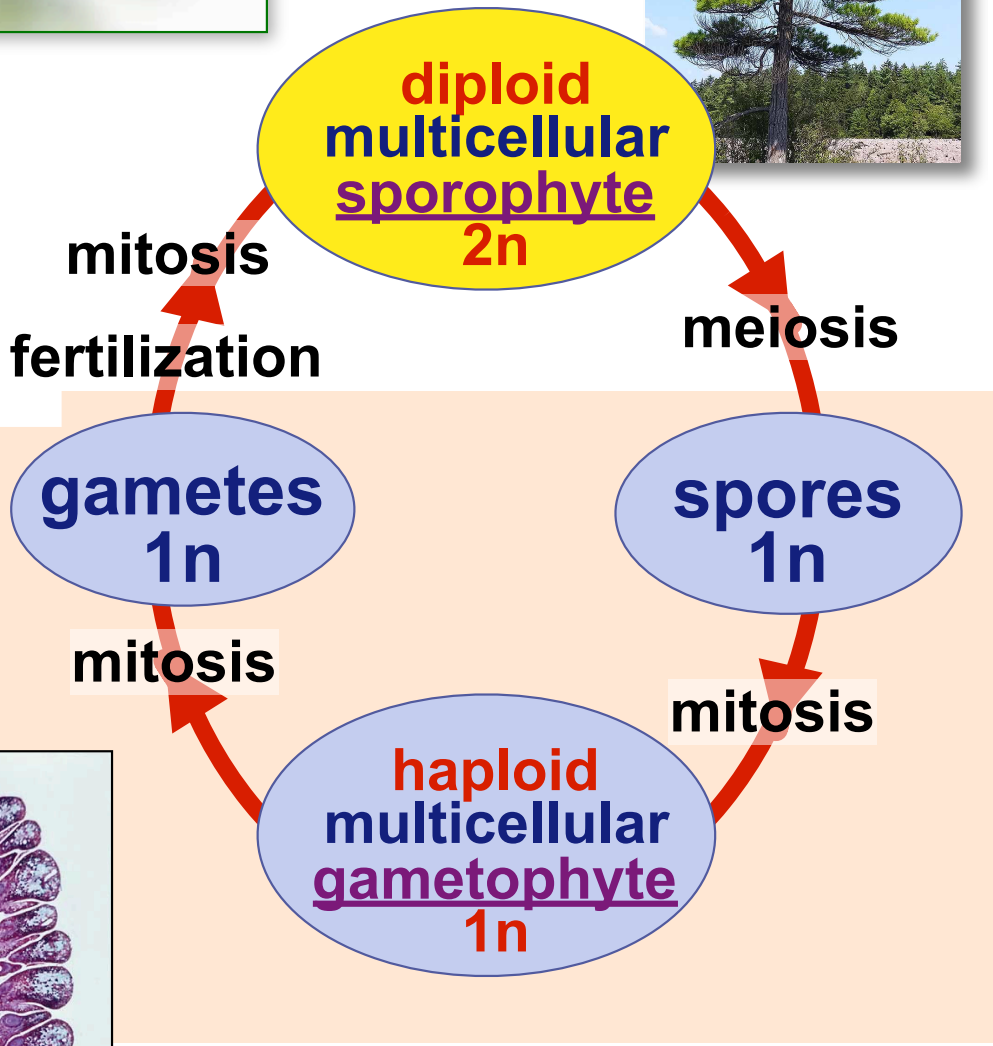


male

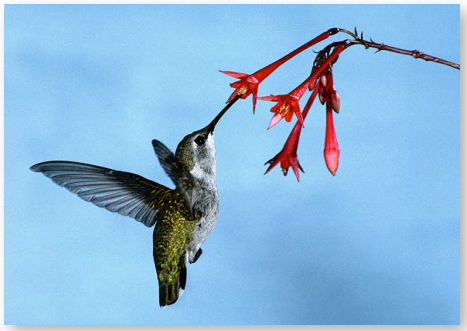


female

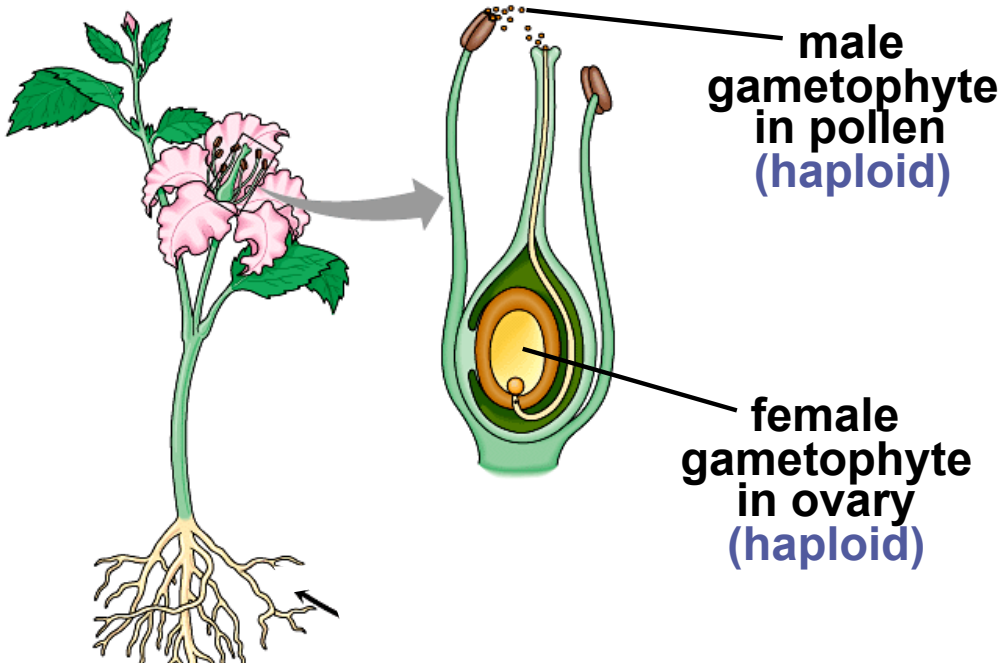


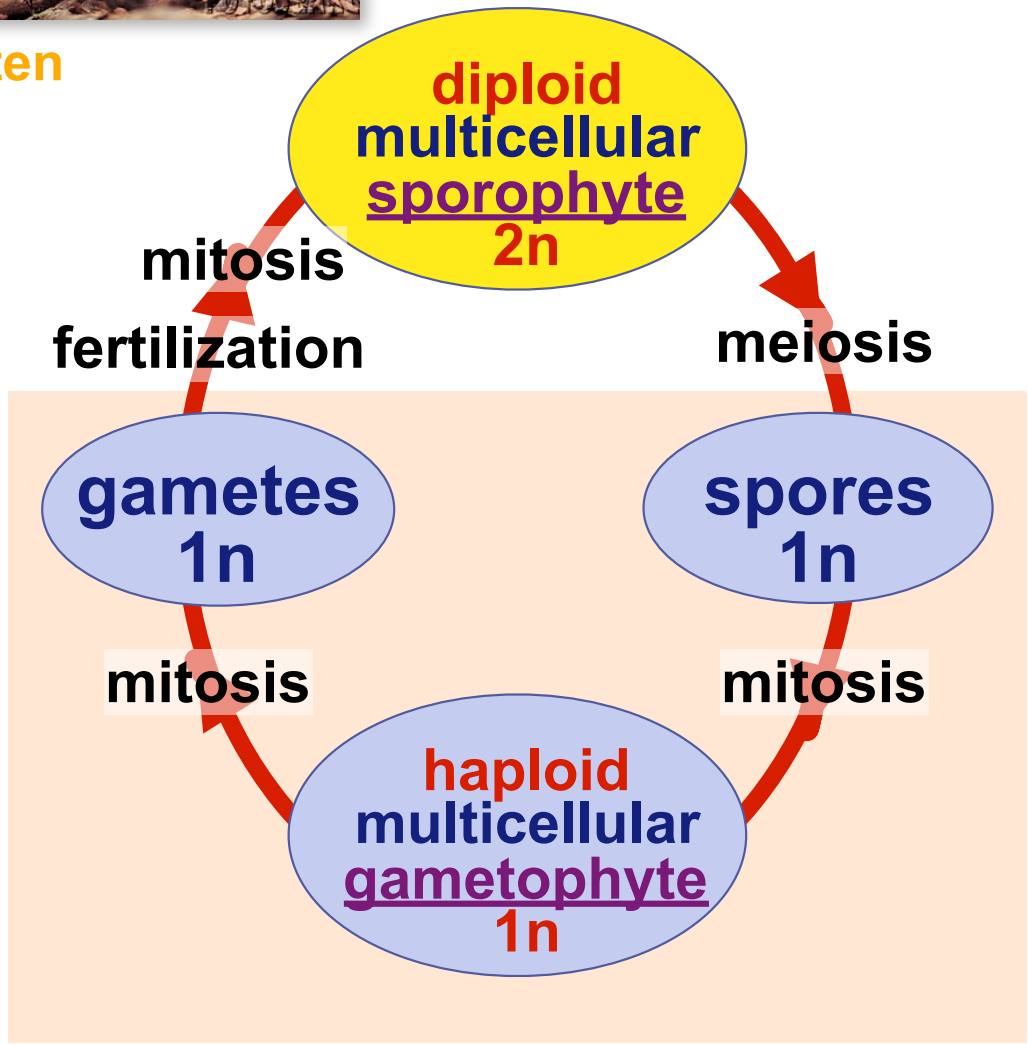


Angiosperm

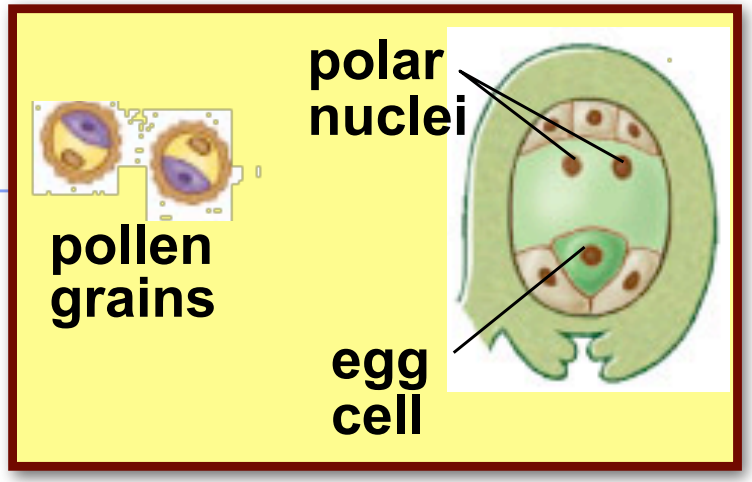


- **Flowering plants**
  - vascular
  - pollen (non-flagellated sperm) often carried by pollinators
  - dominant sporophyte
  - dependent reduced gametophyte
  - flowers, fruits, seeds for reproduction
  - pollinators spread pollen grains





Angiosperm life cycle



male gametophyte in pollen (haploid)

fertilization

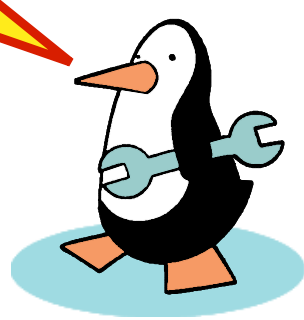
female gametophyte in ovule (haploid)

Sporophyte embryo in seed (diploid)

Ovule develops into seed.
Ovary helps make up the fruit.

Double Fertilization

What's the adaptive advantage?



pollen grain

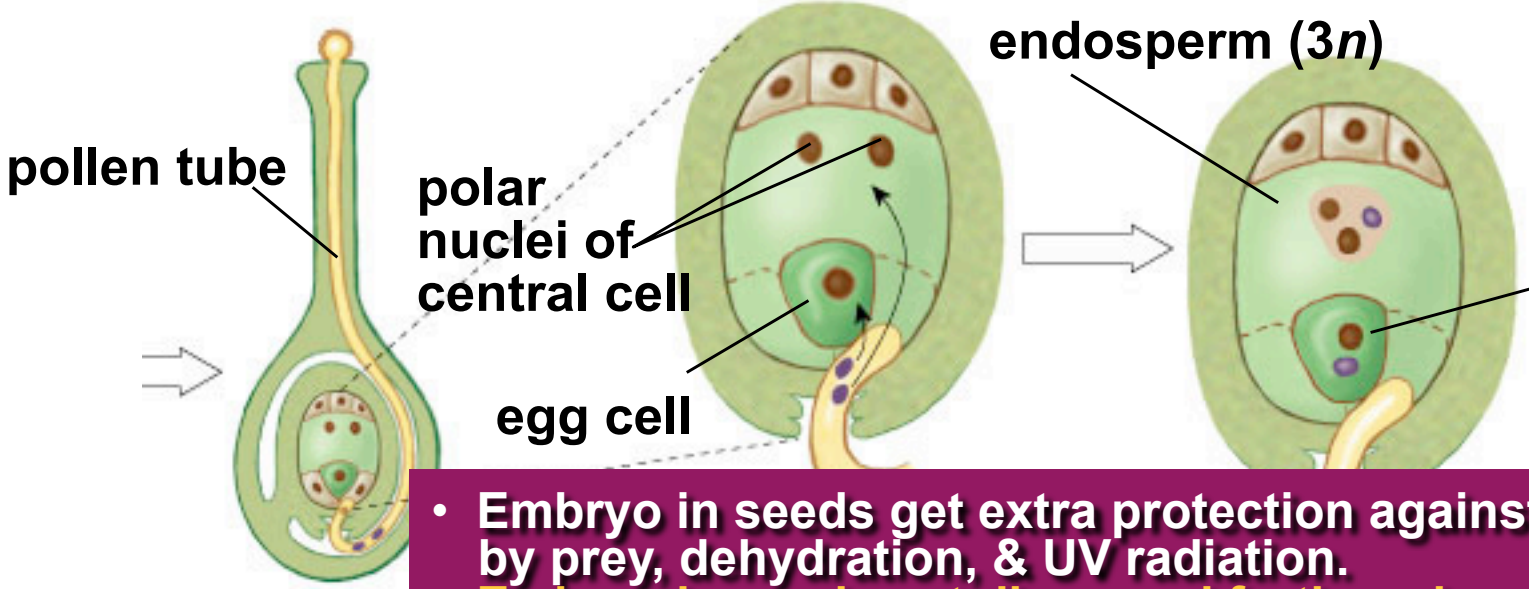
pollination

sperm cells

pollen tube

ovule

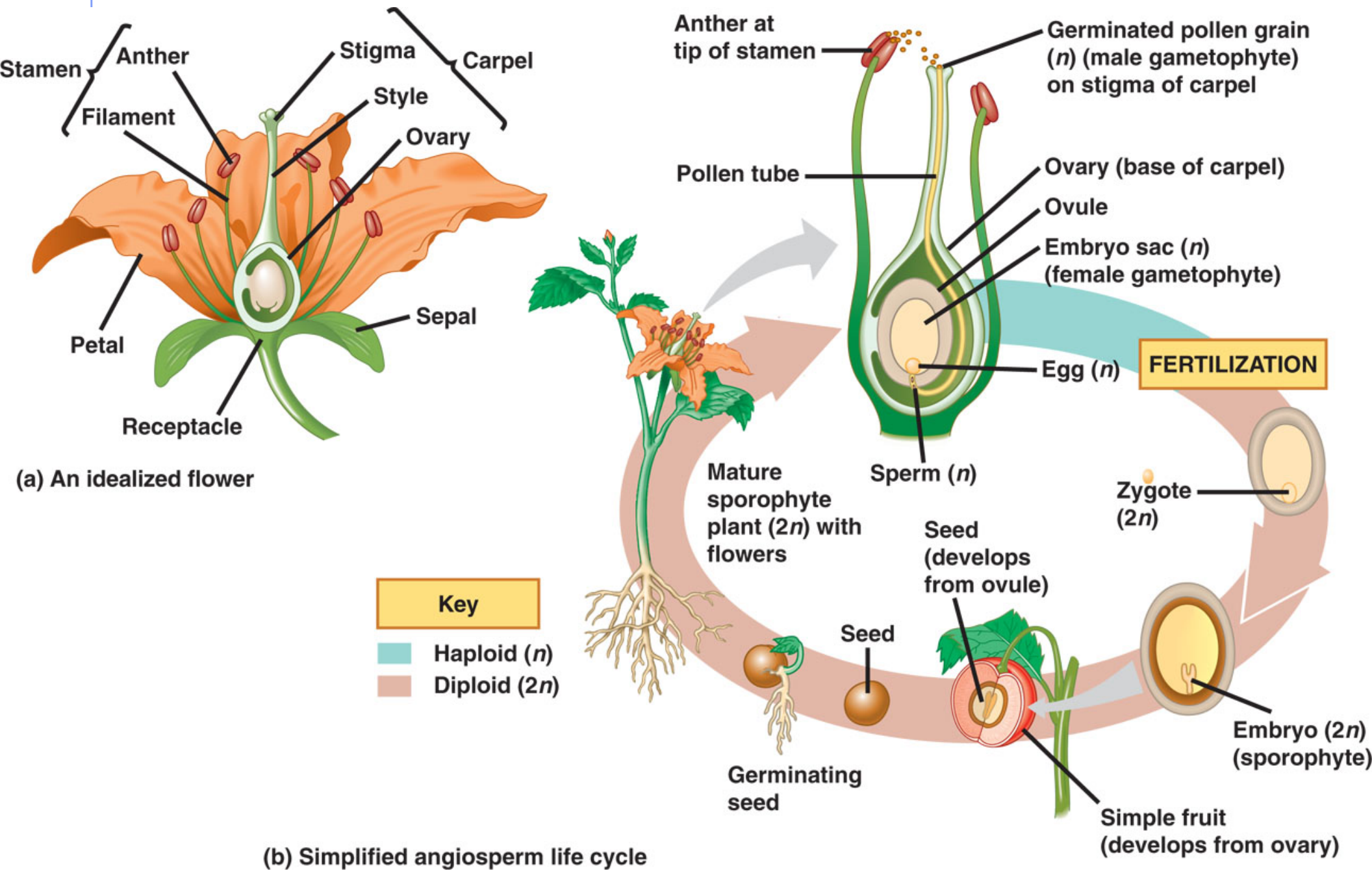
ovary

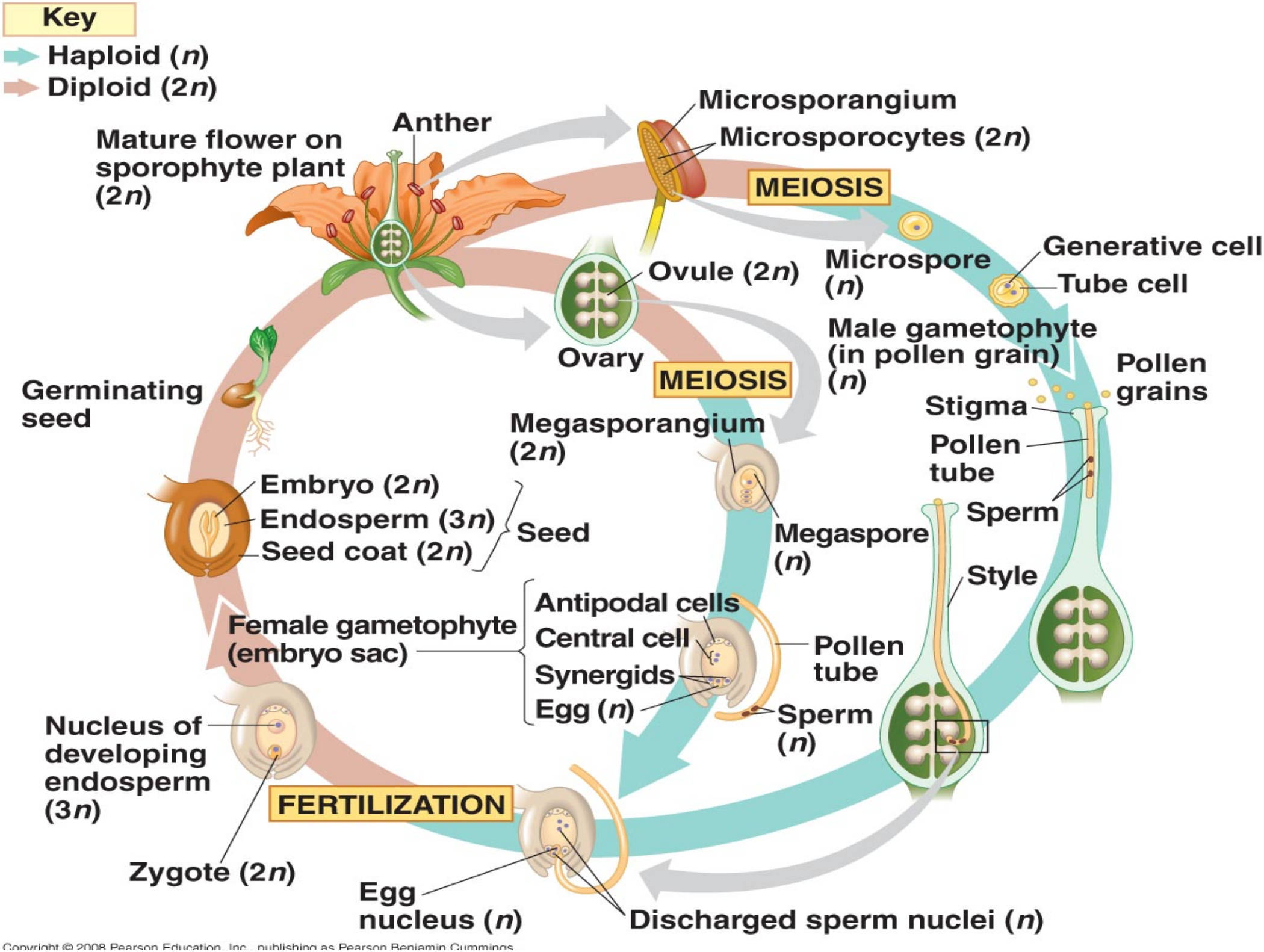


Endosperm (3n)
- **triploid**
  - food in seed for embryo
    - grains
    - beans
    - coconut milk

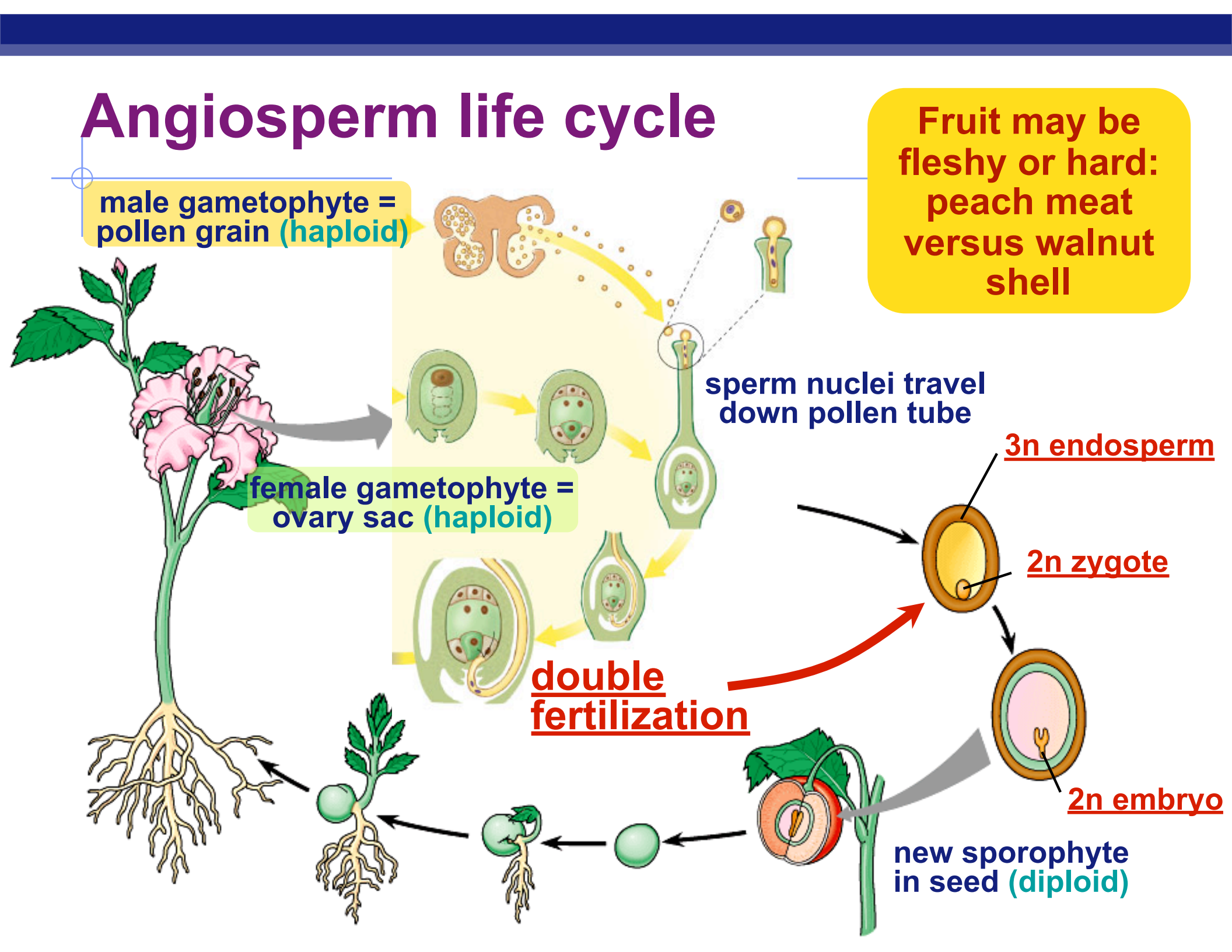
- Embryo in seeds get extra protection against destruction by prey, dehydration, & UV radiation.
- Embryo in seeds get dispersed further - less competition w. parent.
- Embryo in seed has built in food source so that germination occurs only in optimal conditions.

A different depiction…



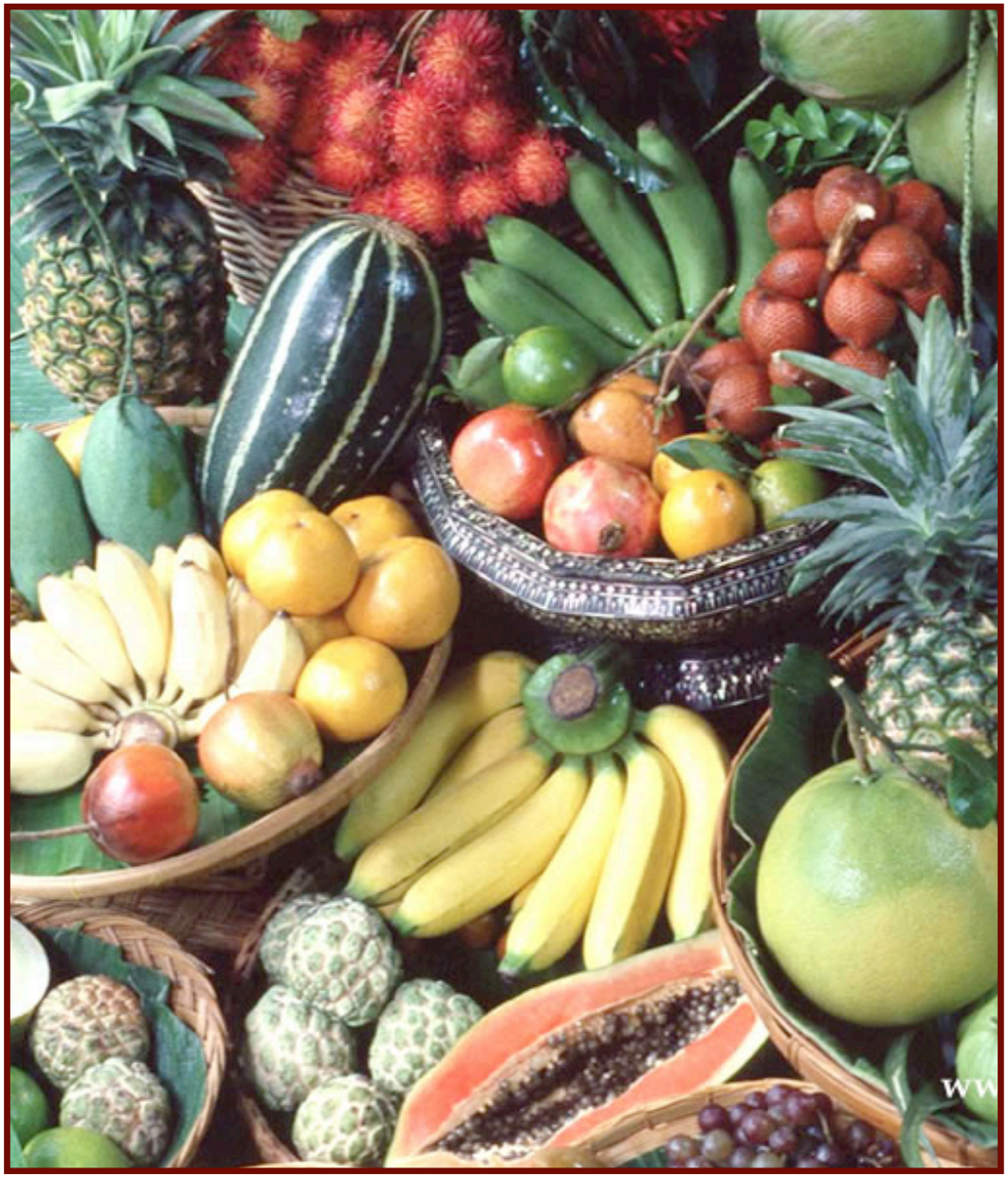


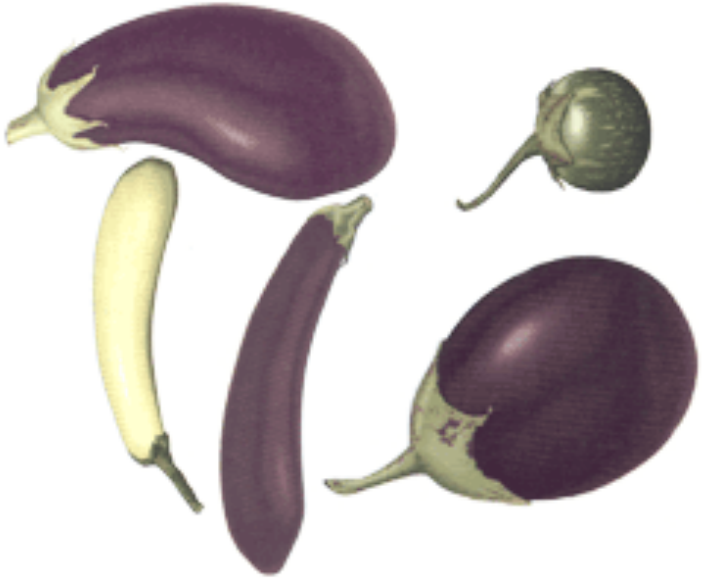
Angiosperm life cycle



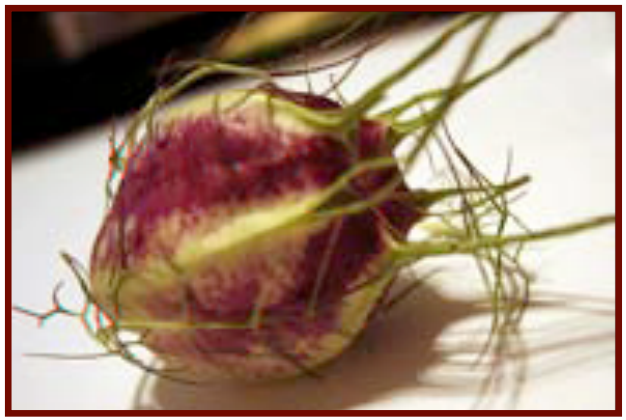
Fruit may be fleshy or hard: peach meat versus walnut shell

Angiosperm: fruiting plants





Fruits are formed when an ovary undergoes changes, becoming either dry and hardened or enlarged and fleshy.

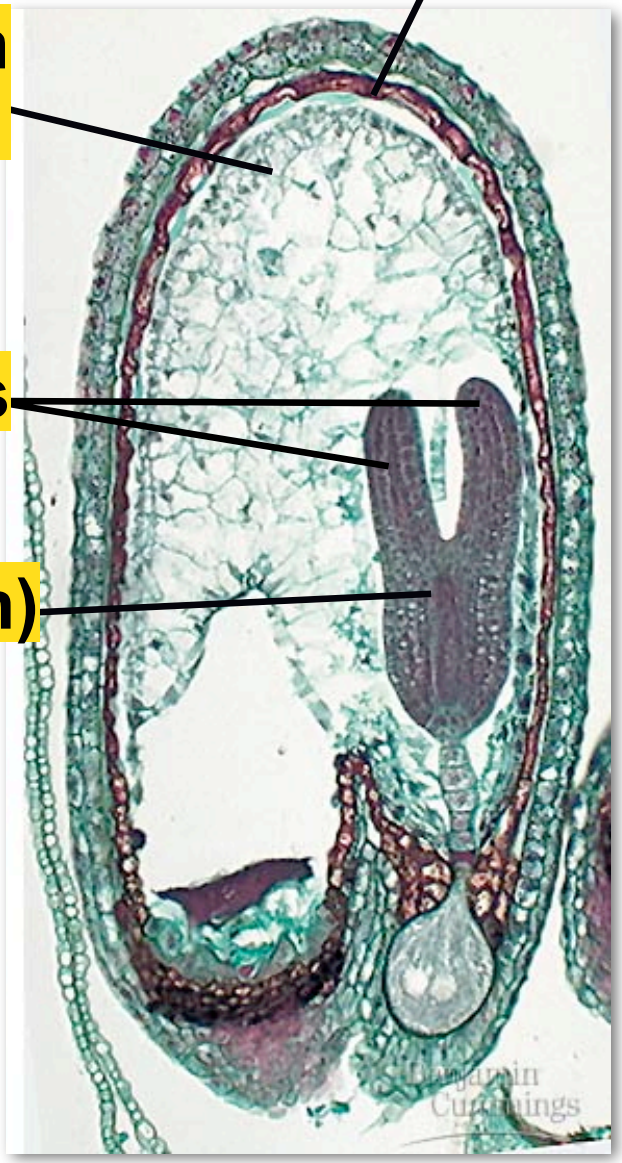


Seed dispersal

- Plants produce **enormous numbers** of seeds to compensate for low survival rate of seedling after germination, though some seeds provide more "parental" care & food to embryo than others.
  - This provides a vast amount of genetic variation for natural selection to screen.

Seed & Plant embryo

- **Seed offers…**
  - protection for embryo from herbivores, omnivores, UV, dehydration, even fire in some cases.
  - stored nutrients for growth of embryo

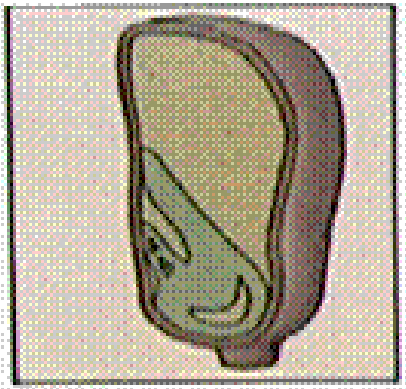
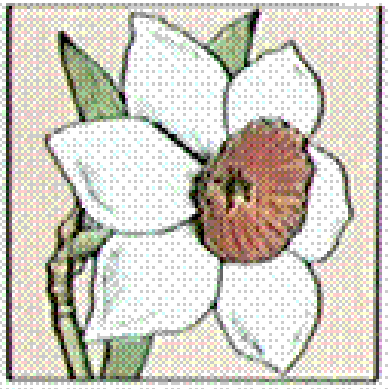
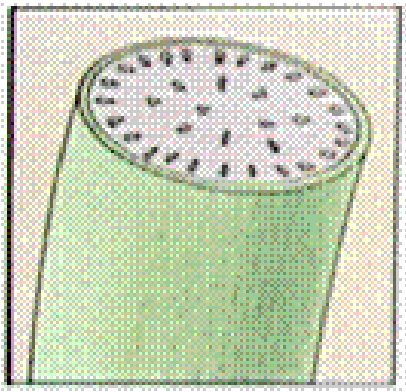


cotyledons = “seed” leaves, first leaves of new plant

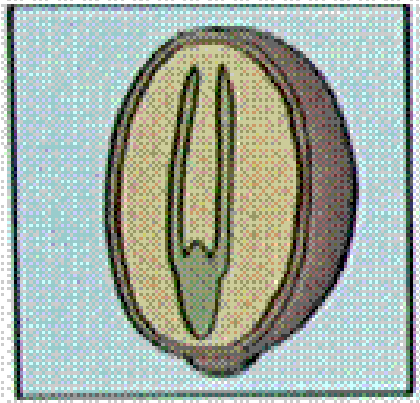
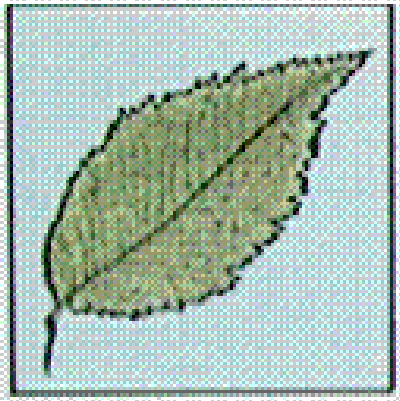
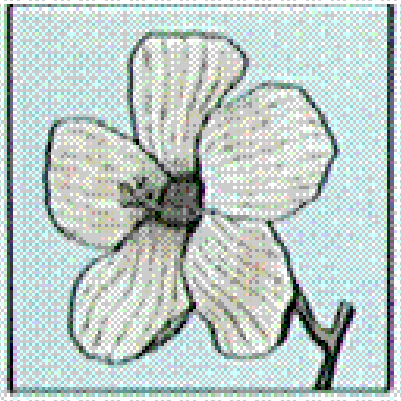
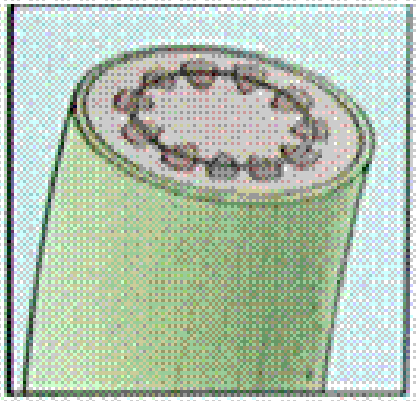
Angiosperm life cycle

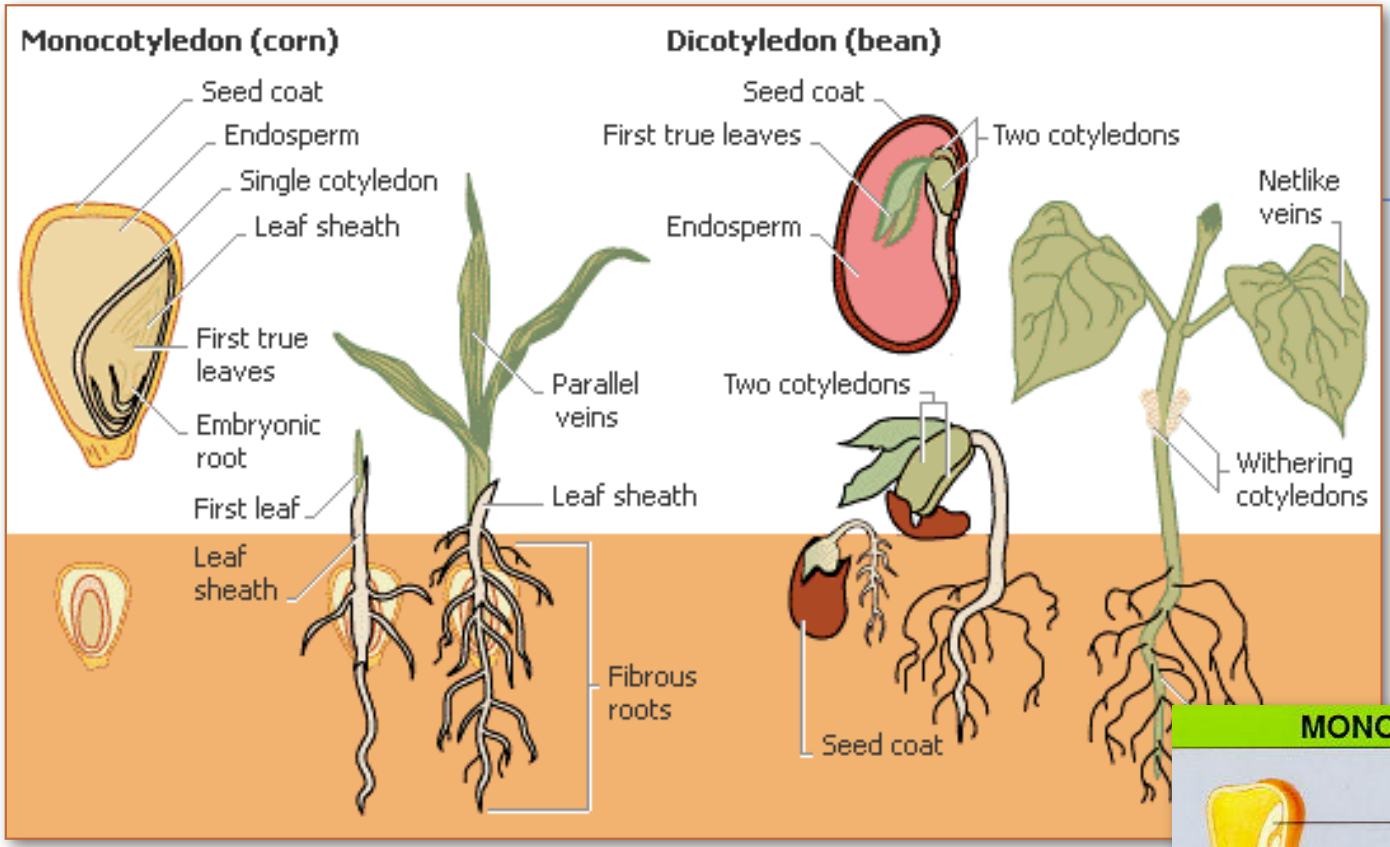
- SEEDS form….
  - Seed = embryo, endosperm, and a seed coat derived from the integuments
    - Inside the embryo has a rudimentary root and one or two seed leaves called cotyledons
    - 1 cotyledon = MONOCOT
      - Leaf veins usually parallel
      - Vascular tissue scattered
      - Root system fibrous with no main root
      - Pollen grain with one opening
      - Floral organs in multiple of three
    - 2 cotyledons = DICOT OR EUDICOT
      - Leaf veins net-like
      - Vascular tissue arranged in rings
      - Taproot is the main root
      - Pollen grain with three openings
      - Floral opening in multiple of four or five

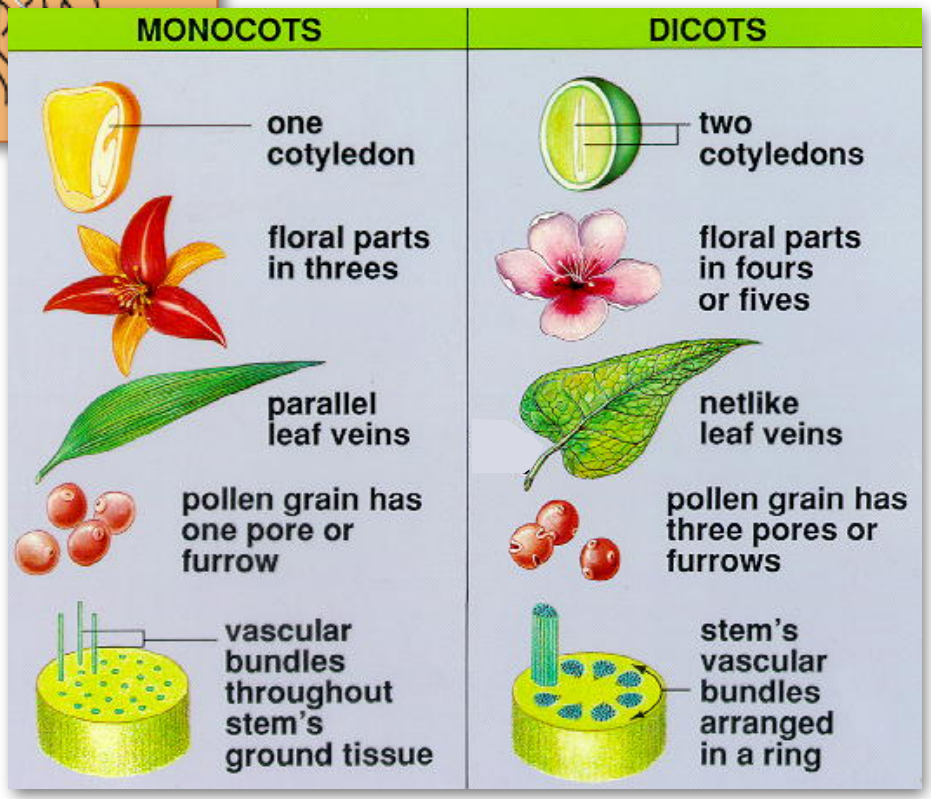
MONOCOTS

Cotyledons	Veins in leaves	Flower parts	Arrangement of primary vascular bundles in stem
			
One cotyledon	Usually Parallel	Usually in multiples of three	Scattered

DICOTS

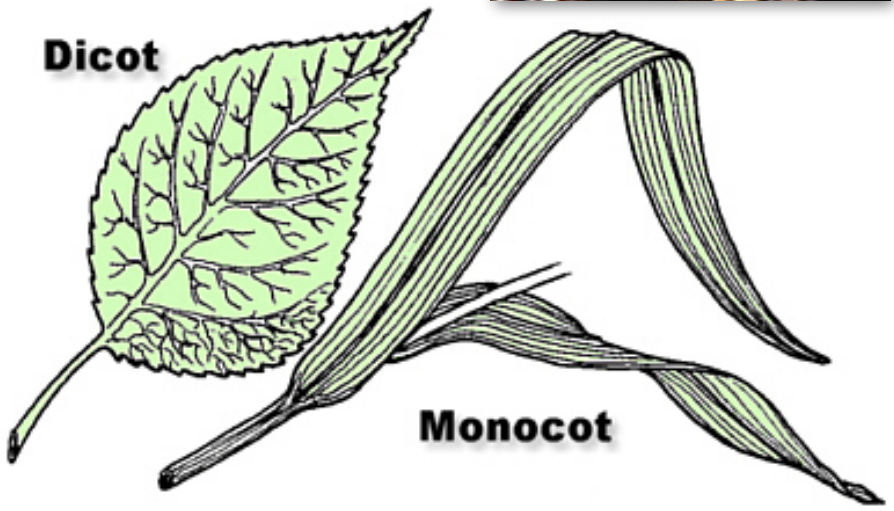
Two cotyledons	Usually netlike	Usually in fours or fives	In a ring
			


Monocotyledon (corn)
Seed coat
Endosperm
Single cotyledon
Leaf sheath
First true leaves
Embryonic root
First leaf
Leaf sheath
Parallel veins
Leaf sheath
Fibrous roots
Dicotyledon (bean)
Seed coat
First true leaves
Two cotyledons
Endosperm
Netlike veins
Two cotyledons
Withering cotyledons
Seed coat

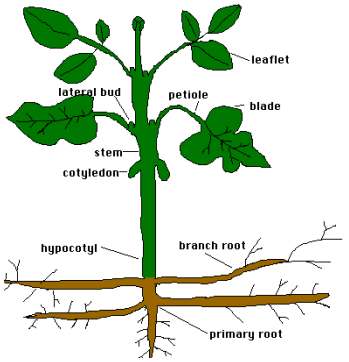

MONOCOTS
DICOTS
one cotyledon
two cotyledons
floral parts in threes
floral parts in fours or fives
parallel leaf veins
netlike leaf veins
pollen grain has one pore or furrow
pollen grain has three pores or furrows
vascular bundles throughout stem's ground tissue
stem's vascular bundles arranged in a ring

Monocots & Dicots (Eudicots)

- Angiosperm are divide into 2 classes
  - dicots (eudicot)
    - 2 cotyledons (seed leaves)
    - leaves with network of veins
    - woody plants, trees, shrubs, beans
  - monocots
    - 1 cotyledon
    - leaves with parallel veins
    - grasses, palms, lilies



Four key traits found in land plants and NOT in charophyte algae ancestor

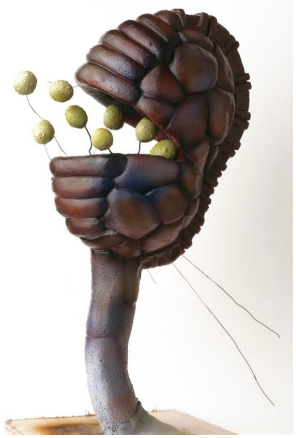


1. Alternation of Generation and multicellular embryos

- Part of the plant life cycle allows embryos to develop from zygotes inside the female tissue of the gametophyte.
  - Parental tissue provides embryo with nutrients to better ensure survival
    - Because of this, all land plants are known as embryophytes

2. Walled Spores produced in Sporangia

- Sporophyte 2n has organs called sporangia that produce spores through meiosis
  - Sporopollenin polymer makes walls of plant spores tough and resistant to harsh environments higher in UV and dryness
    - Spores can be dispersed in dry air without harm
      - Algae have spores that lack sporopollenin and are flagellated, needing water to move



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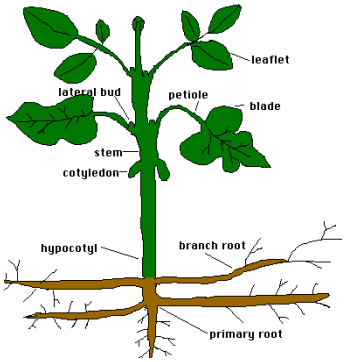

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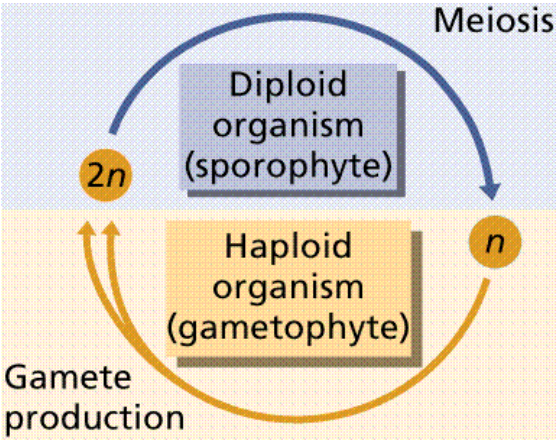

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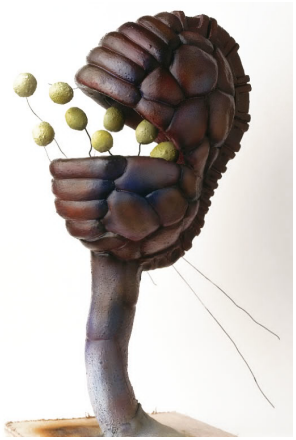

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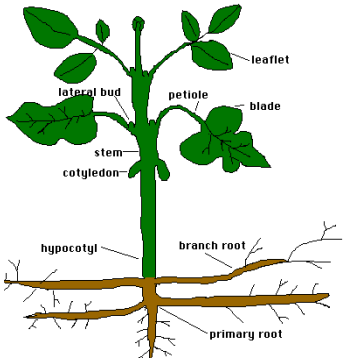

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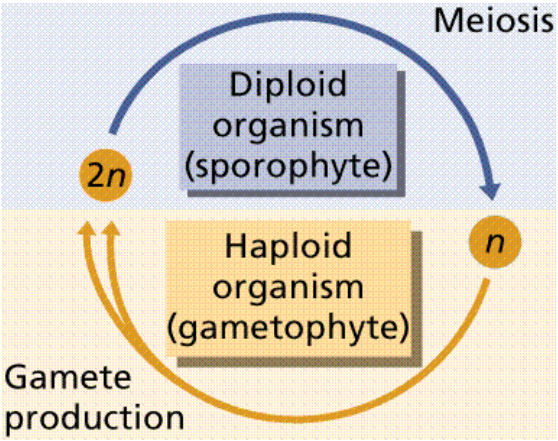

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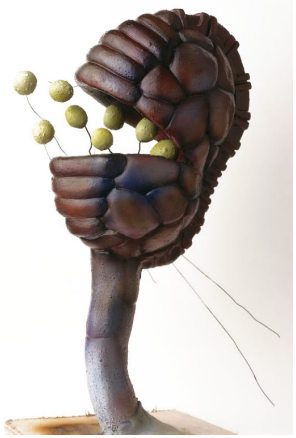
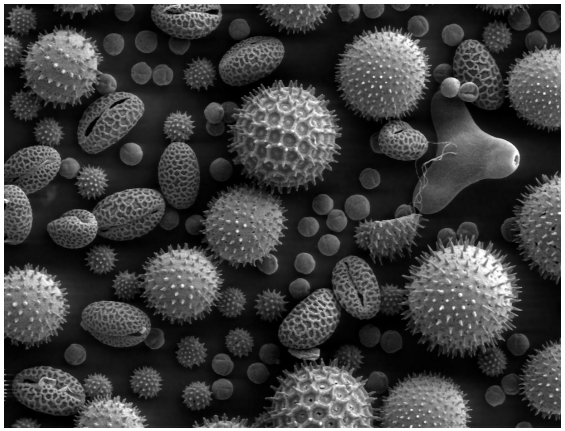
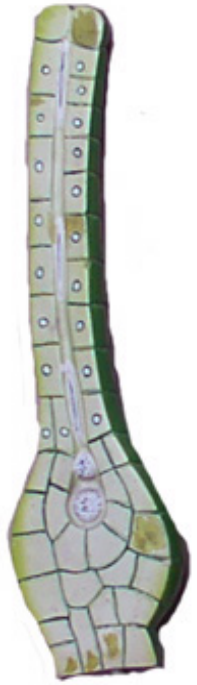




Four key traits found in land plants and NOT in charophyte algae ancestor

3. Multicellular Gametangia

- Gametes are produces within multicellular organs called gametangia.
  - Female gametangia are called archegonia and produces a single nonmotile egg
  - Male gametangia are called antheridia and produce many sperm releasing them into environment
  - Egg fertilized inside archegonium, wher zygote develops into embryo
    - Today, gametangia of seed plants are very reduced or have been lost entirely

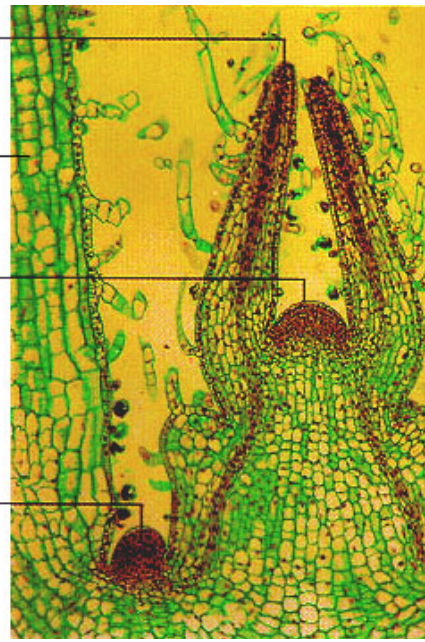


Moss Archegonium

Moss Antheridium

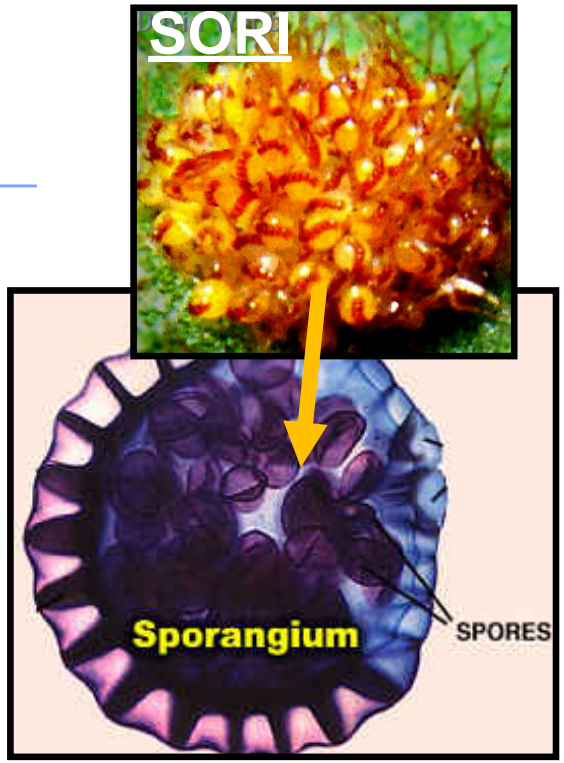
4. Apical Meristems

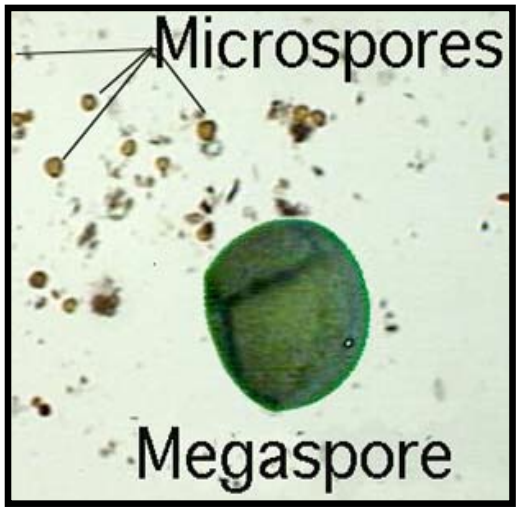
- Localized regions of cell division exist at the tips of shoots and roots elongate structures so the plant body can be exposed to environmental resources,



Types of Spores Produced

- Seedless Vascular plants produce SPORES
  - Homosporous plants
    - one type of sporangium on sporophyte produces one type of spore that forms a bisexual gametophyte, which makes both sperm and eggs.
      - i.e. THE FERN (gametophyte = bisexual)
  - Heterosporous plants
    - two types of sporangia on sporophyte produce two different types of spores
      - Megasporangia produce megaspores that develop into female gametophytes, which will make the egg
      - Microsporangia on microsporophylls produce microspores and develop into male gametophytes, which will make the sperm.
        - Later in evolutionary time, you will see that *ALL SEED-PRODUCING PLANTS WILL EVOLVE TO BE HETEROSPOROUS!*





Any Questions??