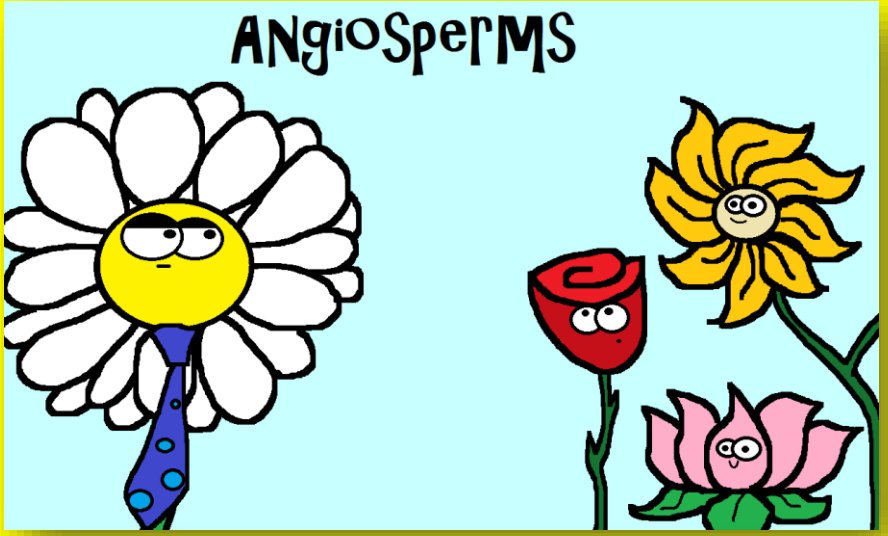
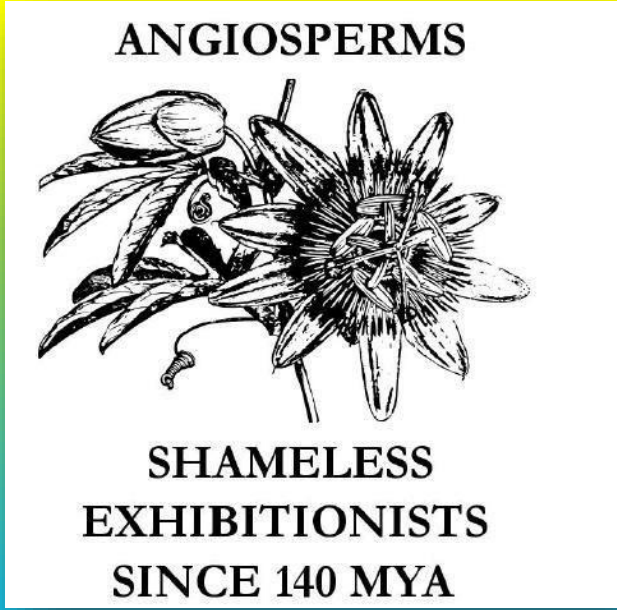
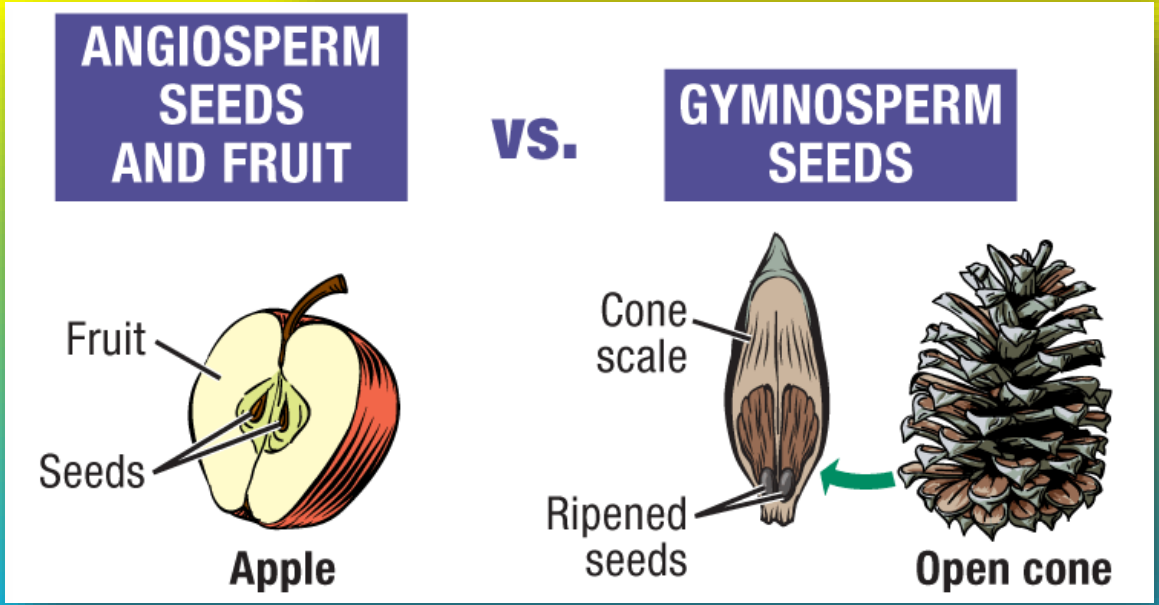
Chapter 38

Angiosperm Reproduction & Biotechnology





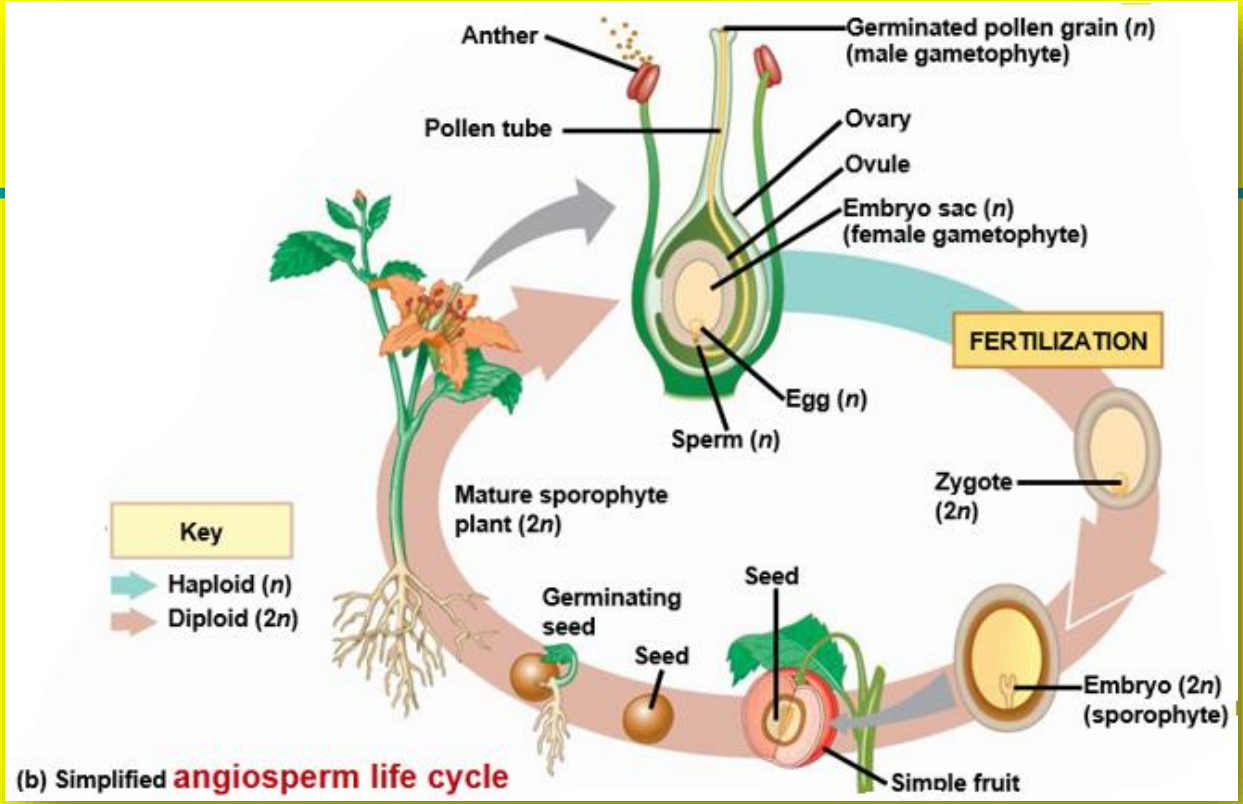


Flowers, double fertilization, and fruits are unique features of the angiosperm life cycle

Alternation of Generations:

- Diploid (2*n*) sporophytes produce spores by meiosis 2n ---> n
  these spores (n) grow into haploid (*n*) gametophytes. NON-VASCULAR PLANTS

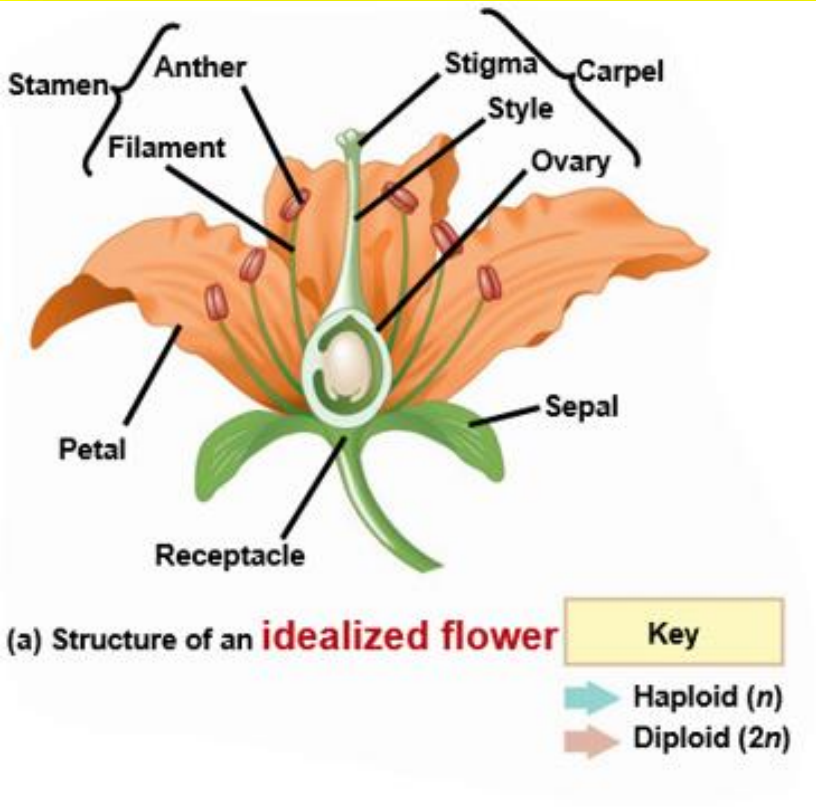
- Gametophytes produce haploid (*n*) gametes by mitosis
  fertilization of gametes produces a zygote = sporophyte cell (2n). VASCULAR PLANTS



- In angiosperms, the sporophyte is the dominant generation, the large plant that we see.
- The gametophytes are reduced in size and depend on the sporophyte for nutrients.
- The angiosperm life cycle is characterized by "***three Fs***": **F**lowers, double **F**ertilization, and **F**ruits.

Flower Structure and Function

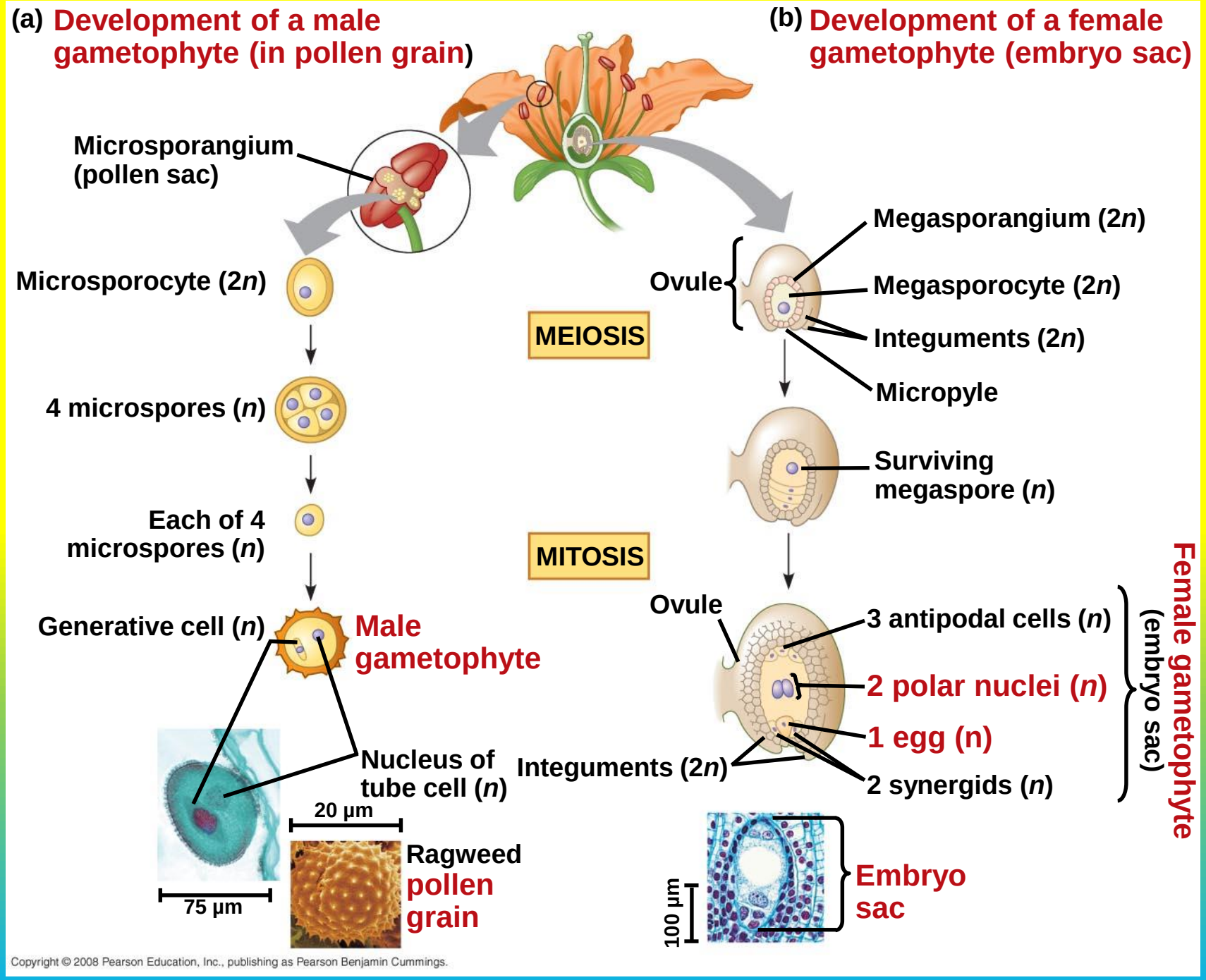
- Flowers are the reproductive shoots of the angiosperm sporophyte; they attach to a part of the stem called the **receptacle.**
- Flowers consist of four floral organs: **sepals**, **petals**, **stamens**, and **carpels.**
- A stamen consists of a filament topped by an **anther** with pollen sacs that produce pollen.
- A **carpel / pistil** has a long **style** with a **stigma** on which pollen may land.
- At the base of the style is an **ovary** containing one or more **ovules.**



- **Complete flowers** contain all four floral organs.
- **Incomplete flowers** lack one or more floral organs, for example stamens or carpels.
- Clusters of flowers are called **inflorescences.**

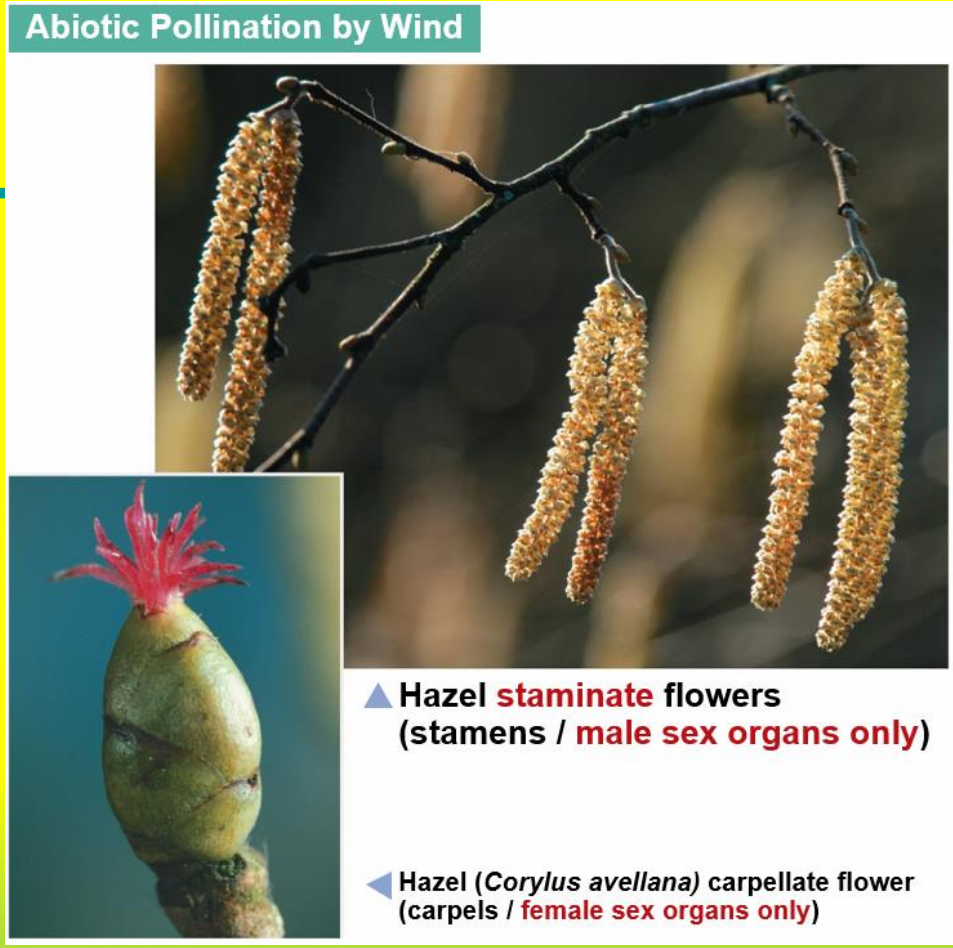
Development of Male Gametophytes in Pollen Grains

- Pollen develops from **microspores** within the microsporangia, or pollen sacs, of anthers.
- If pollination succeeds, a **pollen grain:** generative nucleus ---> 2 SPERM, and tube nucleus ---> produces a **pollen tube** that grows down into the ovary and discharges 2 sperm near the embryo sac.
- The pollen grain consists of the two-celled male gametophyte and the spore wall.



Pollination

- In angiosperms, **pollination** is the transfer of pollen from: anther to stigma (male -> female).
- Pollination can be aided by environmental agents such as: wind, water, insect, bird, or mammal.

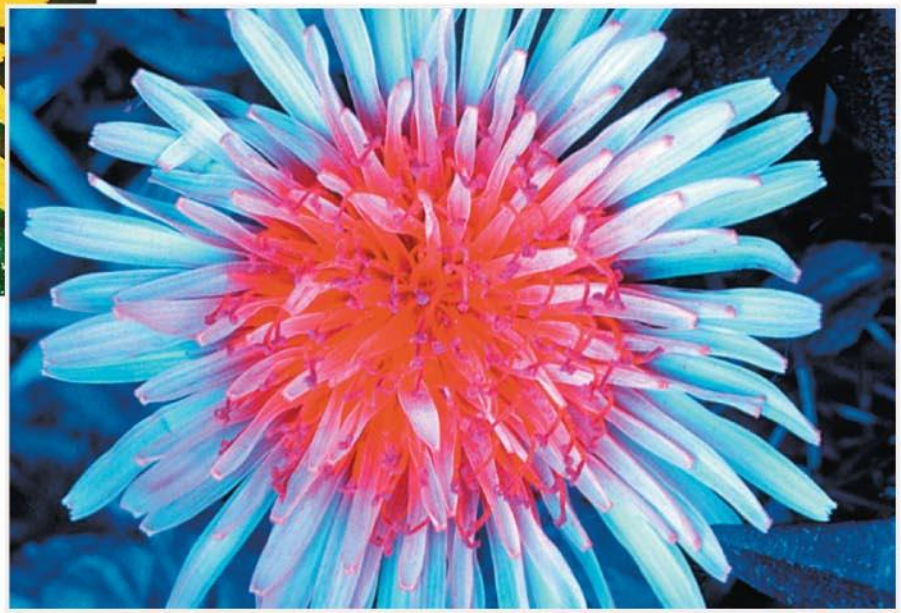


Season of the Witch… hazel

Pollination by Bees

Color = visual cue / signal to attract pollinators

Common dandelion under normal light



Common dandelion under ultraviolet light

Chemical signal: Odor attracts flies

Blowfly on carrion flower & corpse flower (*Refflesia arnoldii & Amorphophallus titanum*)

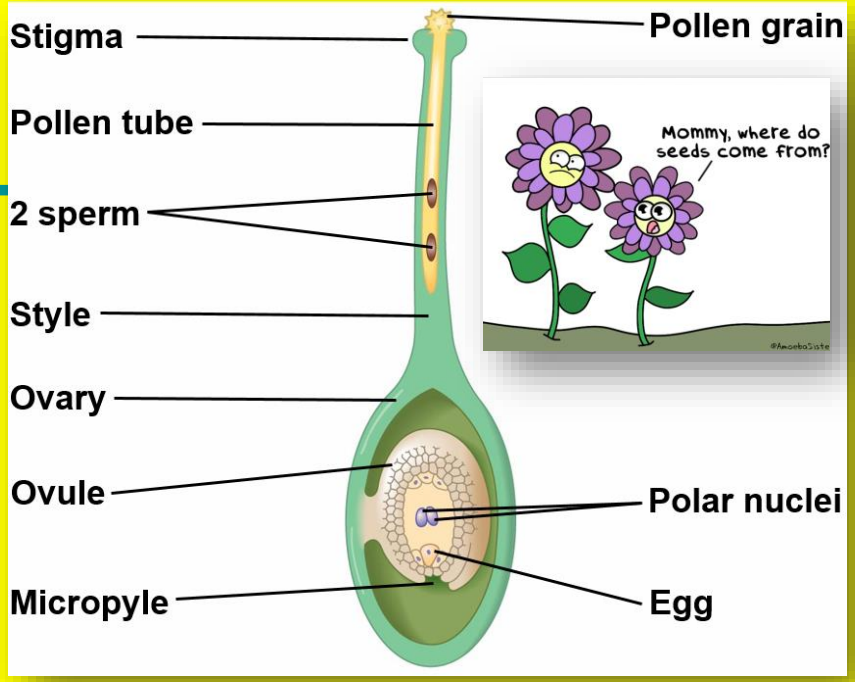
Pollination by Birds

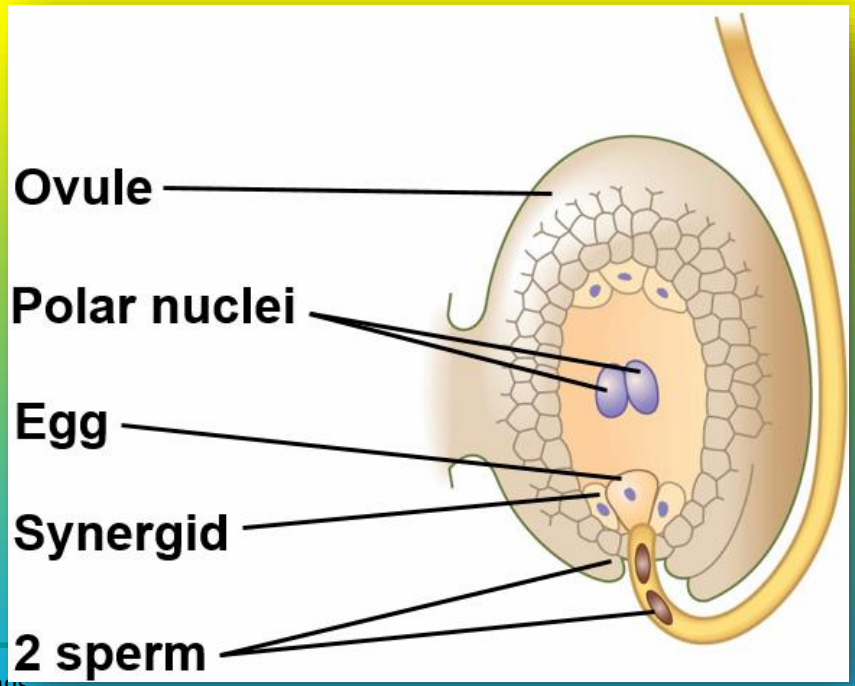
Nectar = chemical attractant

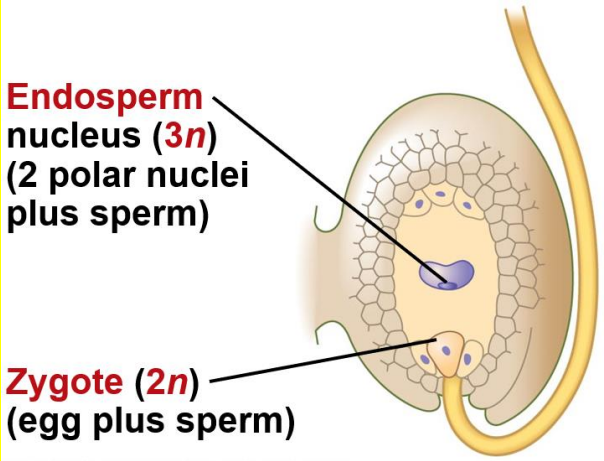
Hummingbird drinking nectar of poro flower

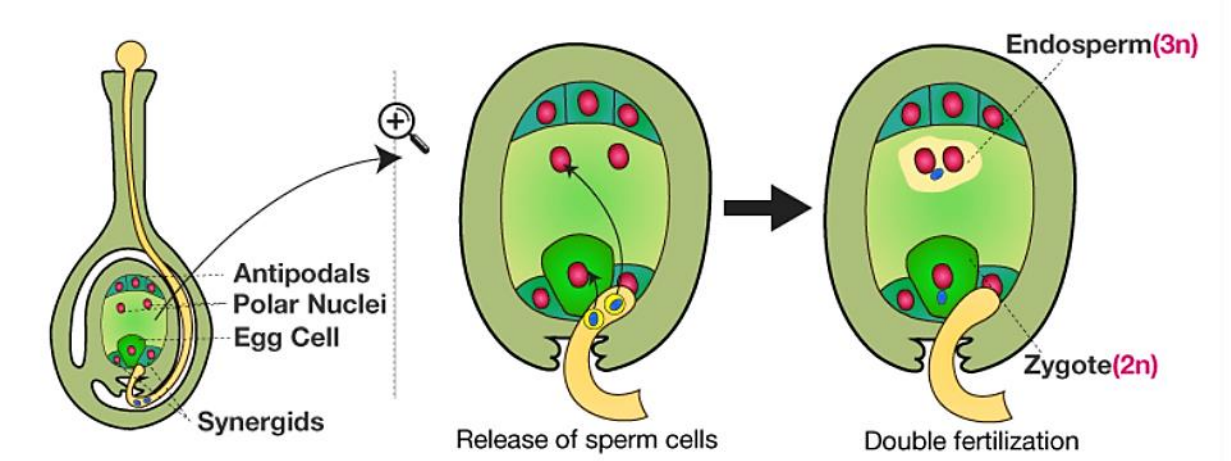
Double Fertilization

- After landing on a receptive stigma, a pollen grain produces a pollen tube that extends between the cells of the style toward the ovary.
- **Double fertilization** results from the discharge of two sperm from the pollen tube into the embryo sac in the ovule.
- Sperm + egg = **zygote 2n**
- Sperm + 2 polar nuclei = **endosperm 3n**
- One sperm fertilizes the egg, and the other combines with the polar nuclei, giving rise to the triploid (3*n*) food-storing **endosperm.**









Double Fertilization:

Seed Development, Form, and Function

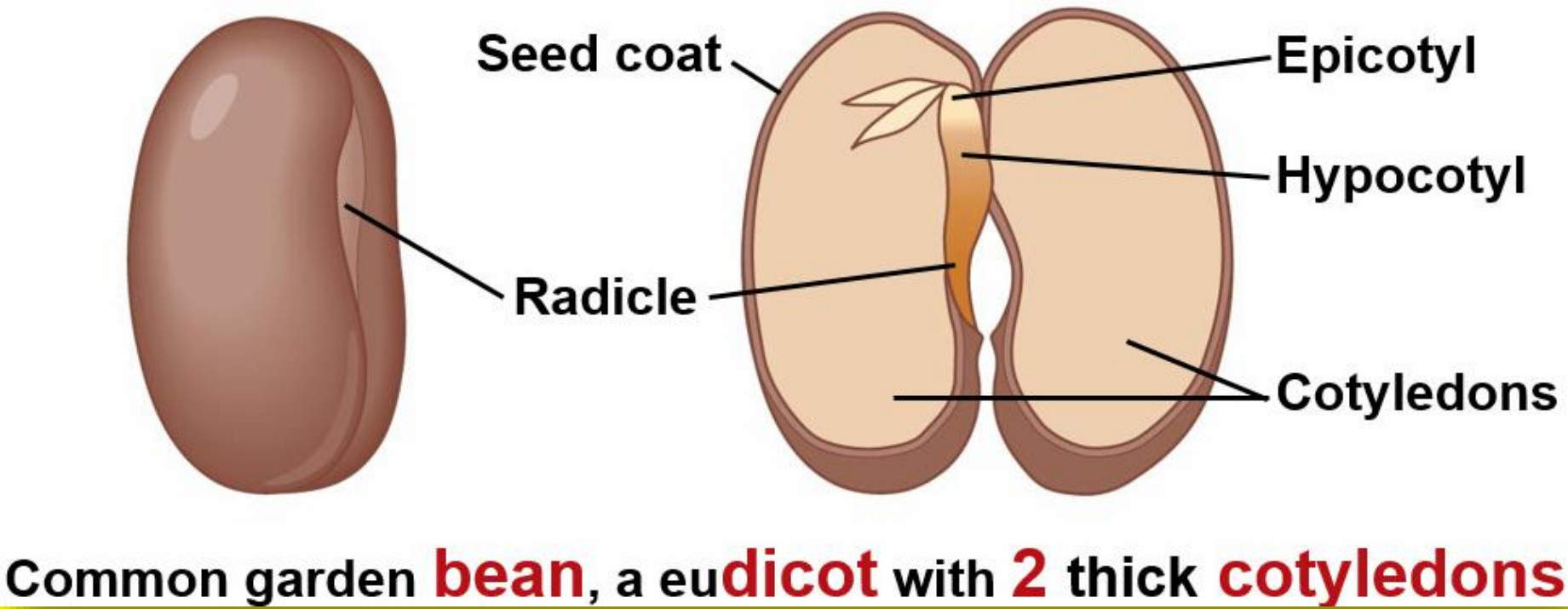
- After double fertilization, each *ovule develops into a seed*.
- The *ovary develops into a fruit* enclosing the seed(s).

Endosperm Development

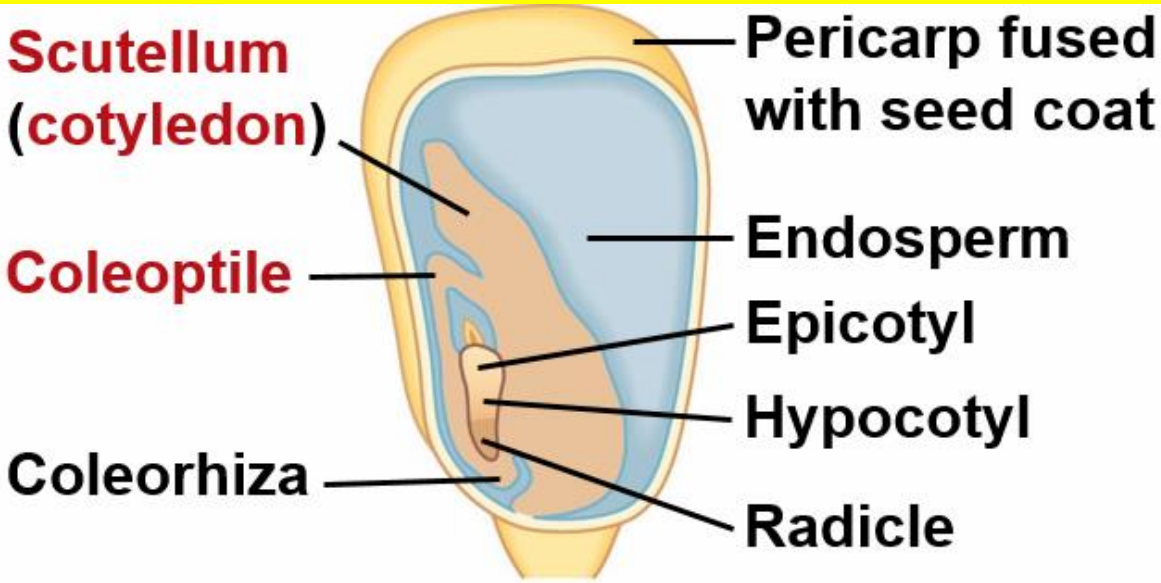
- Endosperm development usually precedes embryo development.
- In most monocots and some eudicots, endosperm stores nutrients that can be used by the seedling.
- In other eudicots, the food reserves of the endosperm are exported to the cotyledons.

Structure of the Mature Seed

- The embryo and its food supply are enclosed by a hard, protective **seed coat.**
- The seed enters a state of **dormancy.**



- In some eudicots, such as the common garden bean, the embryo consists of the embryonic axis attached to two thick cotyledons (seed leaves).
- Below the cotyledons the embryonic axis is called the **hypocotyl** and terminates in the **radicle** (embryonic root); above the cotyledons it is called the **epicotyl.**



Maize = corn , a **monocot**

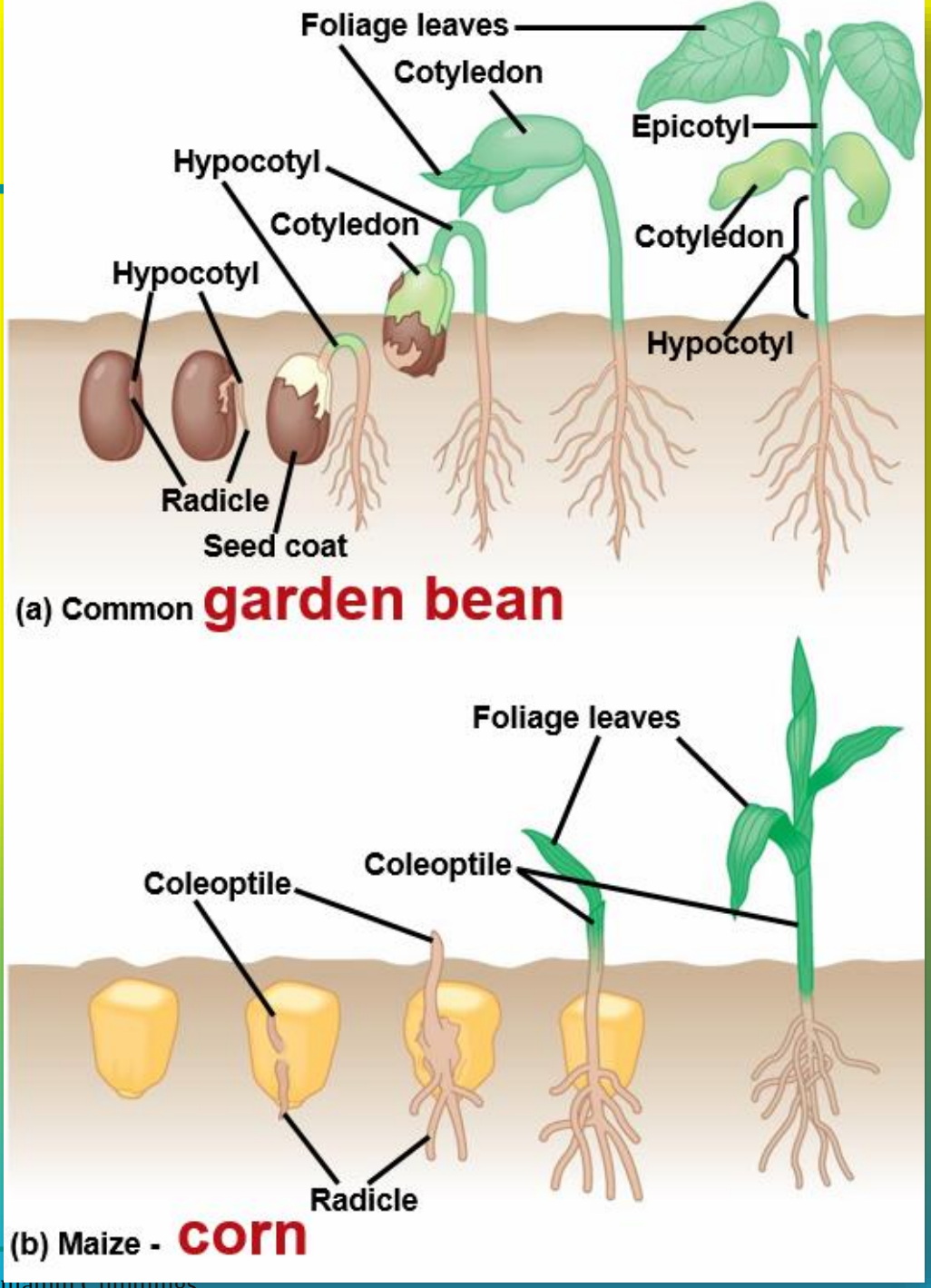
- A monocot embryo has one cotyledon.
- Grasses, such as maize and wheat, have a special cotyledon called a *scutellum.*
- Two sheathes enclose the embryo of a grass seed: a **coleoptile** covering the young shoot and a **coleorhiza** covering the young root.

Seed Dormancy: An Adaptation for Tough Times

- *Seed dormancy increases the chances that germination will occur at a time and place most advantageous to the seedling*.
- The breaking of seed dormancy often requires *environmental cues*, such as temperature or lighting changes.

Seed Germination and Seedling Development

- Germination depends on **imbibition**, the uptake of water due to low water potential of the dry seed.
- The radicle (embryonic root) emerges first.
- Next, the shoot tip breaks through the soil surface.

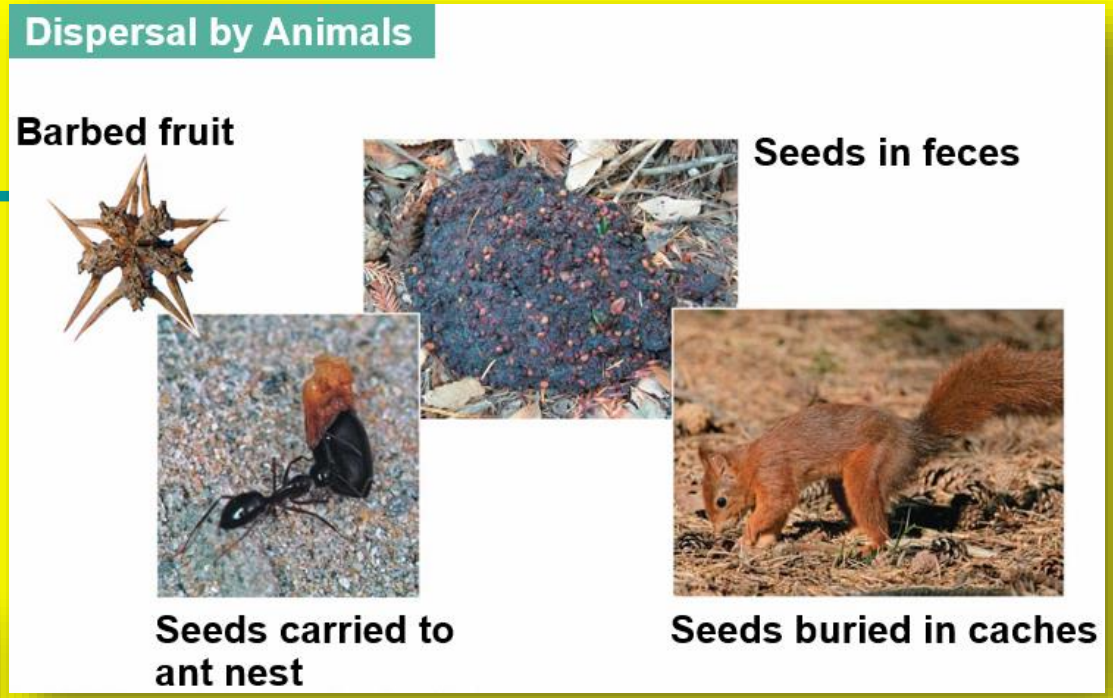


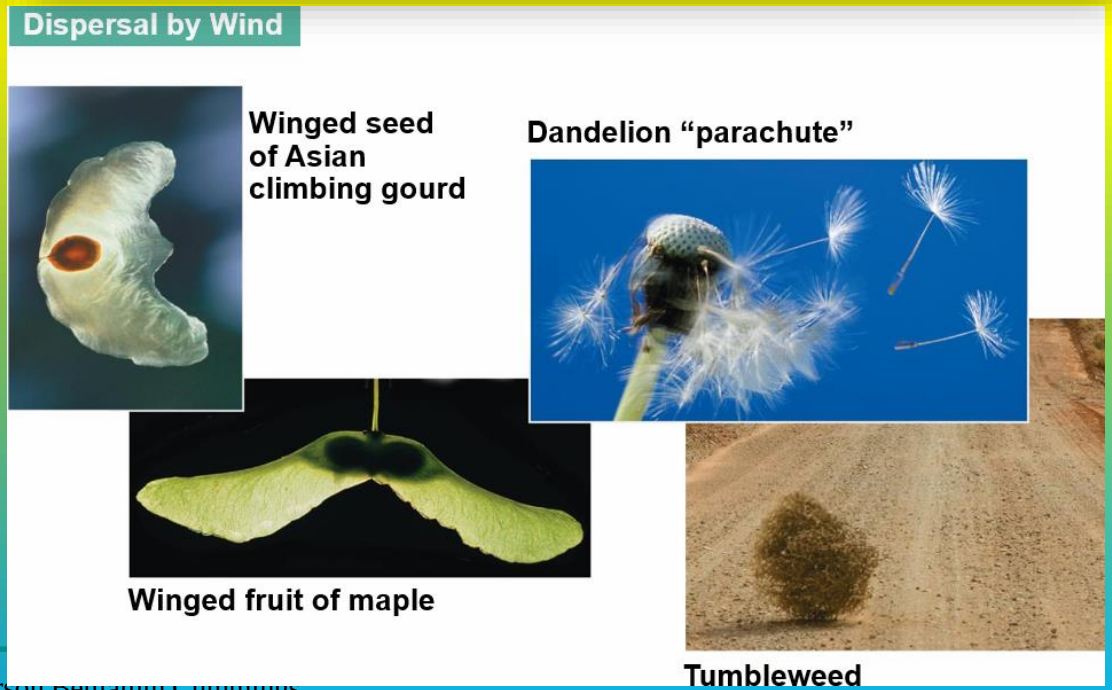
Fruit Form and Function

- A **fruit** develops from the ovary.
- It protects the enclosed seeds and *aids in seed dispersal by wind or animals*.
- A fruit may be classified as dry, if the ovary dries out at maturity, or fleshy, if the ovary becomes thick, soft, and sweet at maturity.

Fruit dispersal mechanisms include:

- *Water*
- *Wind*
- *Animals*



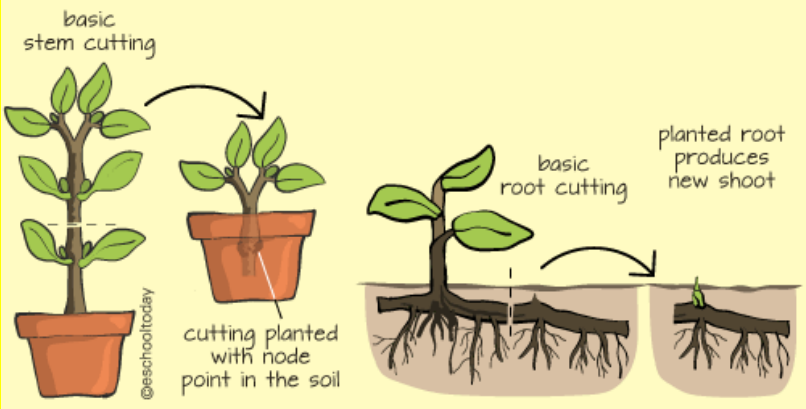


Plants reproduce sexually, asexually, or both

- Many angiosperm species reproduce both asexually and sexually.
- Sexual reproduction results in offspring that are genetically different from their parents.
- **Asexual reproduction** results in a clone of genetically identical organisms.

Mechanisms of Asexual Reproduction

- **Fragmentation**, separation of a parent plant into parts that develop into whole plants, is a very common type of asexual reproduction.

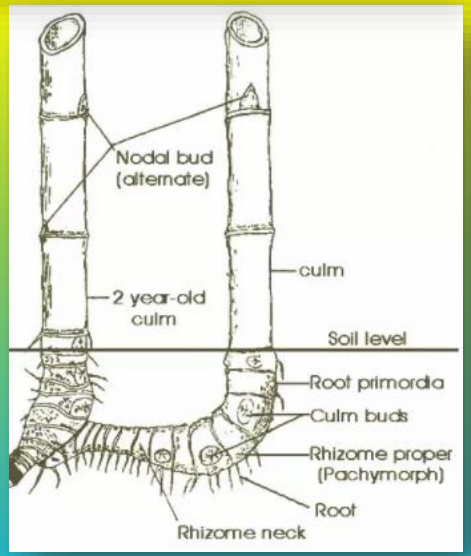


- In some species, a parent plant's root system gives rise to adventitious shoots that become separate shoot systems.

- **Apomixis** is the asexual production of seeds from a diploid cell.

Advantages and Disadvantages of Asexual Versus Sexual Reproduction

- Asexual reproduction is also called **vegetative reproduction.**
- Asexual reproduction can be beneficial to a successful plant in a stable environment.
- However, a clone of plants is vulnerable to local extinction if there is an environmental change.



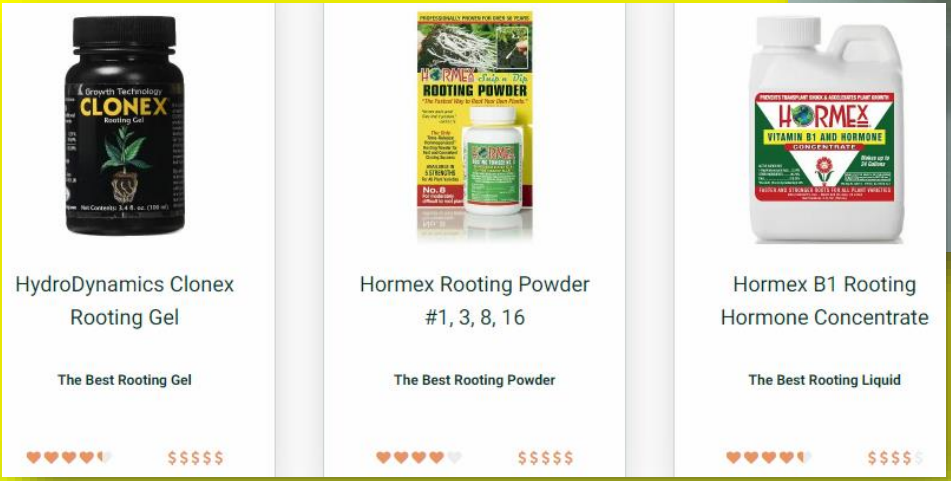
- *Sexual reproduction generates genetic variation that makes evolutionary adaptation possible*.
- However, only a fraction of seedlings survive.

Floral Adaptations that prevent self-fertilization:

- The most common is **self-incompatibility**, a plant's ability to reject its own pollen.
- Researchers are unraveling the molecular mechanisms involved in self-incompatibility.
- Some plants reject pollen that has an *S*-gene matching an allele in the stigma cells.
- *Recognition of self pollen triggers a signal transduction pathway leading to a block in growth of a pollen tube*.

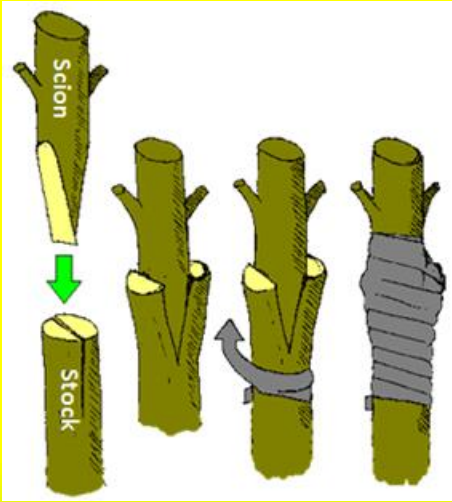
Clones from Cuttings

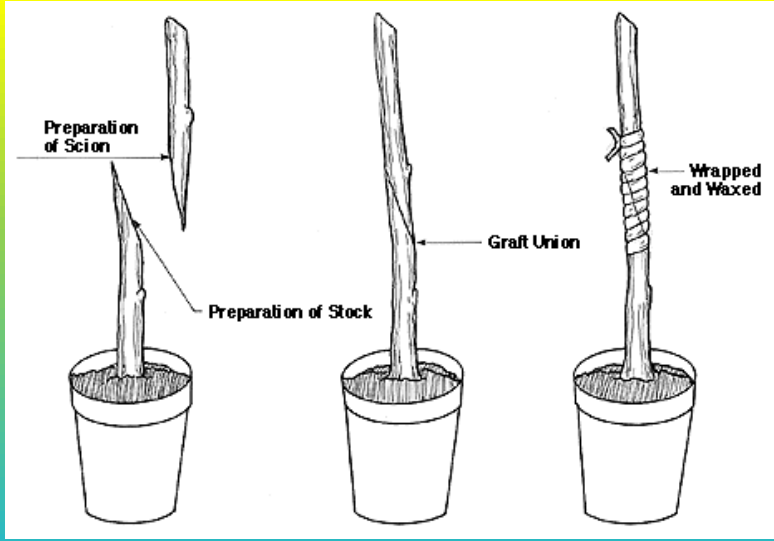
- Many kinds of plants are asexually reproduced from plant fragments called cuttings.
- A **callus** is a mass of dividing undifferentiated cells that forms where a stem is cut and produces adventitious roots.

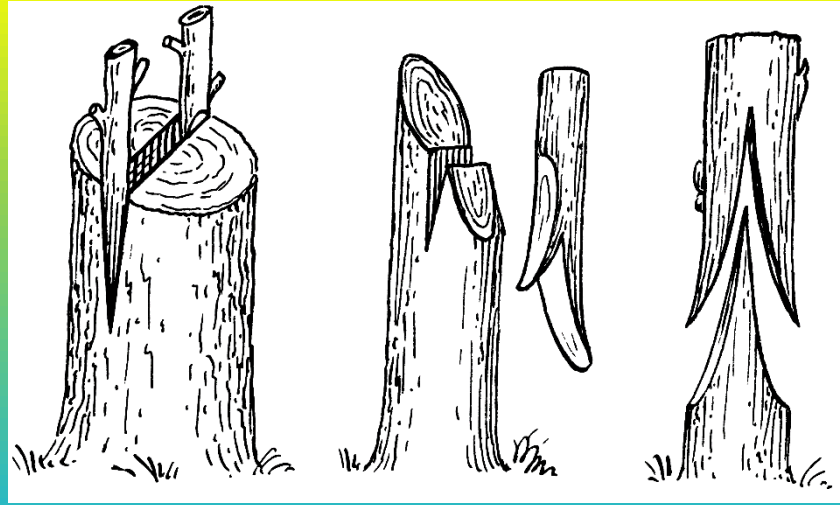


Grafting

- A twig or bud can be grafted onto a plant of a closely related species or variety.
- The **stock** provides the root system.
- The **scion** is grafted onto the stock.

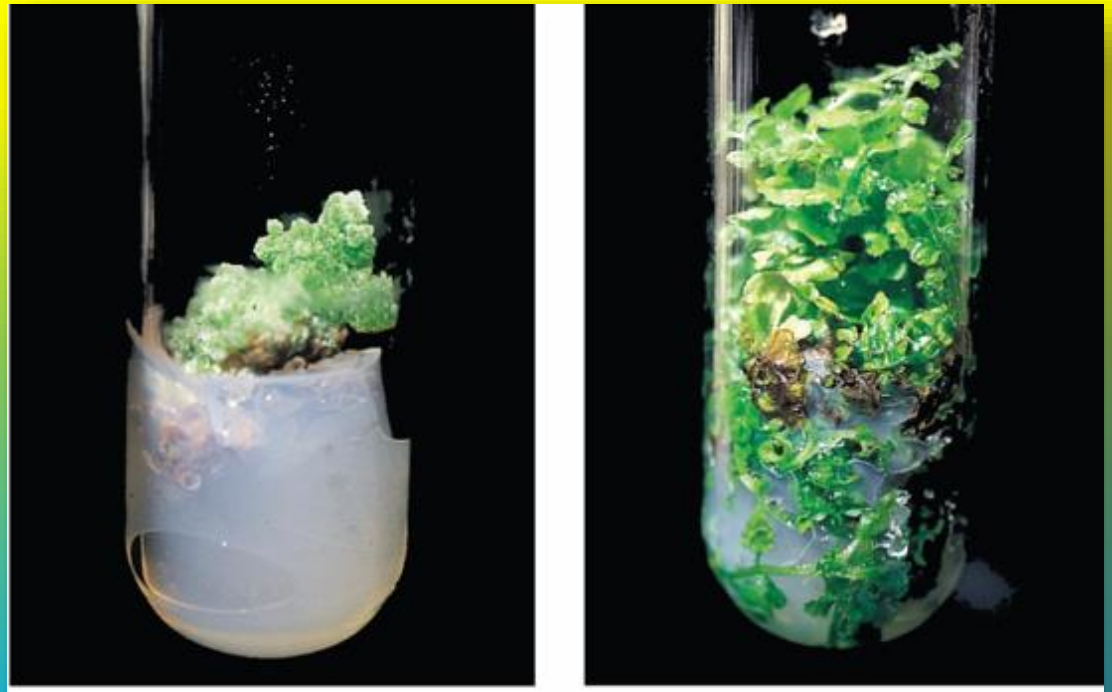




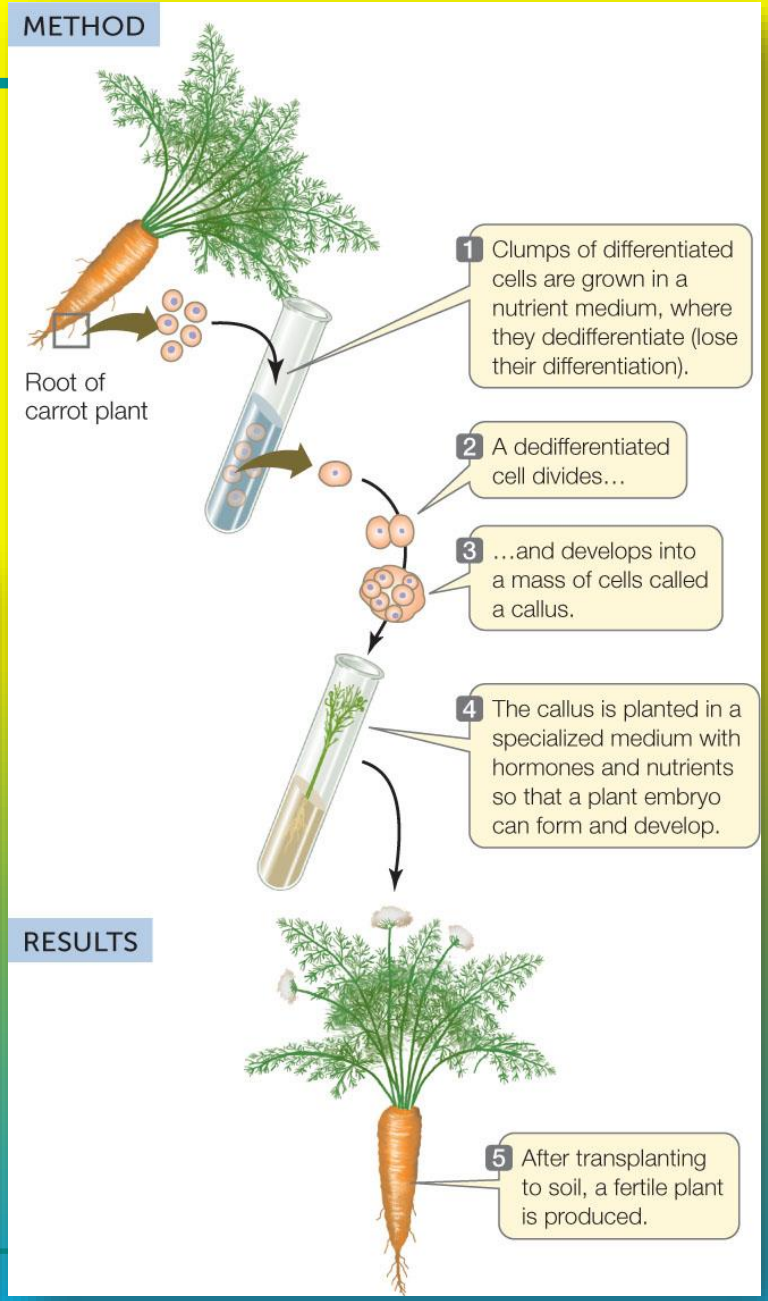


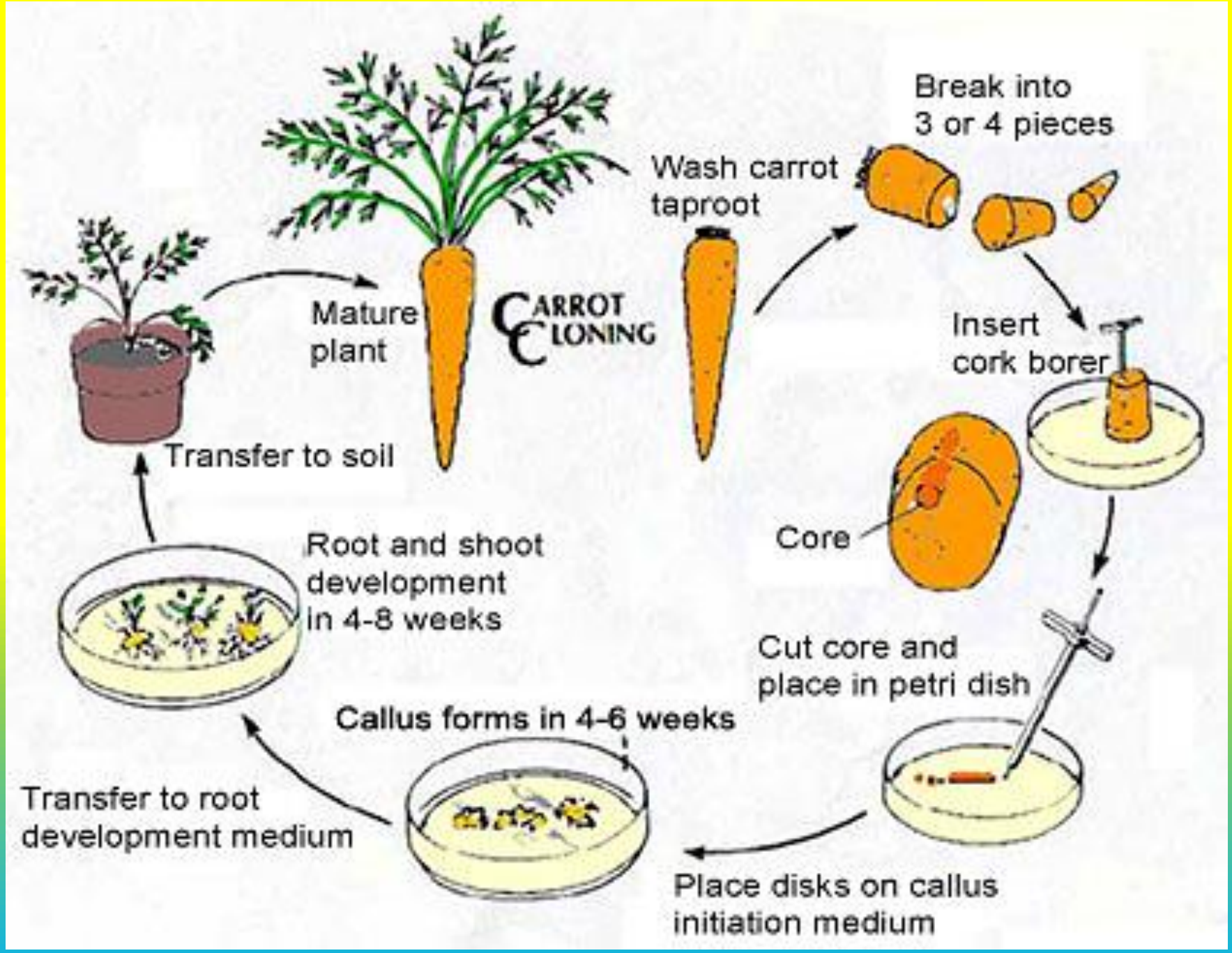
Test-Tube Cloning and Related Techniques

- Plant biologists have adopted *in vitro* methods to create and clone novel plant varieties.
- **Transgenic** plants are genetically modified (**GM**) to express a gene from another organism.



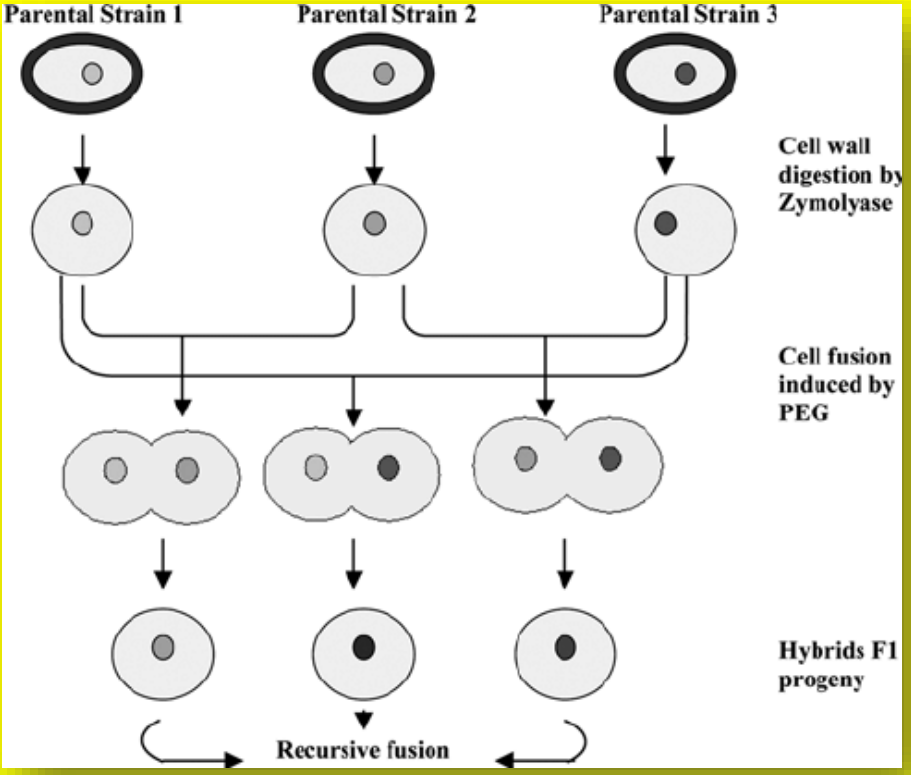
(a) Undifferentiated carrot cells (b) Differentiation into plant

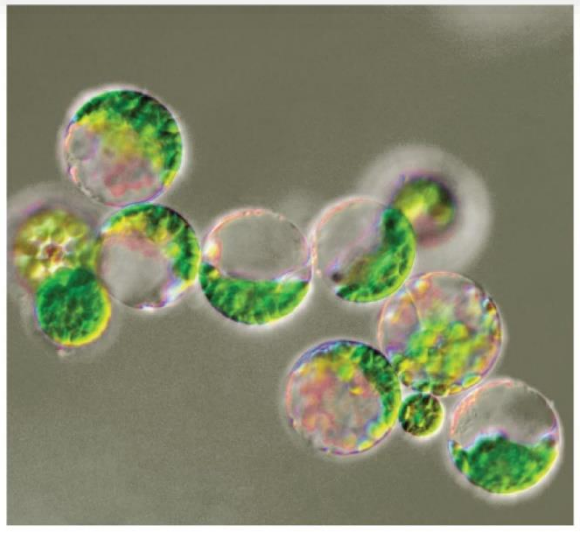



CARROT CLONING
Mature plant
Wash carrot taproot
Break into 3 or 4 pieces
Insert cork borer
Core
Cut core and place in petri dish
Place disks on callus initiation medium
Callus forms in 4-6 weeks
Transfer to root development medium
Root and shoot development in 4-8 weeks
Transfer to soil

Protoplasts

- **Protoplast fusion** is used to create hybrid plants by fusing protoplasts, plant cells with their cell walls removed.





Humans modify crops by breeding and genetic engineering

- Humans have intervened in the reproduction and genetic makeup of plants for thousands of years.
- Hybridization is common in nature and has been used by breeders to introduce new genes.
- Maize, a product of artificial selection, is a staple in many developing countries.

Plant Breeding

- Mutations can arise spontaneously or can be induced by breeders.
- Plants with beneficial mutations are used in breeding experiments.
- Desirable traits can be introduced from different species or genera.
- The grain triticale is derived from a successful cross between wheat and rye.

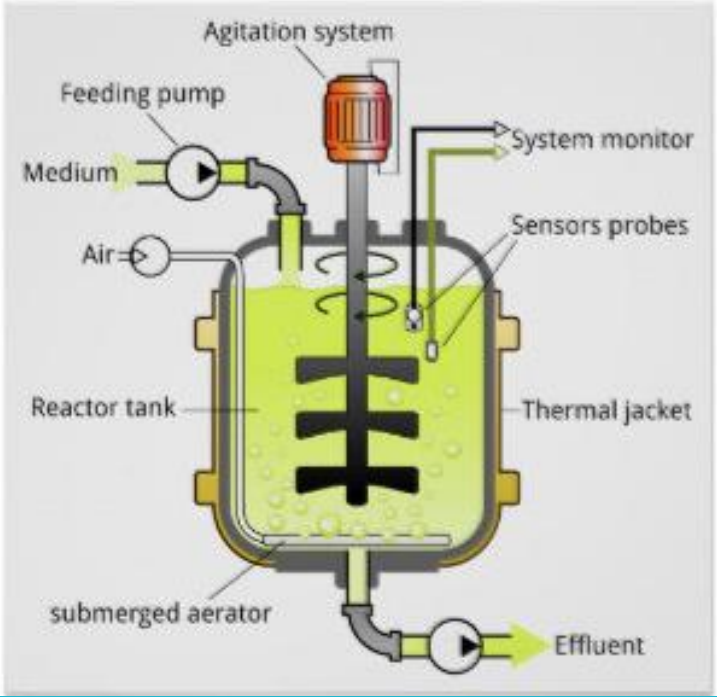
Plant Biotechnology and Genetic Engineering

- ***Plant biotechnology*** has two meanings:
  - In a general sense, it refers to *innovations in the use of plants to make useful products*.
  - In a specific sense, it refers to *use of GM organisms in agriculture and industry*.
- Modern plant biotechnology is not limited to transfer of genes between closely related species or varieties of the same species.

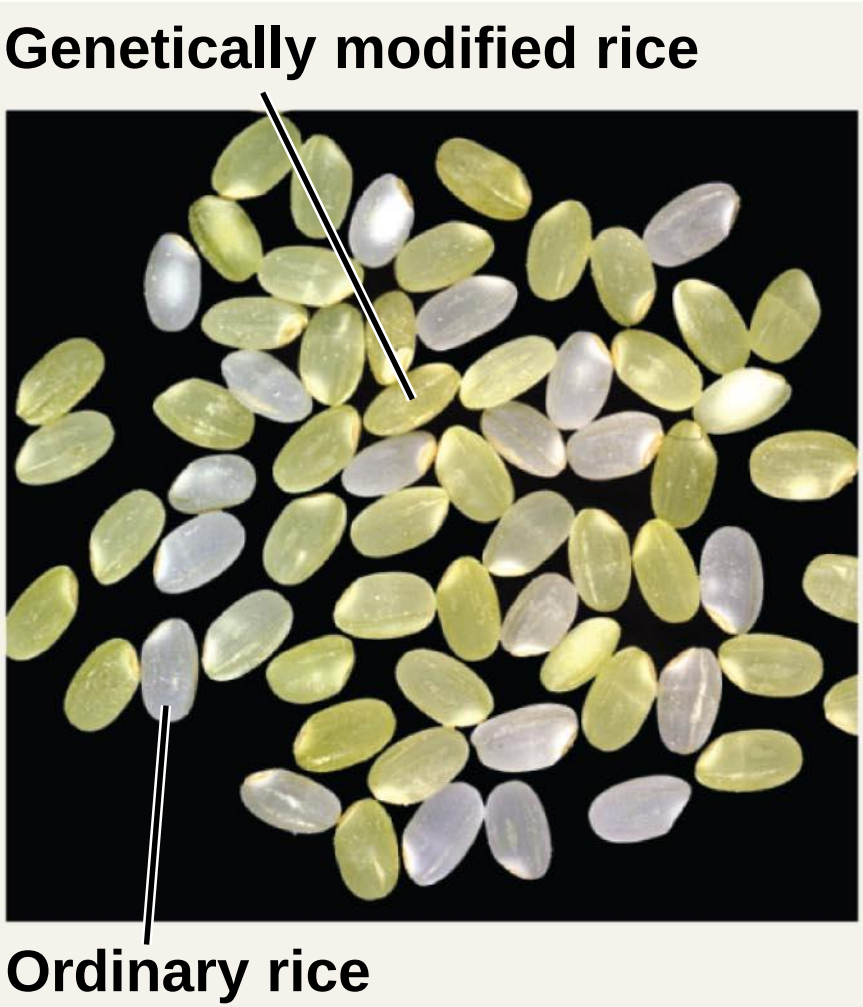
Reducing World Hunger and Malnutrition

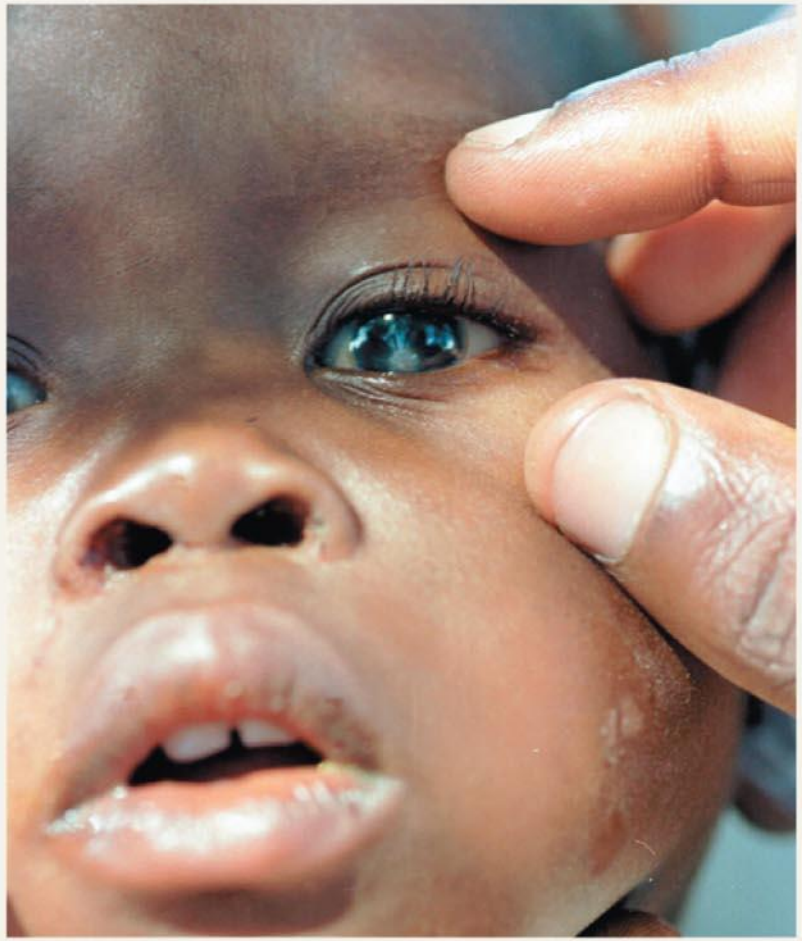
- Genetically modified plants may increase the quality and quantity of food worldwide.
- **Transgenic crops** have been developed that:
  - Produce proteins to defend them against insect pests
  - Tolerate herbicides
  - Resist specific diseases.

- **Biofuels** are made by the fermentation and distillation of plant materials such as cellulose. Biofuels can be produced by rapidly growing crops and reduce dependency on fossil fuels.
- Nutritional quality of plants is being improved. “Golden Rice” is a transgenic variety being developed to address vitamin A deficiencies among the world’s poor.



“Golden Rice” and prevention of blindness associated with vitamin A deficiency





The Debate over Plant Biotechnology

Some biologists are concerned about risks of releasing GM organisms into the environment:

- One concern is that genetic engineering may transfer allergens from a gene source to a plant used for food.
- Many ecologists are concerned that the growing of GM crops might have unforeseen effects on nontarget organisms.
- The most serious concern is transgene escape = the possibility of introduced genes escaping into related weeds through crop-to-weed hybridization.

- Efforts are underway to prevent this by introducing:
  - Male sterility
  - Apomixis – asexual reproduction
  - Transgenes into chloroplast DNA (not transferred by pollen)
  - Strict self-pollination.

You should now be able to:

1. Describe how the plant life cycle is modified in angiosperms.
2. Identify and describe the function of a sepal, petal, stamen (filament and anther), carpel (style, ovary, ovule, and stigma), seed coat, hypocotyl, radicle, epicotyl, endosperm, cotyledon.

You should now be able to:

3. Distinguish between complete and incomplete flowers; bisexual and unisexual flowers; microspores and megaspores; simple, aggregate, multiple, and accessory fruit.
4. Describe the process of double fertilization.
5. Describe the fate and function of the ovule, ovary, and endosperm after fertilization.

6. Explain the advantages and disadvantages of reproducing sexually and asexually.

7. Name and describe several natural and artificial mechanisms of asexual reproduction.

8. Discuss the risks of transgenic crops and describe four strategies that may prevent transgene escape.