Flower Morphology and Distribution

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Sexual Reproduction

Kinds of Flowers

Fig. 1 A *complete* **flower has all four floral organs: Pistil, stamen, sepals and petals.**

Fig. 2 *Incomplete* **flowers lack one of the four floral organs (here, petals).**

Fig. 3 This flower is *incomplete* because it lacks stamens. It is also considered *imperfect* because it has only one sexual organ (pistil).

Inflorescence type influences the techniques that are used to control pollination in developing cultivars and in maintaining the genetic purity of cultivars. Inflorescence types can also be used to identify plants.

Flowers are classified into a couple of categories. Flowers are either complete or incomplete and either perfect or imperfect. A flower having all of the main floral parts (sepals, petals, pistils, and stamens) is said to be complete, whereas a flower lacking one or more of these structures is said to be incomplete. The stamen (male part) and pistil (female part) are not always present together in a single flower. When both are present, the flower is said to be perfect (or bisexual). Imperfect flowers are those that are unisexual, either male or female.

Table 1 Examples of plants with complete and incomplete flowers.

Complete flowers	Incomplete flowers
Soybean	Maize
Alfalfa	Sorghum
Clovers	Oat
Common bean	Barley
Vetches	Wheat
Cotton	Sugar beet
	Forage grasses
	Turf grasses

Complete flowers	Incomplete flowers
	Rice
A tomato flower. Licensed under CC-BY-SA 3.0 via Wikimedia Commons.	
Tomato	**A fig flower. Licensed under CC-BY-SA 3.0 via Wikimedia Commons.**
Rapeseed	**Fig**
Sunflower	Date palm
Tomato	Spinach
Cabbage	
Tobacco	

Notice that plants in the legume family (*Leguminosae* or *Fabaceae*) have complete flowers, whereas plants belonging to the grass family (*Gramineae* or *Poaceae*) have incomplete flowers.

Flower Dissection

Dissect a complete and incomplete flower. Think about how the presence or absence of a floral structure might influence the pollination process, and thus, the methods that can be used to develop improved cultivars or to maintain the genetic purity of the cultivar.

Complete Flower

Fig. 4 Soybean flowers in the field.

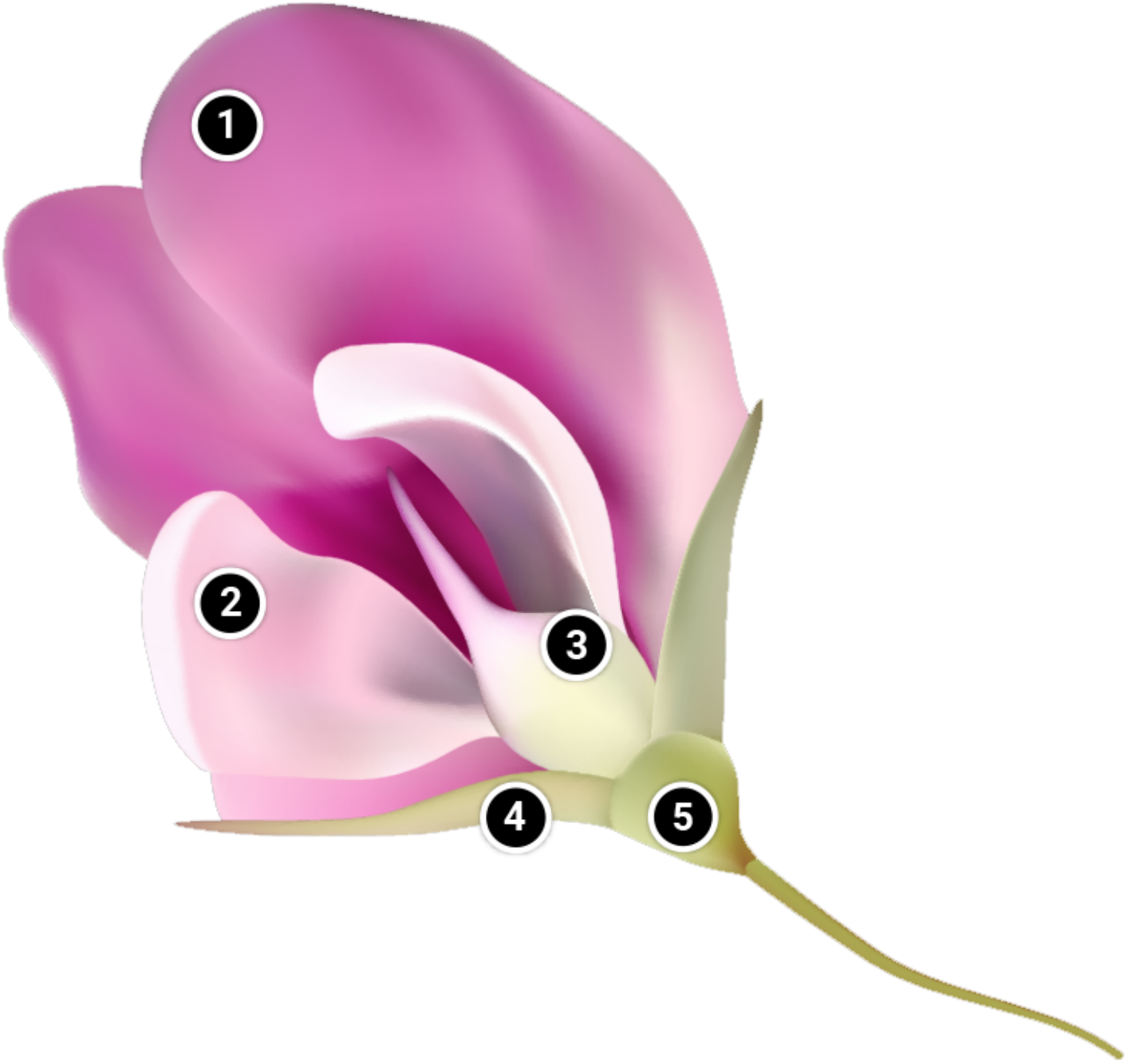
Incomplete Flower

Fig. 5 Green wheat florets. Photo by Stephencdickson. Licensed under Own work, CC BY-SA 4.0 via https://commons.wikimedia.org/w/index.php?curid=41699882

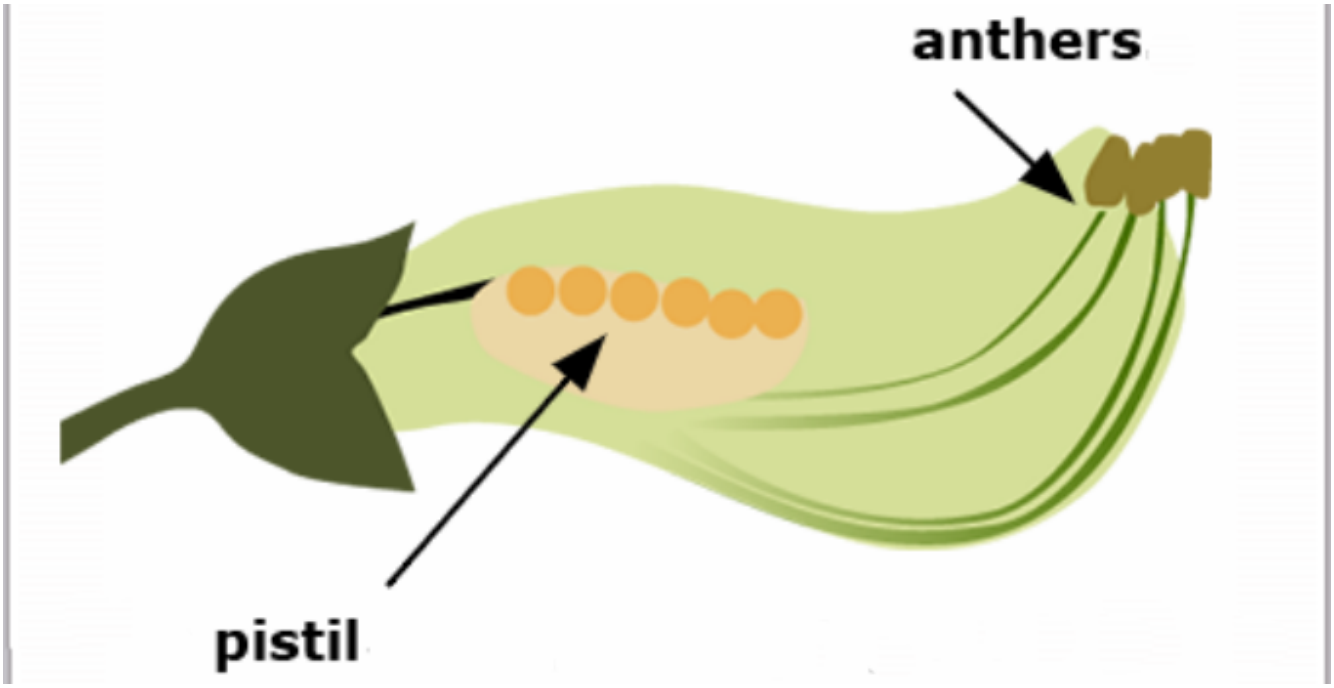
Grass Floret

Fig. 6 Grass flowers. Photo by Hardyplants at English Wikipedia. Licensed under Public Domain via https://commons.wikimedia.org/w/index.php?curid=20502896

Complete Soybean Flower Dissection



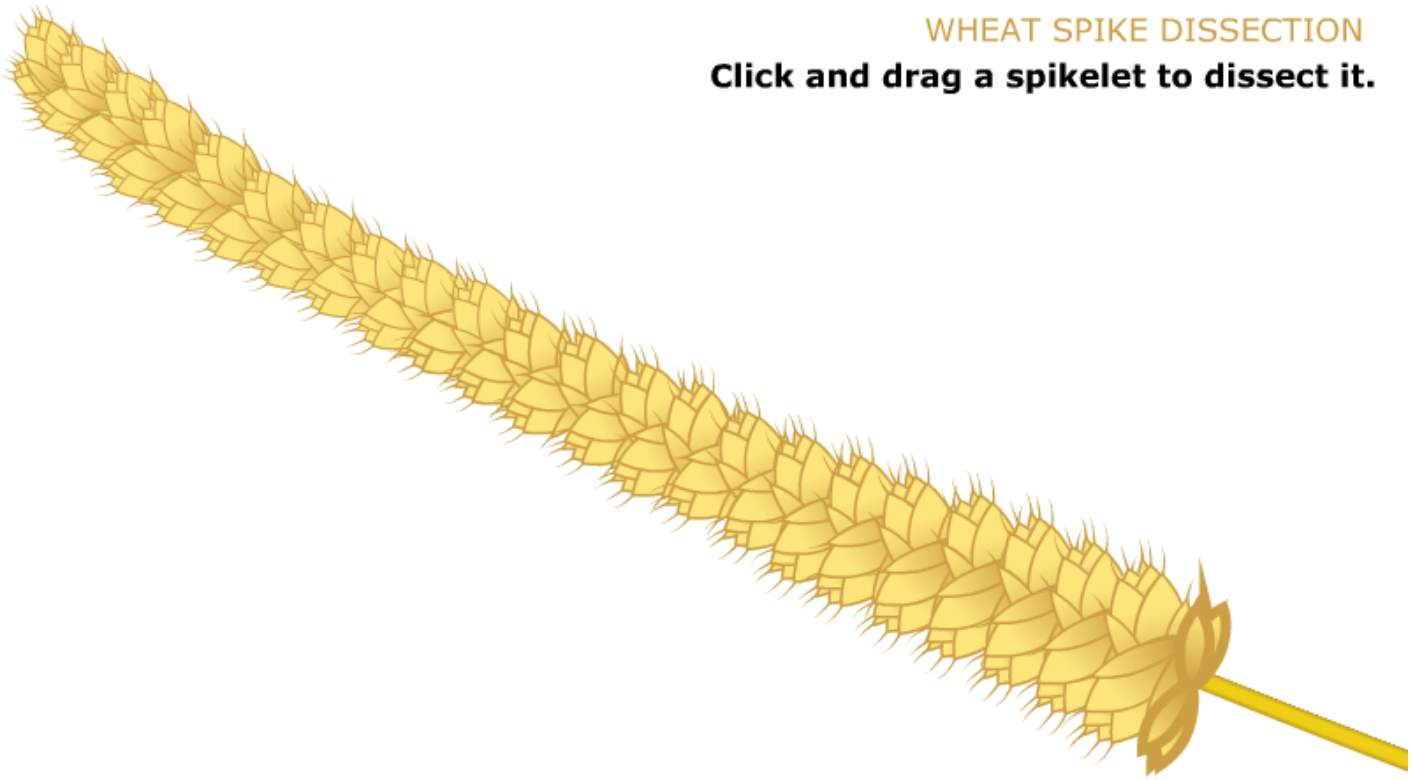
1. **Standard petals**
   Collectively, petals are called the corolla. Petals are typically large and conpicuous and are not required for reproduction. Soybean has five petals: one standard petal, two wing petals and two keel petals
2. **Wing petals**
   The dissected view of the two wing petals.
3. **Keel**
   The keel is composed of two united petals. The keel encloses the stamina column.
   Stamens are the pollen-bearing organs of the flower. Staments are composed of slender stalks (filaments) that support anthers. Pollen grains are produced in the **anthers**.



The **pistil** is the seed-bearing organ of the flower. It consists of stigma, style, and ovaries. The stigma is the part that is receptive to pollen. Following pollination and fertilization, seed form in ovaries.

4. **Sepals**
   Like the petals, sepals are not neccessary for reproduction. Sepals are small and inconspicuous. They enclose and protect the flower while still a bud. Collectively they form the calyx.
5. **Pedicel**
   The pedicel is the stalk of the flower, attaching to the plant.

Wheat Spike Dissection



Study Question 4

What features distinguish **complete** from **incomplete** flowers?

Enter your answer here.

Show Answer

Study Question 5

Select the floral part or parts **necessary for reproduction:**

- [ ] Pistils
- [ ] Sepals
- [ ] Stamen
- [ ] Petals

Check

Perfect and Imperfect

Table 2 Examples of crops and different floral systems. Adapted from Lersten (1980).

Flower Characteristics	Terms	Examples
Male and female expression in INDIVIDUAL FLOWERS		
Male and female in ONE flower	bisexual, hermaphroditic, monoclinous, perfect	Wheat, peach
1. Pollen shed before stigma is receptive	protandry (prevent self-pollination)	Carrot, walnut
2. Stigma matures and ceases to be receptive before pollen is shed	protogyny (prevent self-pollination)	Pearl millet, pecan
3. Stigma receptive, and pollen shed, after flower opens	chasmogamy (promote self-pollination)	Violet, rye
4. Stigma receptive, and pollen shed, in closed flower	cleistogamy (ensure self-pollination)	Oat, peanut
Perfect flowers of TWO types on SAME plant	heterostyly	Buckwheat, flax
1. Long styles and short stamens	pin flower	
2. Short styles and long stamens	thrum flower	
Male and female in SEPARATE flowers	unisexual, diclinous, imperfect	Cucumber, hemp
1. Male flower	male, staminate	
2. Female flower	female, pistillate, carpellate	

Flower Characteristics	Terms	Examples
Flower DISTRIBUTION on PLANTS		
Male and female flowers on one plant	monoecious	Maize, oak
Male and female flowers on separate plants	dioecious	Yams, asparagus
• Male, female, and perfect flowers	mixed, polygamous	Red maple, papaya
1. On same plants	polygamomonoecious	Coconut, mango
2. On separate plants	polygamodioecious	Strawberry, holly

Descriptions

Perfect flowers have both staminate and pistillate structures in the same flower.

Imperfect flowers are either staminate or pistillate. An imperfect flower is staminate if it possesses stamen. Conversely, an imperfect flower is pistillate if it bears a pistil. Staminate flowers are considered “male” because they produce pollen, whereas pistillate flowers are “female” because they possess ovules. Staminate and pistillate flowers may occur on the same or different plants of the same species.

Species having such specializations are either

- monoecious — staminate and pistillate flowers are separate but occur on the same plant; or
- dioecious — staminate and pistillate flowers are on separate plants.

Analogous to the separate sexes in animals, a dioecious plant must have a partner of the opposite type to complete its life cycle. Usually, about half of all individuals of a dioecious species are of each type, staminate or pistillate. Thus, the dioecious condition is reproductively expensive in that only about half of the species’ plants can produce seed.

Table 3 Examples of monoecious and dioecious plants.

Monoecious	Dioecious
Maize	Hemp
Squash	
Cassava	**Hops flowers. Licensed under CC-BY-SA 3.0 via Wikimedia Commons.**
Wile rice	**Hops**
Castor bean	Spinach
White pine	Yam
	Date palm
Walnut flower. Licensed under CC-BY-SA 3.0 via Wikimedia Commons.	Cottonwood
Walnut	Asparagus
Oil palm	Nutmeg

The "mono-" prefix indicates one and the "di-" prefix indicates two. The "-oecious" part of the word translates to "house." Thus, an easy way to remember the distinction between these terms is to remember that in monoecious species, the staminate and pistillate flowers reside in the same house or plant, whereas in dioecious species, these flowers reside in two different houses or plants.

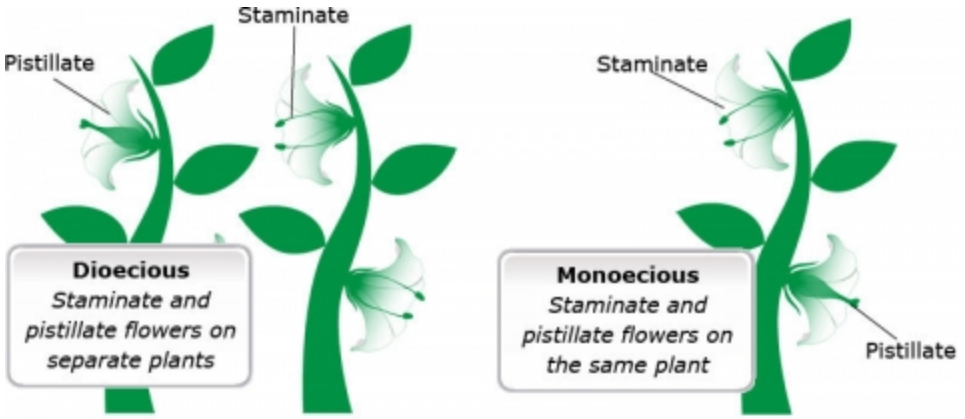


Fig. 7 Dioecious and monoecious plants.

Study Question 6

In addition to being either complete or incomplete, flowers are also either perfect or imperfect. Explain the structural difference(s) between perfect and imperfect flowers.

Enter your answer here.

Show Answer

Pollination and Fertilization

Pollination and Fertilization

Pollination occurs when a pollen grain (from the staminate flower) is placed on a receptive stigma (of the pistillate flower), either naturally or artificially. Fertilization requires that a male gamete and a female gamete fuse to form a zygote. These gametes may be from the same or different plants.

There are two kinds of pollination processes in sexual reproduction.

- **Self-pollination** — seeds develop from the union of male and female gametes produced on the **same** plant or clone. The development of seed by self-pollination is also referred to as **autogamy**.
- **Cross-pollination** — seeds develop from the fusion of gametes produced on **different** plants. The development of seed by cross-pollination is known as **allogamy**.

Pollination

Self-Pollination

Several floral mechanisms enforce self-pollination.

- Flowers do not open, preventing external pollen from reaching the stigma.
- **Anthesis** occurs before the flower opens.
- Stigma elongates through the staminal column (filaments and anthers) immediately after anthesis.
- Floral organs may obscure the stigma after the flower opens.

Although these mechanisms usually enforce self-pollination, a low frequency of cross-pollination may occur. The frequency of cross-pollination in normally self-pollinating species generally depends on the species and environmental conditions.

Soybean is an example of a species that is normally self-pollinated. Before the flower opens, the anthers burst and pollen grains fall out of the anthers on to the receptive stigma contained in the same flower: self-pollination occurs.

Cross-Pollination

Floral Mechanisms of Promotion

Several floral mechanisms promote cross-pollination.

- Emergence or maturity of the staminate and pistillate flowers is asynchronous.

Protandry — anthesis occurs before stigma are receptive.

Protogyny — pistillate flower matures before the staminate flower.

- Flowers are monoecious or dioecious. Mechanical obstruction between the staminate and pistillate flowers in the same individual prevents self-pollination. Gametes produced on the same plant or clone are unable to effect fertilization.

- Mechanical obstruction between the staminate and pistillate flowers in the same individual prevents self-pollination.

Alfalfa flowers, for example, have a membrane over the stigma that precludes self-pollination. When a bee lands on the flower, the keel is tripped, rupturing the membrane and exposing the stigma to pollen carried by the bee from other plants it has visited, effecting cross-pollination.

Fig. 8 An alfalfa leafcutting bee on an alfalfa flower.

- Gametes produced on the same plant or clone are unable to effect fertilization.

Self-sterility — gametes from same individual cannot successfully fuse to form a zygote. Sterility can be caused by lack of function of pollen (male gametes) or ovules (female gametes).

Male sterility — either genetic or cytoplasmic, occurs because the pollen is not viable. Female sterility occurs when the ovule is defective or seed development is inhibited.

Self-incompatibility — self-pollination may occur, but fertilization and seed set fail.

Pollen Transportation

Pollen is transported from the staminate flower to the pistillate flower by wind, insects, or animals. Occasionally pollen is transported to receptive stigma of the same individual and self-pollination may occur. For example, pollen from the tassel of a maize plant may land on and pollinate silks on the same plant, effecting self-pollination.

Sunflower is ordinarily cross-pollinated. Bees often carry pollen from one plant and deposit it on other plants.

Fig. 9 Close-up of a sunflower head. Photo by Allen Knapp, Iowa State University.

Fig. 10 Beehives on the edge of a sunflower field. Photo by Allen Knapp, Iowa State University.

Classification

Plants are classified as either self- or cross-pollinated based on which of these processes most frequently produces its seed. Click each category for more information.

Study Question 7

You encounter an unfamiliar flowering plant. What **key floral feature(s)** would you check to determine the plant's likely mode of pollination, self or cross-pollinating?

Enter your answer here.

Show Answer

Study Question 8

For each of the following types, indicate the probable mode of pollination by clicking on the appropriate button. Assume no male sterility or self-incompatibility.

Complete Flowers

- ○ Self
- ○ Cross
- ○ Often-Cross

Check

Incomplete Flowers

- ☐ Cross
- ☐ Self
- ☐ Often-Cross

Check

Perfect Flowers

- ○ Often-Cross
- ○ Self
- ○ Cross

Check

Imperfect Flowers

- ○ Cross
- ○ Self
- ○ Often-Cross

Check

Monoecious Plants

- Cross
- Self
- Often-Cross

Check

Dioecious Plants

- Often-Cross
- Cross
- Self

Check

Asexual Reproduction

Types

Some species can be propagated without a gametophytic stage. The fusion of gametes (fertilization) is omitted from the life cycle. Reduction in chromosome number (meiosis) and seed production may or may not occur. Asexual reproduction produces individuals genetically identical to the maternal parent.

There are several mechanisms of asexual reproduction.

- Vegetative Propagation
- Tissue Culture
- Apomixis

Vegetative Propagation

In some species, new individuals can arise from a group of differentiated or undifferentiated cells of the parent plant; no embryo or seed is produced. Because such new individuals develop asexually from a single parent, they are genetically identical to that parent. These progeny are **clones**. Numerous tissues and organs may asexually produce progeny.

- **Rhizomes** - Rhizomes are specialized underground stems that can branch at nodes to produce new plants. Banana, bromegrass, hops, and johnsongrass can be reproduced from rhizomes.
- **Stolons** - These "runners" or horizontal-growing, above-ground stems develop adventitious roots whose axillary buds can become independent plants. Strawberry is an example of a crop that can be reproduced from stolons.
- **Bulbs and bulbils** - These short underground stems have thickened or fleshy scales (modified leaves) that can form buds. These buds detach and form "offsets" or new individuals. Onions and garlic are commonly propagated from bulbs.
- **Tubers** - Tubers are also short, enlarged stem tissue, containing food reserves. Nodes or "eyes" in such tissue can give rise to adventitious roots and separate plants. Potatoes are commonly propagated from eyes cut from tubers.
- **Suckers** - Suckers arising as lateral shoots from the base of stems can separate and form new plants. Pineapple, sweet potato, and date palm are examples. Suckers may also derive from adventitious buds on the roots. Roses, poplars, and some other woody species can be propagated from such root cuttings or rootstocks.
- **Corms** - A corm is an underground, tuber-like base of a vertical stem that can also produce a separate plant. Taro, an important starch crop in Southeast Asia and the Pacific Islands, is propagated from corms. Banana also can be propagated from corms.
- **Stem cuttings** - When placed in moist soil, cuttings from aerial stems of some species, such as sugarcane, pineapple, and cassava, can give rise to new plants from the nodes and lateral buds.

The usual mode of reproduction of some species is vegetative. However, other species that reproduce sexually are more commonly propagated vegetatively to maintain genetic purity, including some forage cultivars and many horticultural species.

Vegetative reproduction does not usually provide opportunity for selection of genetic variants.

Tissue Culture

Tissue culture is a specialized type of asexual propagation. Tissue culture usually involves excision of undifferentiated cells or **meristematic** pieces of a plant and growing these in vitro on sterile nutrient agar medium; cell division is by mitosis. By manipulating the components of the medium, the tissue can be prompted to develop roots or shoots. Eventually, new individuals may be separated and transplanted to soil.

Tissue culturing takes advantage of the **totipotency** of somatic cells. That is, these cells contain the plant's entire genome and have the potential to develop into whole plants. Some species that cannot normally be reproduced vegetatively may be reproduced by tissue culture.

Tissue culture is of interest to plant breeders as a technique to

- maintain and propagate genetically identical plants that otherwise can only be reproduced sexually;
- provide disease-free plants of species that often transmit pathogens to progeny when propagated by conventional vegetative means; and
- create novel genetic variation within which selections can be made. Under some conditions, tissue culturing can promote genetic changes.

Apomixis Process

Apomixis differs from other forms of asexual reproduction in that seed is produced. Unlike sexual reproduction, however, apomictic seed is developed from sexual organs or related structures without fertilization. Pollination is also usually omitted.

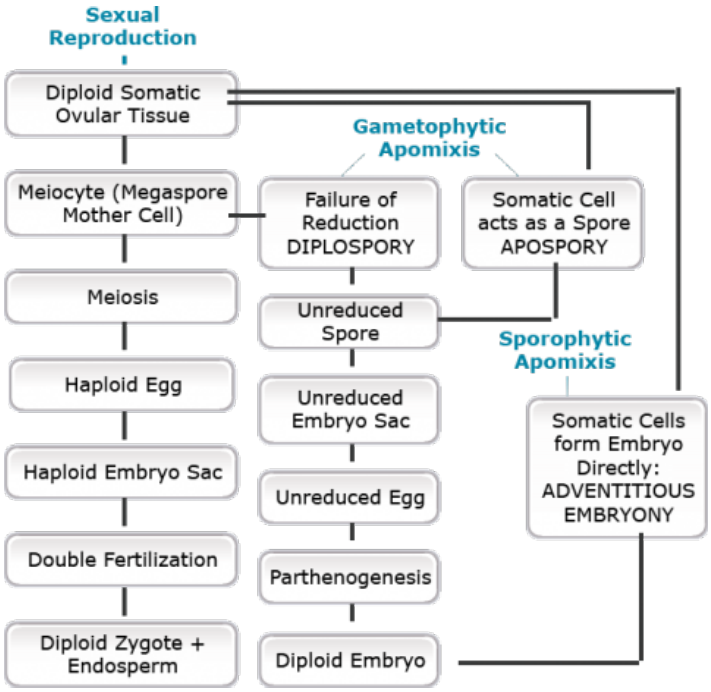


Fig. 11

Agamospermy

Apomixis generally involves forms of agamospermy, which is a process through which seeds develop without fertilization. There are two different degrees of agamospermy.

- **Obligate** – Seed produced arises from asexual reproduction.
    - **Advantages:** Preserves genotype, including heterozygotic genotypes
    - **Disadvantages:** Precludes genetic recombination and variation for selection of improved cultivars
- **Facultative** – Although most of the seed generated is asexually produced, sexual reproduction occurs regularly.
    - **Advantages:** Permits development of genetic variation for selection of improved cultivars
    - **Disadvantages:** Cultivars may be genetically unstable, making it difficult to maintain the desired genotype

Each of these degrees of agamospermy provides advantages and disadvantages from the plant breeding perspective.

There are also two general types of agamospermy.

- **Autonomous** – Endosperm forms without pollination or fertilization.
- **Pseudogamous** – Although fertilization (the fusion of gametes) does not occur, pollination is apparently required to stimulate apomictic embryo or embryo sac development to produce seed. Pollination adds no genetic material.

Mechanisms of Cause

The mechanisms that cause apomixis differ by the cell that undergoes mitosis to produce the embryo of the

seed.

- **Adventitious embryony** — The embryo develops directly from diploid sporophytic tissue, skipping the gametophytic stage. This is the simplest form of agamospermy.
- **Apospory** — Nucellus or integument cells, which are somatic cells, undergo mitosis to produce a diploid embryo sac.
- **Apospory** is the most common form of apomixis in angiosperms.
- **Diplospory** — The embryo and endosperm derive from the diploid megaspore mother cell. The megaspore mother cell's nucleus divides by mitosis, rather than meiosis, resulting in a diploid embryo sac.
- **Parthenogenesis** — The egg cell divides mitotically to form the embryo without fertilization.
- **Androgenesis** — A haploid embryo develops from a male sperm nucleus after it enters the embryo sac. The individual that develops from the seed is haploid and has the genotype of the sperm from which it is derived.

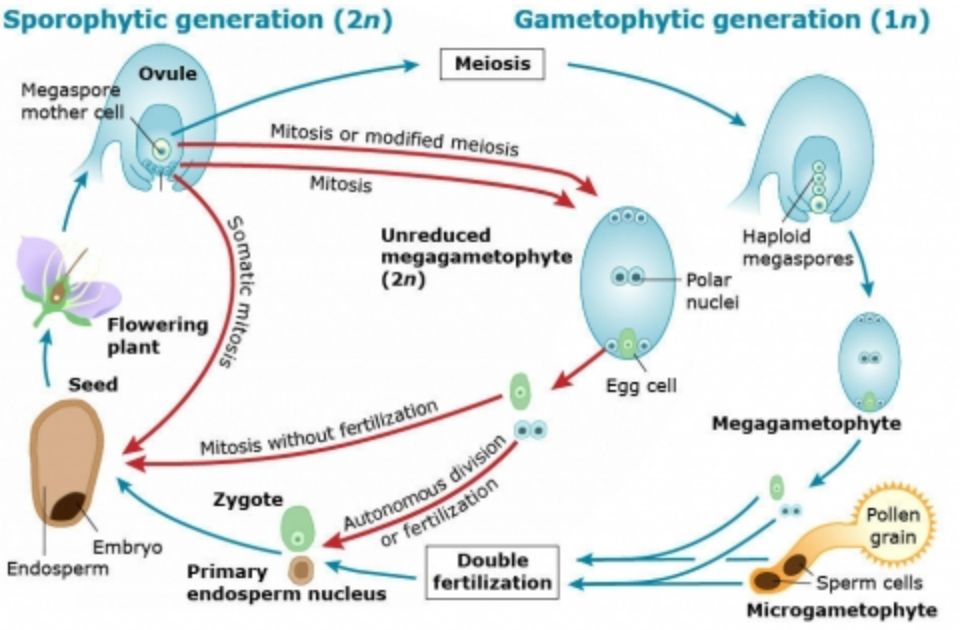


Fig. 12 The sexual life cycle of flowering plants and the apomictic reproduction by seed which occurs when the sexual life cycle is short-circuited. Adapted from Vielle-Calzada et al., 1995.

Study Question 9

Apomictic embryos may form from reduced (haploid) or unreduced (diploid) cells. For each situation, select the button according to whether the resulting embryo could be homozygous, heterozygous, neither, or both. Answer both parts of this question and then check your answer.

Embryo is derived from a reduced cell.

- ○ Heterozygous
- ○ Neither
- ○ Both
- ○ Homozygous

Check

Embryo is derived from an unreduced cell.

- ○ Homozygous
- ○ Heterozygous
- ○ Neither
- ○ Both

Check

Discussion

Crops can be self-pollinated, cross-pollinated, or vegetatively propagated. Discuss the breeding consequences of these three different methods of propagation. In addition: previously, a student suggested that with today's technologies, plants can simply be converted into self- or cross-pollinated or into vegetatively propagated species. Do you agree? Provide arguments in favor or against this statement, and examples, in case you are aware of any. Finally, if it was possible, which type of crops would be your favorite, and why?

Study Question 10

For each of the following terms, identify whether the term is associated with sexual, asexual, or both manners of reproduction by clicking on the appropriate button.

Seeds

- ○ Sexual
- ○ Both
- ○ Asexual

Check

Agamospermy

- ○ Asexual
- ○ Sexual
- ○ Both

Check

Self-pollination

- ○ Asexual
- ○ Both
- ○ Sexual

Check

Cross-pollination

- ○ Sexual
- ○ Both
- ○ Asexual

Check

Clones

- Sexual
- Both
- Asexual

Check

Gametes

- Sexual
- Asexual
- Gametes

Check

Meiosis

- Both
- Asexual
- Sexual

Check

Reflection

The Module Reflection appears as the last "task" in each module. The purpose of the Reflection is to enhance your learning and information retention. The questions are designed to help you reflect on the module and obtain instructor feedback on your learning. Submit your answers to the following questions to your instructor.

1. In your own words, write a short summary (< 150 words) for this module.
2. What is the most valuable concept that you learned from the module? Why is this concept valuable to you?
3. What concepts in the module are still unclear/the least clear to you?

References

Bicknell, A. R. and Koltunow, M., A. 2004. Understanding Apomixis: Recent Advances and Remaining Conundrums [Online]. Available by web link to American Society of Plant Biologists (http://www.plantcell.org/content/16/suppl_1/S228.full.pdf) (verified Jan 24, 2017).

Bashaw, E.C. 1980. American Society of Agronomy-Crop Science Society of America: 1980 Madison, WI, Hybridization of Crop Plants [Online]. Available at http://www.agron.iastate.edu/faculty/fehr/HOCP/03HOCP.pdf (verified Jan 24, 2017).

Chang, M.T., and M.G. Neuffer. 1989. Maize microsporogenesis. Genome 32(2): 232-244.

Lersten, N. R. 1980. Reproduction and Seed Development. Chapter 2, p. 17-44. In W.R. Fehr. and H. H. Hadley, editors. Hybridization of Crop Plants. American Society of Agronomy, Madison, WI.

Ozias-Akins, P. 2006. Apomixis: Developmental Characteristics and Genetics. Critical Reviews of Plant Sciences. 25: 199-214.

Pierce, B. A. 2008. Genetics: A Conceptual Approach. 3rd edition. W.H. Freeman, New York.

Schlegel, R.H.J. 2010. Dictionary of Plant Breeding. 2nd edition. CRC Press, New York.

Simmonds, N. W., and J. Smartt. 1999. Principles of Crop Improvement. 2nd. edition. Blackwell Science, Oxford, UK.

Smartt, J., and N. W. Simmonds. 1995. Evolution of Crop Plants. 2nd. edition. Longman, Essex, UK.

Vielle-Calzada, J-P., C. F. Crane and D. M. Stelly. 1996. Apomixis: the asexual revolution. Science 274: 1322-1323.

mcar2010. 2010. Plant reproduction.mov [Online]. YouTube. Available at http://www.youtube.com/watch?v=ZvBMQIrlhYw (verified Jan 24, 2017).

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