

Sexual Reproduction in Seed Plants


In the previous section you saw that plants can reproduce by asexual reproduction, which can quickly establish a population of plants. However, asexual reproduction cannot begin until at least one individual grows in an area. How does a plant get to a new area? In most vascular plants, it is by their seeds. The seed is the critical structure that allows the introduction of an individual to a new area (**Figure 1**). 



Figure 1 After a fire, the seeds of the jack pine are released from the cones into the community. These, along with seeds carried in from elsewhere, start the process of secondary succession.

CAREER LINK

Forest Fire Management

Some forest fires are a natural part of the developmental cycle of a forest. Species such as the jack pine could not survive without forest fires. However, other fires are caused by human activity and are more destructive than helpful. Forest fire management can involve determining when to let a fire burn and when to douse it. To learn more about a career in forest fire management,



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Seed Function and Structure

A seed has two main functions: to protect and nourish the enclosed embryo, and to carry the embryo to a new location. Seeds, and in the case of angiosperms, the fruits that contain them, have a wide range of structures and mechanisms to help them disperse (**Figure 2**). The ability of plant seeds to travel to a new location is crucial to introducing a species to a new area during succession. It is also important once a plant has established itself. Dispersal can move a plant's seeds to a location where there is less competition from other plants for resources, which increases the seeds' chances of survival.



Figure 2 Seeds are dispersed primarily by wind and animals. (a) Dandelion seeds have special structures that allow them to be carried long distances by wind. (b) The nutrient-rich tissues of some seed-containing fruits, such as serviceberries, attract mammals and birds, which carry them away from the parent plant. If the seeds then fall on fertile ground, they can grow.

endosperm the nutritive tissue in an angiosperm seed

Figure 3 shows examples of the general structures in monocot and eudicot seeds. The seeds of these plant groups contain an embryo, nutritive tissue to support embryo growth, and a protective seed coat. In angiosperms, the nutritive tissue may be supplied either by cotyledons or by a specialized nutritive layer called the **endosperm**. The seeds of angiosperms are contained in fruits, but gymnosperm seeds are not.

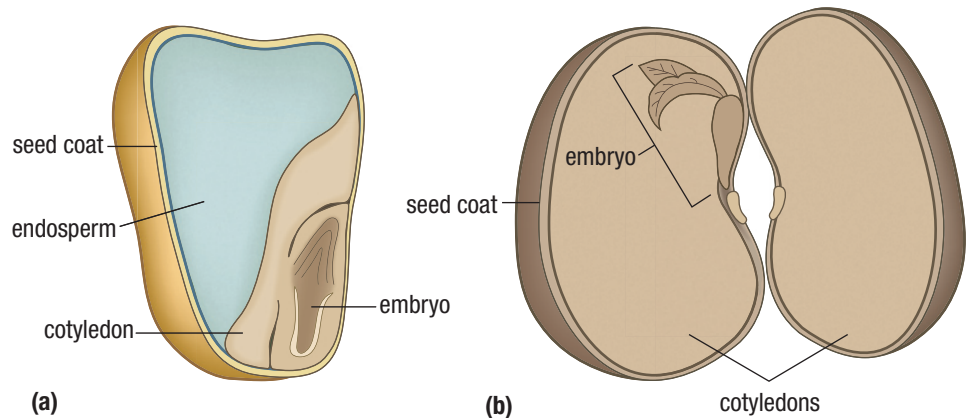


Figure 3 General seed structure in angiosperms. (a) A monocot and (b) a eudicot

LEARNING TIP

Chromosome Number

During meiosis, the number of chromosomes in a cell is halved, usually from diploid ($2n$) to haploid (n). Chromosomes undergo independent assortment during meiosis. You can review meiosis in Chapter 4.



Figure 4 Fruits of a potato plant

Costs and Benefits of Sexual Reproduction

Unlike asexual reproduction, sexual reproduction involves the union of two haploid cells. Sexual reproduction requires structures and cells that are devoted entirely to this process. A plant must devote a lot of resources to sexual reproduction, so when resources are scarce, carrying out sexual reproduction can lower the chances that an individual organism will survive. However, the potential costs of sexual reproduction are outweighed by its advantages.

- Populations produced by sexual reproduction have a high level of genetic diversity. If the environmental conditions change, there is a higher chance that some individuals in a genetically diverse population will have traits that are suited to that environment and will survive and reproduce.
- The products of sexual reproduction are seeds. Seeds can be dispersed away from the parent plant, and so the seedlings may have less competition for resources or better growing conditions.
- Seeds can remain dormant for long periods and then germinate when conditions are favourable, increasing the chance of survival.

Many plants can readily reproduce both sexually and asexually. For example, a potato plant produces numerous tubers from which genetically identical plants can arise. It also produces seeds by sexual reproduction. These are found in fruits that resemble small green tomatoes (**Figure 4**).

When a plant reproduces sexually, it uses specific structures and processes. These structures and processes vary among the different plant groups.

Sexual Reproduction in Gymnosperms

Cone-bearing gymnosperms, such as pines and cedars, provide us with most of the wood used in construction and paper products, as well as other useful products such as disinfectants and varnishes. The reproduction of gymnosperms therefore has great importance to our way of life. Conifers produce both male cones and female cones. Haploid cells called microspores are produced by meiosis within male cones. Each microspore develops into a pollen grain containing a male gametophyte. Meiosis in female cones produces megaspores that give rise to the egg-producing female gametophytes.

Pollination and Fertilization

Pollen grains have to get from a male cone to an ovule in a female cone. This happens by pollination. **Pollination** is the process of transferring pollen grains to an ovule. All gymnosperm pollination takes place by wind. The surface and structure of pollen grains help them to be carried by wind (Figure 5). In gymnosperms, pollination happens only when a pollen grain lands close to an ovule on a female cone (most pollen grains do not). A sticky resin and the cone's scale shape then help guide the pollen to the ovule. The pollen grain grows a **pollen tube**, which is a tube that grows down to the ovule.

As the pollen tube grows, its haploid nucleus divides by mitosis, producing two haploid sperm nuclei. Once the pollen tube reaches the female gametophyte, it releases the two sperm nuclei. One sperm nucleus fertilizes the egg, and the diploid zygote is formed. The other sperm nucleus degrades. It takes about 13 months for the egg to be fertilized after the pollen grain lands on the ovule. Upon fertilization, the ovule develops the various structures in the seed, and the zygote develops into the embryo. If this seed germinates, it may eventually become a mature sporophyte, and the cycle will be repeated (Figure 6).

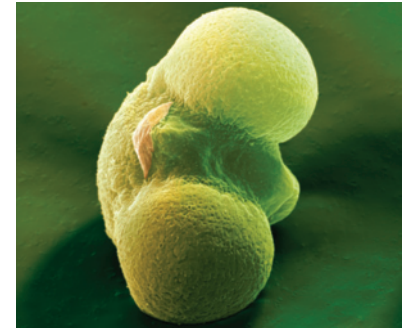


Figure 5 Pollen grain from a Scots pine ($\times 1600$ magnification)

pollination the transfer of pollen grains to an ovule

pollen tube a hollow tube that grows out of a pollen grain and carries the pollen nucleus to the female sex cell

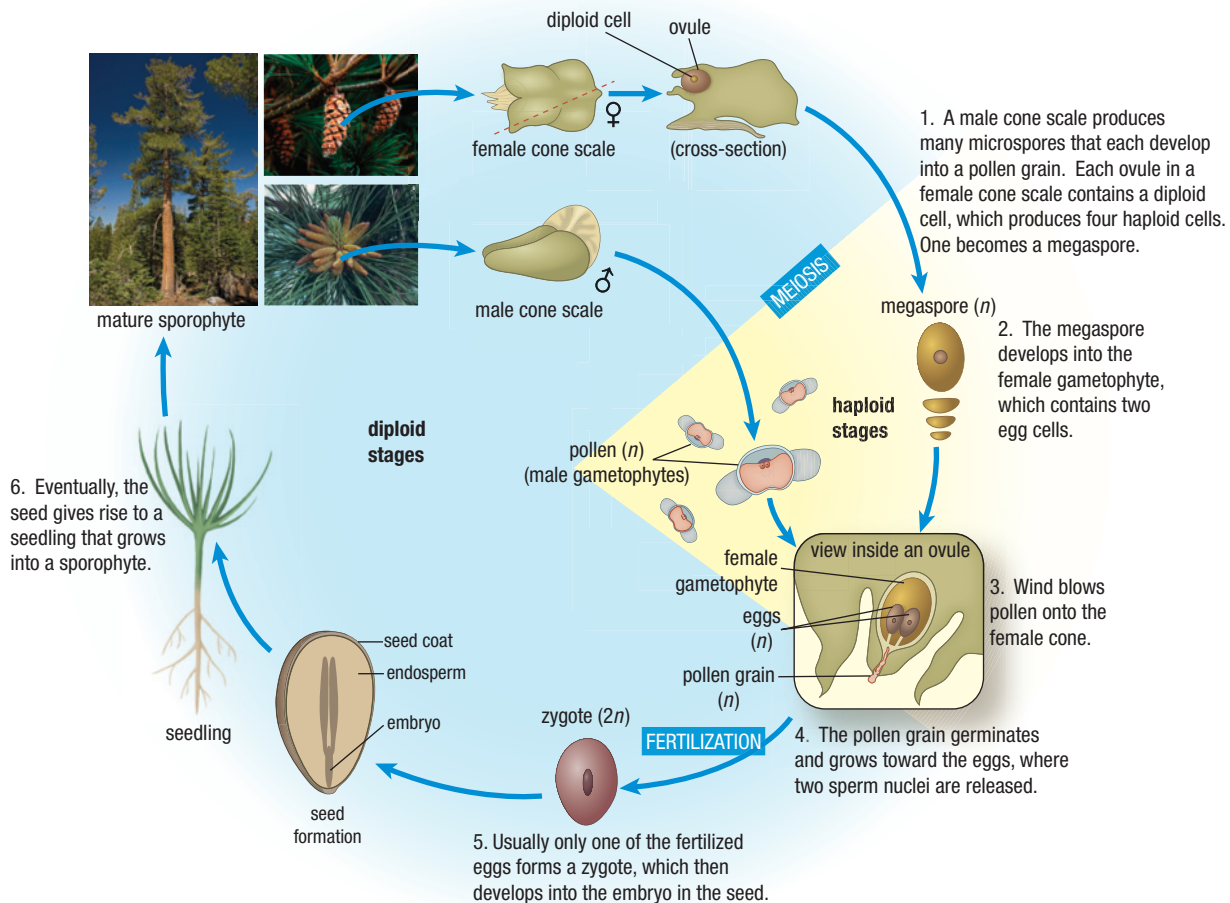


Figure 6 Life cycle of a gymnosperm

Sexual Reproduction in Angiosperms

The products of sexual reproduction in angiosperms are seeds contained inside a fruit, which is a mature or ripened ovary. These seeds and fruit are important to many organisms, since they contain energy and nutrients. For example, squirrels and many birds depend on angiosperm seeds to get through the winter months. Much of the human diet comes from angiosperm seeds and fruits.

stamen the male reproductive floral part, comprising an anther and a filament

anther the floral organ that produces pollen

filament the thin stalk that supports the anther

carpel the female reproductive floral part, comprising a stigma, a style, an ovary, and an ovule

stigma the sticky surface on top of the style

style the stalk that leads to the ovary

Flowers are the key organs in sexual reproduction of angiosperms. **Figure 7** shows the generalized structure of a flower. The **stamens** make up the male reproductive flower parts. A stamen is composed of an anther and a filament. The **anther** produces pollen grains. The **filament** raises the anther above the female organs. The **carpel** includes the female reproductive parts. The **stigma** is a sticky surface that acts as a landing site for pollen grains. Below the stigma is the **style**, a tube-like structure that leads down to the ovary. The ovary contains one or more ovules, each of which forms a seed when it is fertilized.

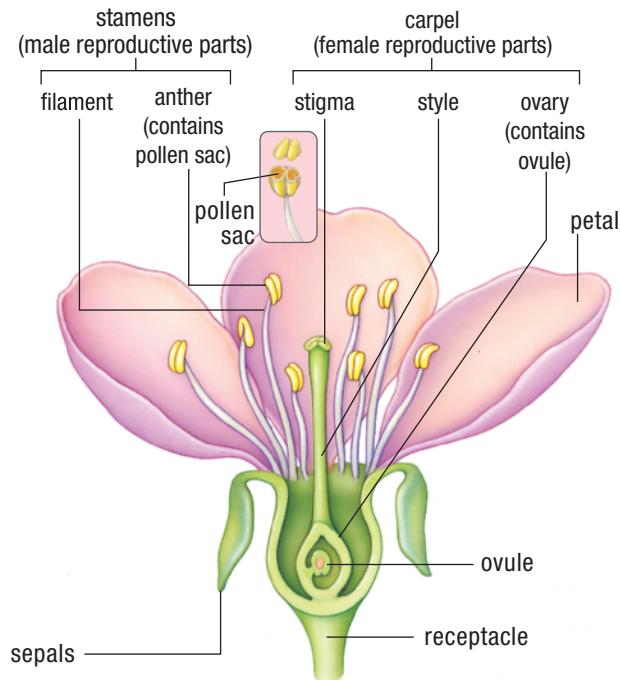


Figure 7 The flower of the wild rose contains both male and female structures.

There are distinct differences between monocot and eudicot flowers (**Figure 8**). The petals and stamens of monocot flowers are always in multiples of three. In eudicot flowers, petals and stamens are in multiples of four or five.



Figure 9 The flower of the dragon arum plant is very large and smells like rotting flesh to attract flies.



Figure 8 (a) The floral parts of monocots, such as this tulip, are always in groups of three or in multiples of three. (b) The floral parts of eudicots, such as this rose, are always in groups of four or five, or multiples of these.

Many animal-pollinated flowers are very showy, such as the dramatic flower shown in **Figure 9**, while wind-pollinated flowers, such as the flowers of a maple tree or a wheat plant, often go unnoticed. Not all species have all the structures shown in **Figure 7**. In some species, such as corn, each plant produces two types of flowers: the “tassels” on the top of the plant are flowers that have only male structures, and the cobs that grow lower on the plant are flowers that have only female structures. In other species, such as willows, an individual plant produces only male flowers or only female flowers. Some species, such as pepper plants, have many ovaries fused together, which contain many ovules.

Figure 10 (next page) shows the changes that take place in flower structures during the life cycle of a typical angiosperm.

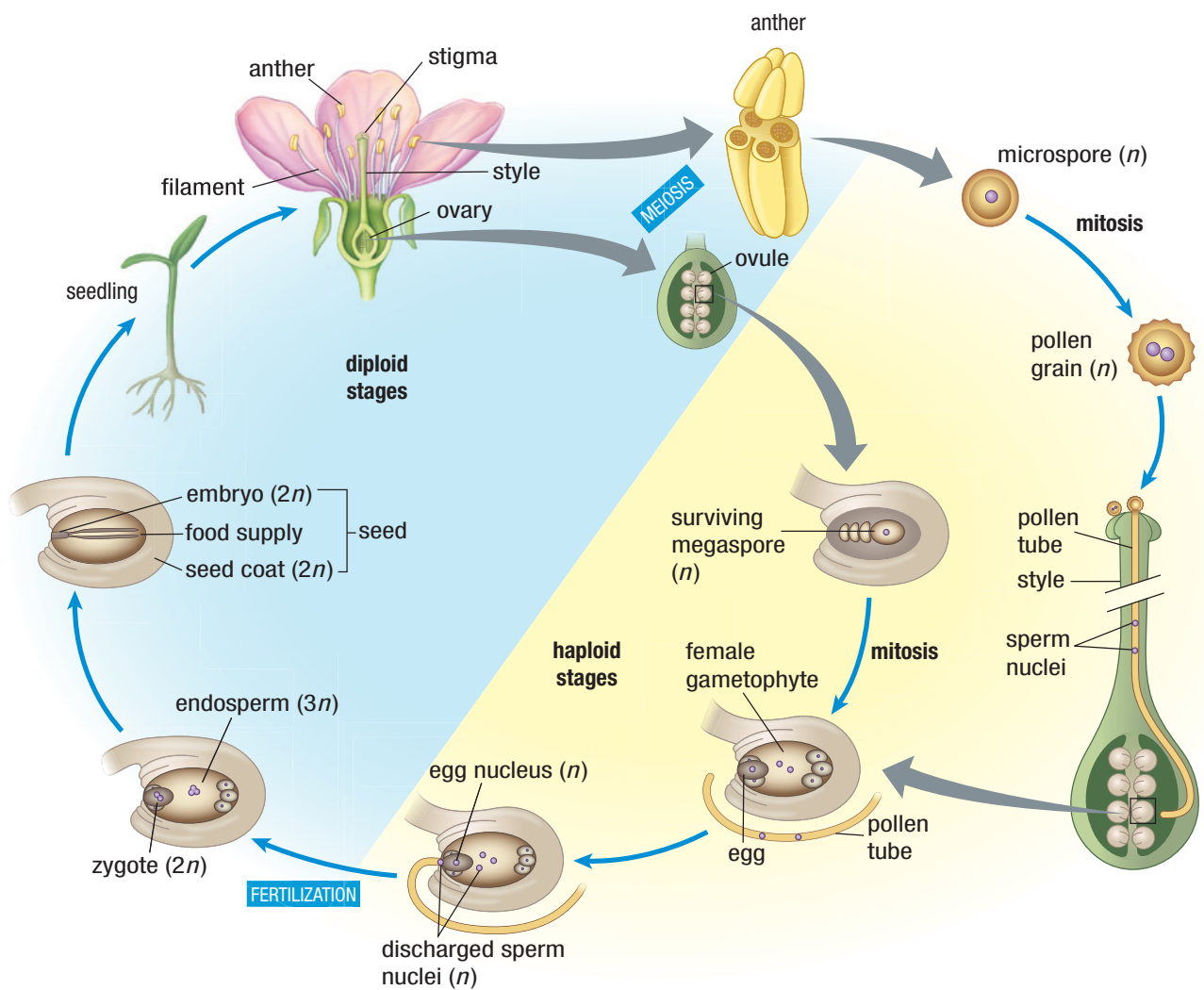


Figure 10 Life cycle of an angiosperm

Pollination and Fertilization

In angiosperms, pollination happens by wind or by animals, depending on the species. Animals that transfer pollen from one plant to another are called pollinators. Most pollinators are insects, such as bees, but other species can also be pollinators (**Figure 11**).

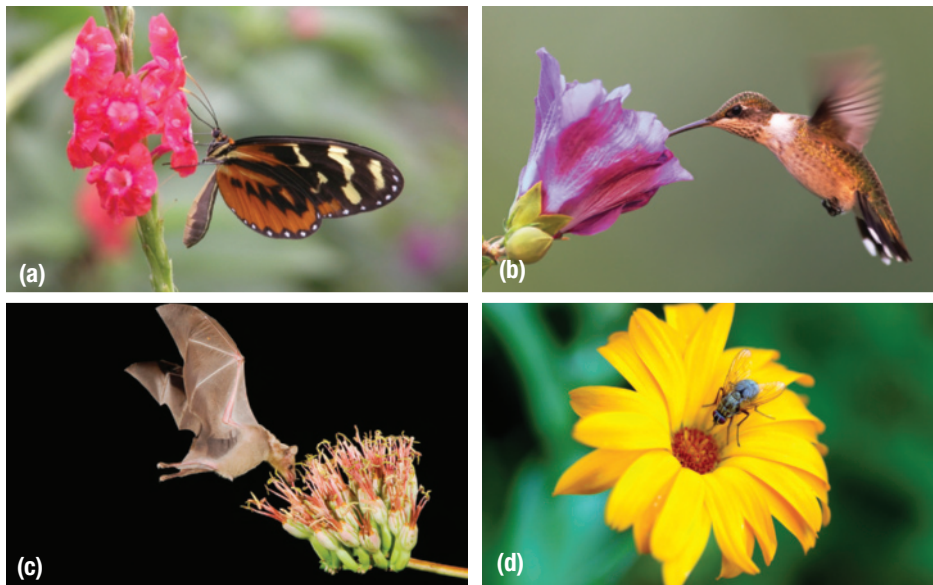


Figure 11 (a) Butterflies, (b) hummingbirds, (c) some bat species, and (d) flies all transfer pollen as they feed on nectar and pollen produced by flowers.

cross-pollination the transfer of pollen grains from one plant to another

self-pollination the transfer of pollen from one flower to another on the same plant

fruit mature ovary of an angiosperm, which contains the seed(s)

pericarp the fruit wall, which develops from the ovary wall of a fertilized angiosperm carpel

CAREER LINK

Fruit Grower

To find out more about careers related to fruit production,



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Unlike in gymnosperms, angiosperm pollination varies. Most species can only cross-pollinate. In **cross-pollination**, pollen grains must be transferred from one individual plant to another. Some plants, such as wheat and peas, can self-pollinate. In **self-pollination**, pollen can be transferred from one flower to another on the same individual plant. Plants that are capable of self-pollination can also cross-pollinate.

In angiosperms, an anther releases many pollen grains, which are then carried by wind or by a pollinator to the stigma of another flower. Pollination occurs as soon as a pollen grain sticks to the stigma. When conditions are right, the pollen grain begins to grow a pollen tube. The pollen tube grows down the style until it reaches the ovary. As with gymnosperms, the pollen tube of angiosperms carries two haploid sperm nuclei to the ovary.

Once the pollen tube reaches the ovary, both sperm nuclei are involved in separate fertilization events. This is called double fertilization. One sperm nucleus unites with the egg cell contained in the ovary, forming the diploid zygote. The second sperm nucleus fuses with two polar nuclei in the ovule, forming a triploid ($3n$) cell. This triploid cell develops into the endosperm.

Fruit Formation

A **fruit** is a mature ovary. Fruit development starts when an ovule is fertilized during double fertilization. The ovary wall develops into the fruit wall, called the **pericarp**. The pericarp may be fleshy or dry. A fruit helps to protect and disperse the seed, but the fruit does not provide nutrients to the developing embryo. Commonly, the word “fruit” is used for sweet, fleshy fruits, such as plums or strawberries, while “nut” and “grain” are used for dry fruits, such as walnuts or wheat. Fruits that are less sweet, such as peppers, squash, tomatoes, and peas, are usually called “vegetables” in everyday speech. However, the correct scientific term for any structure that is formed from a ripened ovary is “fruit” (**Figure 12**). 🌱

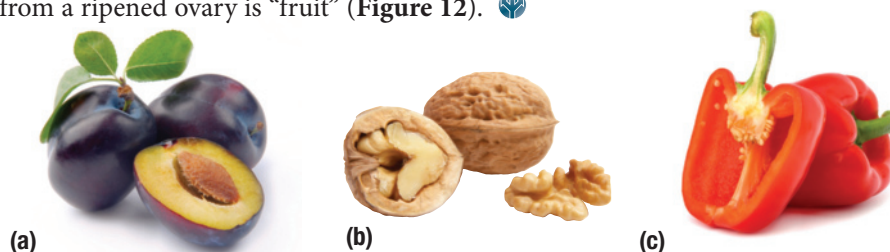


Figure 12 (a) Plums, (b) walnuts, and (c) red peppers are all fruits.

Research This

Disappearing Pollinators

Skills: Researching, Analyzing, Evaluating, Communicating, Defining the Issue, Identifying Alternatives, Defending a Decision

SKILLS
HANDBOOK A5.1

Angiosperms make up almost all food crops worldwide. Most of this food consists of seeds and fruits, which depend on pollination. Some scientists estimate that one mouthful in three requires insect pollination. Much of the variety in the flower structure of plants is designed to attract and stick pollen to a pollinator. In return, the plant gives food in the form of nectar and pollen to its pollinators. The most important insect pollinator in Canada is the European honeybee. Europeans brought this bee species to North America around 1638.

Unfortunately, recent studies have shown that the number of pollinators worldwide is falling. Honeybee populations have received the most attention. A condition called colony collapse disorder has decimated commercial hives, which in turn has reduced the productivity of fruit and vegetable crops that depend on these bees.

In 2009, the annual value of crop pollination by commercial honeybee hives in Canada was about \$1.2 billion.


Conduct research to find out more about the importance of pollinators to food production and the factors that are causing a decline in their numbers.


1. What do scientists think are the leading causes of colony collapse disorder?
 2. What are Africanized bees, and how do they affect pollination of crops?
 3. What other factors are affecting bee populations?
- A. Canada has a number of native bee species. Given this, do you think that the decline in honeybee population is a serious problem? Explain. T/I A
- B. Suggest changes that Canadians could make in their activities to help maintain the population of pollinators. T/I A



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Human Uses of Seeds and Fruits

Seeds of angiosperms such as wheat, rice, and corn serve as food staples for most humans. Seeds also have had a profound influence on the development of human culture. For example, the Hopi and other indigenous peoples of Central and North America refer to themselves as “The People of the Corn.” 

The development of agriculture depended on people learning to collect and save seeds. Much plant breeding still involves collecting seeds from plants with desirable traits. In developing countries, agriculture depends on individual farmers saving seeds from each year's crop. In countries such as Canada, agricultural companies rather than individual farmers carry out most seed production. 

Seed (grain) and fruit production is an important industry worldwide. In 2009, Canadian grain crops were worth \$13 billion, and fruit and vegetable crops were worth \$753 million. Most growers plant monocultures (for example, an apple orchard or a wheat field). This method is efficient, but it greatly reduces biodiversity and often relies on the use of fertilizers, pesticides, and irrigation (a watering system), as well as machinery that uses fossil fuels. Some fruits, such as peppers and tomatoes, are grown in greenhouses, which may require even more intense use of non-renewable resources.

Farmers, growers, scientists, and home gardeners are making changes to make fruit production more sustainable. These changes include growing varieties bred to be more resistant to pests, disease, or drought; covering soil to reduce moisture loss; and planting more than one species in an area (**Figure 13(a)**). Some greenhouse operators use predatory insects to limit pest infestations rather than using chemical insecticides. We can all make fruit production more sustainable by buying locally grown fruit in season and growing our own fruits in our yards or in community gardens (**Figure 13(b)**).



Figure 13 (a) Squash and zucchini planted between nectarine trees. (b) Community gardens in cities are becoming increasingly popular.

WEB LINK

Corn and Culture

To learn more about how corn cultivation affected the growth of civilization in the Americas,



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CAREER LINK

Seed Supplier

To find out more about careers related to seed production,



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Research This

Seed Banks


Skills: Researching, Analyzing, Communicating, Defining the Issue, Defending a Decision





SKILLS
HANDBOOK  A5.1

Approximately 75 % of the genetic diversity of agricultural crops has been lost in the last century. Over time, we have also come to rely on only a few plant species for food. Scientists estimate that 90 % of all human food energy comes from only 15 crops. The big three—rice, maize (corn), and wheat—provide 60 % of our food energy needs! Given the significance of a relatively small number of crops, it is vitally important to conserve the diversity within these major crops for global food security.

1. To keep our food supply secure, several nations have developed seed banks. Use the Internet to research seed banks and then answer the following questions.

- A. (i) What is a seed bank? Give an example of a specific seed bank in your answer.

- (ii) Do seed banks store only crop plants? Why or why not?
- (iii) Storing seeds in seed banks is costly because the environment must be strictly controlled. Do you think this cost is justified? Explain. 

- B. Conduct research to find out about seed banks around the world.  
- C. Determine what criteria seed banks use to choose which seeds to store, and why. 
- D. Identify the main reason why seed banks are being expanded. 



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13.3 Summary

- Seeds are the product of sexual reproduction; they, along with fruits, provide a dispersal mechanism and protect the embryo within them.
- Seeds are produced when haploid male sex cells in pollen unite with haploid female sex cells in an ovule.
- In gymnosperms, the pollen is produced in smaller male cones, and pollination and fertilization occur in the ovules contained in larger female cones.
- In angiosperms, the main reproductive structure is the flower. Pollen is produced by anthers on the stamen. The carpel contains the stigma and the style, which leads down to the ovary. The ovary contains one or more ovules, which form seeds after pollination and double fertilization.
- Angiosperm seeds are produced within a fruit, which is a ripened ovary.
- Seeds are an important food source for many organisms, including humans.
- Human culture was advanced by understanding and using seeds.
- Traditional methods of producing angiosperm fruit by monoculture are not sustainable. However, methods that are more sustainable continue to be developed.

13.3 Questions

1. What are the main functions of a seed? Given these functions, why is it not surprising that seeds are an excellent source of nutrients? **K/U A**
2. Seeds do not germinate until conditions are right. How does this compare with the hatching of a bird's egg? What advantage does this adaptation give plants? **K/U A**
3. Make labelled diagrams of a monocot and eudicot. In what ways are the seeds similar? How do they differ? **K/U C**
4. List and state the functions of each of the seed parts you labelled in Question 3. **K/U**
5. Describe the unusual adaptation of jack pines for releasing their seeds. Relate this feature to the ecological process of succession. **K/U A**
6. Describe the function of pollen in gymnosperm and angiosperm sexual reproduction. **K/U**
7. Some pollen grains are dry and some are sticky. **T/I A**
 - (a) Which would you expect to be carried on wind and which on the body of a pollinator?
 - (b) Many people have pollen allergies. Suggest whether dry or sticky pollen would cause more allergies. Give reasons for your answer.
8. In angiosperms, pollination occurs when the pollen lands on and sticks to the stigma. Has fertilization occurred at this point? If not, describe the events that lead to fertilization. **K/U**
9. Define the scientific term "fruit" and give four examples of fruits. Include examples that are commonly referred to as grains, nuts, and vegetables. **K/U T/I C**
10. Is the traditional way of growing fruit sustainable? Explain why or why not. **T/I A**
11. Name at least three things you could do to reduce the negative effects of fruit production on the environment. Would you be willing to do these things? Why or why not? **K/U A**
12. Create a table or a graphic organizer that summarizes all the structural differences between monocot and eudicot angiosperms that you have encountered so far in this unit. **K/U C**