3.5 Reproductive Technologies in Agriculture

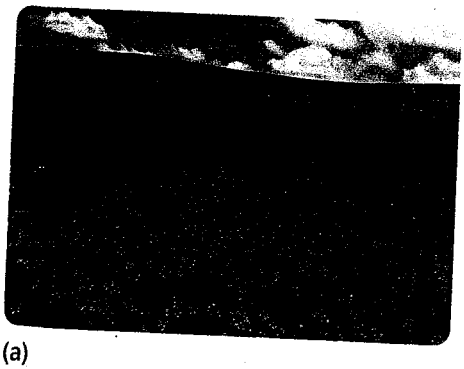
Scientists use their understanding of asexual and sexual reproduction to enhance agricultural crops. Populations of both wild and domestic animals are being managed by humans through the use of reproductive technologies. In fact, most of the foods you eat are the result of reproductive technologies.

LEARNING TIP

Headings act as guidelines for reading. Check your understanding as you read. Turn each heading into a question, and answer your question.

Selective Breeding

The most commonly used reproductive technique is selective breeding. In **selective breeding**, two plants or two animals of one species that have desirable traits are bred with each other. The breeder then selects the offspring that show the desirable traits of the parents and breeds them with other individuals with the same traits. After selectively breeding individuals over several generations, all the offspring will have the desirable traits (Figure 1). For example, beef cattle have been selectively bred to produce high quality and quantity muscle (meat). Canola plants, whose seeds are used to produce a cooking oil, have been selectively bred to improve the quality of the oil.



(a)

(b)

Figure 1 Selective breeding is used to improve many traits. Canola (a) can be bred to withstand cold weather. Beef cattle (b) can be bred to produce more meat.

Artificial Vegetative Reproduction

Other techniques take advantage of the ability of many plants to reproduce vegetatively, without sexual reproduction. If growers have a plant that has desirable traits, they can take cuttings from it and grow new plants from the cuttings. The drawback to cuttings is that only so many cuttings can be taken from a plant. Scientists have developed a quicker way to produce plant clones. They remove individual cells from a desirable plant and place them in bottles or Petri dishes that contain nutrients and growth hormones (Figure 2). Once the seedlings have grown roots, they are planted in soil. The advantage of this type of cloning is that many more clones can be produced from a single plant.

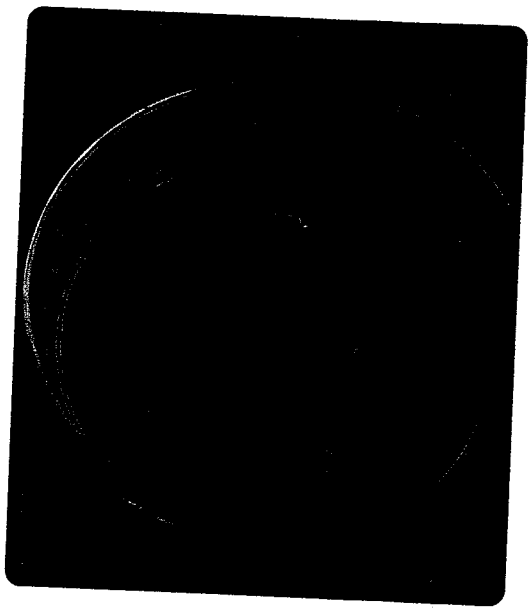


Figure 2 Shoots and roots have started to develop from a few cells that were taken from a carrot plant and placed in a growth medium in this Petri dish.

LEARNING TIP

Photographs play an important role in reader comprehension. As you study Figure 3, ask yourself, "What do these photographs show?" Then move on and look at each photograph.

Another technique is grafting, which is commonly used for fruit trees (Figure 3). Grafting involves attaching a branch from a desirable tree onto the trunk of another tree that may have excellent roots but poor fruit. The bark of the grafted branch will fuse with the bark of the root tree. The branch will grow and eventually produce fruit. Grafting allows growers to turn one good tree into thousands of copies. Most varieties of apples, grapes, and peaches are produced by grafting.

Figure 3 For grafting to work, plants must have a tissue called cambium in their bark. Not all plants have this tissue.

Artificial Insemination and In Vitro Fertilization

Sometimes domestic animals cannot conceive in the normal way as quickly or as often as farmers would like. A technique called **artificial insemination** is used. A veterinarian collects sperm from a male animal and inserts it into a female animal of the same species. This technique is used extensively in agriculture to breed domestic animals with desirable traits. Most dairy cows are conceived using artificial insemination. This technique is also used in zoos to maintain or increase the population of endangered species. In both situations, sperm is collected from the desired male and frozen. It is then transported to female animals in far away farms or zoos. The sperm is inserted into the female's vagina immediately following ovulation. Thus, the sperm of one champion bull can fertilize the eggs of many cows in different locations.

In vitro fertilization is a process that builds on artificial insemination. The sperm and several mature eggs are collected from male and female animals with desired traits and fertilization occurs in a lab, in a Petri dish. (*In vitro* means "in glass.") Once the eggs are fertilized, the embryos can be inserted into many different female cows. These cows are surrogate mothers because they are not genetically related to the embryo. The advantage of in vitro fertilization is that it produces many more embryos than would be produced naturally.

Hatcheries

Fish hatcheries use technology to ensure a higher rate of survival in wild fish populations. For example, wild salmon use external fertilization, which means that relatively few eggs are actually fertilized. Just before they are ready to reproduce, male and female fish are caught. The eggs and sperm are collected and mixed together in a container (Figure 4). The fertilized eggs are incubated in special trays that have a constant supply of cold running water. Once the eggs hatch, the young are fed at the hatchery before they are released into the wild. This process produces a much greater number of young salmon than would occur naturally.

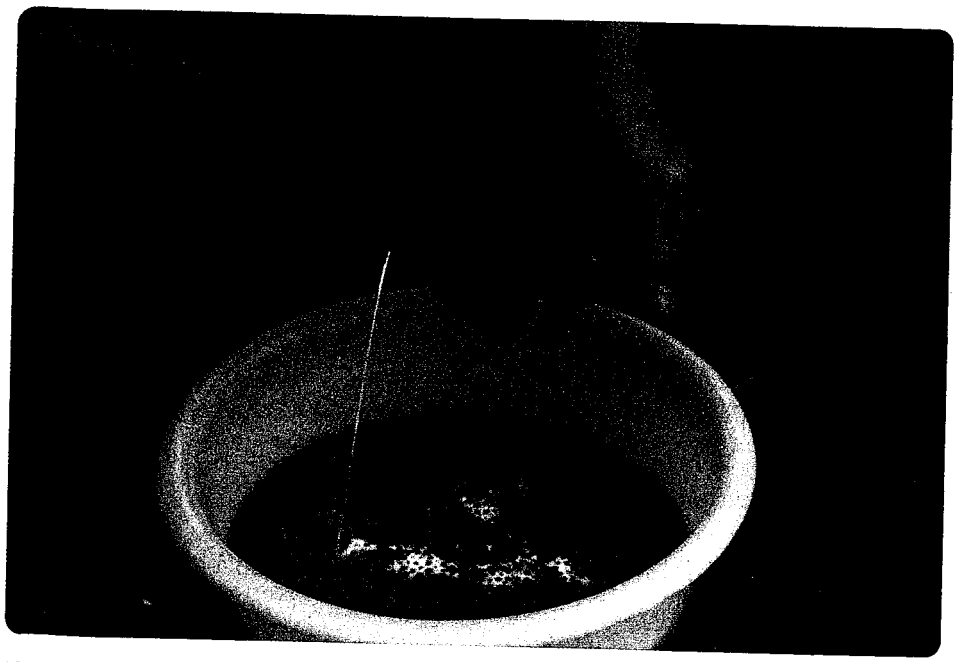


Figure 4 Hatcheries increase the success rate of external fertilization. Here sperm is being squeezed out of a male fish into a bowl of eggs that have been collected in the same way.

Recombinant DNA

Recombinant DNA technology involves combining genes from different individuals or different species into a single molecule of DNA. Biotechnology companies use this technology to produce certain characteristics in organisms or to produce substances from organisms. For example, human growth hormone, which is used to treat some forms of dwarfism, was originally extracted from the pituitary glands of dead people. Now bacteria that contain recombinant DNA produce it. The human gene that codes for growth hormone is inserted into a bacterial cell. The bacterium incorporates the new strand of DNA into its cytoplasm as a plasmid. This new genetic material directs the bacterial cell to produce human growth hormone. Through cell division, the new DNA is replicated in millions of daughter cells. Each daughter cell produces human growth hormone. The growth hormone is then collected. Bacteria are the organisms that are most commonly used to produce drugs, including insulin for diabetics and vaccines to prevent hepatitis B.

Did You KNOW?

Aerostar

Over a million doses of sperm from the famous Canadian Holstein bull, Aerostar, have been used to artificially inseminate cows all over the world. Aerostar's female offspring were among the world's highest milk producers. Born in Ontario in 1985, Aerostar spent his productive years at the B.C. Artificial Insemination Centre in Langley. Aerostar died in 2004. Many of his male offspring are now producing excellent dairy cows.

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TRY THIS: A Model of Recombinant DNA

Skills Focus: creating models, recording

Materials: 2 jars with lids containing ticker tape that has coloured markings, scissors, clear tape

In this activity, you will use jars and ticker tape to simulate recombinant DNA technology.

1. Open the lid of Jar 1, the donor cell's nucleus. Remove a loop of DNA 1. The red gene has been selected for removal. Cut out the red segment.
2. Open the lid of Jar 2, the receiving cell's nucleus. Remove a loop of DNA 2. Notice that there is no red segment in the chromosome. Find the green segment, which represents the gene that will be replaced. Cut out the green segment.
3. Tape the red segment to the open ends of DNA 2. Place the loop back in Jar 2, and close the lid. Remove the label, and replace it with the label "Jar 3."

A. Why did you relabel Jar 2?

B. Explain why Jar 1 no longer represents a complete nucleus.

C. Why is the term "gene splicing" sometimes use to describe recombinant DNA technology?

D. Summarize this model in a labelled diagram.

Genetic Engineering in Agriculture

Organisms with genes that have been intentionally altered are called **genetically modified organisms (GMOs)**. Many food crops have been genetically modified to resist spoilage or disease, to delay ripening, or to improve their nutritional content.

In the 1960s, Canadian scientists used selective breeding to improve the colour and flavour of the oil produced by Canola plants. Recently, GM canola plants that resist drought and disease have been developed.

Controversies can arise with GM crops. A variety of canola has been genetically engineered to resist a particular herbicide (Figure 5). Once the seedlings are a certain height, the fields are sprayed with the herbicide, which kills the weeds but not the canola. A company has patented the seed and sells it at a very high price. One farmer was sued by the company that owns the patent. He had the herbicide-resistant plants growing on his land. The company claimed that the farmer did not purchase the seeds. The farmer claimed that he did not intend to grow the herbicide-resistant plants. The pollen from the adjacent fields of canola must have fertilized his plants so that he, too, had resistant plants. The Supreme Court of Canada ruled that the farmer had violated the company's patent. However, since the farmer's profit was no greater than if he had not used the seed, the Court ruled that he did not have to pay the company's technology fees.

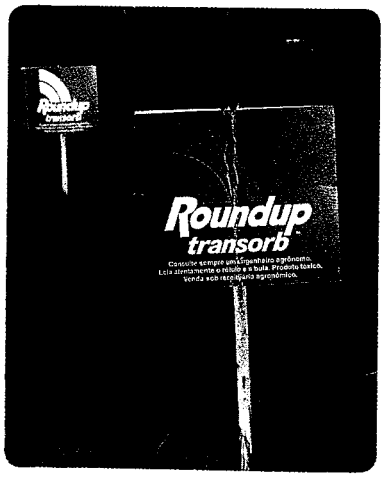

Figure 5 Some GM crops have been developed to resist a herbicide called Roundup.

If you would like to learn more about this court case, go to **www.science.nelson.com**

This case, and others, leads to the concern that GMOs could pass their DNA to wild populations and produce super-organisms. It also raises the issue of who owns these new organisms. Another concern is that GMOs might pose a risk to humans who eat them. Some GMOs contain genes from another species. For example, some pigs have been genetically modified with human genes. The meat of these pigs contains less fat, which is healthier for humans. Some countries have banned GMOs, while other countries have regulations that require food companies to indicate clearly on the label if a product has been genetically modified. Currently, Canada has no regulations regarding labelling.

3.5 CHECK YOUR Understanding

1. Name two organisms that have been improved by selective breeding.
2. (a) Identify the process that is being used in Figure 6.
   (b) Name some plants that are artificially reproduced by this process.
   (c) What is the advantage of this process?

Figure 6

3. In general, what type of plants are artificially reproduced using grafting?
4. Describe the process of artificial insemination in farm animals.
5. In addition to farm animals, with what other animals is artificial insemination sometimes used?
6. (a) What does *in vitro* mean?
   (b) Where does in vitro fertilization take place?
7. Of what benefit to salmon survival is fertilizing the eggs in a bucket instead of naturally in the wild?
8. (a) Which organism is most frequently used for recombinant DNA technology?
   (b) Describe how recombinant DNA technology works.
9. Name three substances that are produced by recombinant DNA technology.
10. What does "GMO" stand for?
11. Give an example of a crop that is a GMO.
12. What are the concerns about eating foods made from GMOs?
13. Compare and contrast three types of vegetative reproduction techniques that are used in agriculture.
14. In vitro fertilization can be used to produce calves that have the same genetic mother and father, but different birth mothers. Explain how this can happen.
15. Explain how artificial insemination is different from in vitro fertilization.
16. Why might a gardener want to graft branches from different trees onto a single stem?
17. A brand of GM crops is called "Roundup Ready" (Figure 7).

Figure 7

   (a) Explain why the crop is called "Roundup Ready."
   (b) Why might farmers find these plants more desirable that non-GM plants?