TOPIC 1.4

How and why are the genes of organisms manipulated?

These two animals, named Pete and Webster, are not typical goats. A Canadian biotechnology company inserted a spider gene into their gametes, and now they produce spider silk protein in their milk. Spider silk has many possible uses, including as a component of tough, light-weight steel. Because spider silk is not rejected by the human body; this steel could be used to create durable, low-weight artificial limbs, tendons, and other replacement connective tissue for use in humans.

Key Concepts

- DNA of a living cell can be copied, modified, and inserted into another organism.
- DNA technology has many uses.
- The use of biotechnology has some risks and raises some ethical issues.

Curricular Competencies

- Communicate ideas, claims, information, and courses of action for specific purposes
- Transfer and apply learning to new situations.
- Consider the role of scientists in innovation.
- Connect scientific explorations to careers in science.

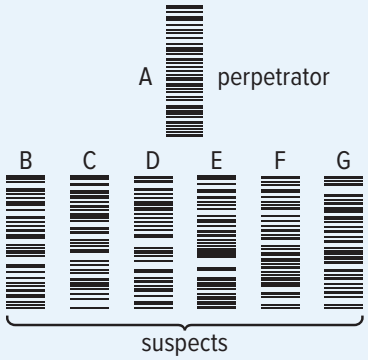
Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** The topic of biotechnology is often in the news. What do you think of when you hear the term? Are the associations you have positive, negative, or neutral? Why?

2. **Checking for Bias** One area of biotechnology includes developing ways to prevent certain types of inherited genetic disorders, especially those that are fatal. Do you think everyone should be tested for possible genetic disorders? Would you want to know if you had a genetic disease that may kill you before you turned 40? Reflect on your ideas in small groups or privately.

3. **Applying** A person can be identified from a single strand of hair. Except for identical twins, every person's body contains unique genetic information. Thus, your DNA is like your fingerprint. Police can use DNA fingerprinting to identify people based on samples such as a hair collected at a crime scene. Can you identify the perpetrator of this crime using DNA evidence shown on the right? Do you think this method is foolproof? Why or why not?



Sample A is the DNA fingerprint taken from a strand of hair. The hair was found on the victim, but it is not the victim's hair. Samples B though G are DNA fingerprints of hair taken from six suspects.

Key Terms

There are seven key terms that are highlighted in bold type in this Topic:

- biotechnology
- recombinant DNA
- in vitro fertilization (IVF)
- cloning
- artificial insemination
- gene therapy
- gene cloning

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meanings. Add other terms that you think are important and want to remember.

CONCEPT 1

DNA of a living cell can be copied, modified, and inserted into another organism.

Activity

Cloning—As easy as it is in science fiction?

You may have seen a science fiction film that had a character that had been cloned. Although a film may make it look easy to clone an organism, it is actually quite complicated to clone a single cell or even a piece of DNA within a cell. What do you think is needed to clone a gene, a cell, or a whole organism? What type of setting and equipment might be needed to clone something?

biotechnology the use of technology and organisms to produce useful products

cloning a process that produces identical copies of genes, cells, or organisms

gene cloning manipulating DNA to produce multiple copies of a gene or another segment of DNA in foreign cells

recombinant DNA a DNA molecule that includes genetic material from different sources

Over the last 60 years, the combination of science and technology has allowed us to learn more about DNA and about how to modify, or make changes to, genes. These techniques are often called **biotechnology**. One example of biotechnology is **cloning**. In general, cloning is defined as a process that produces identical copies of genes, cells, or organisms. However, the word *cloning* can mean very different things, depending on what is being copied. This book focusses on the process scientists use to clone a gene.

Gene Cloning

Gene cloning involves manipulating DNA to produce multiple copies of a gene or another segment of DNA in foreign cells. The cloned DNA can be used for further study or for mass producing the protein that the gene codes for. Proteins produced in this way have many commercial and medical applications. For example, insulin is a hormone that enables the body to use sugar; it is absent in people diagnosed with type I diabetes. Before gene cloning, people with diabetes used purified insulin from animal sources. Producing insulin this way was labour-intensive and expensive. Since the early 1980s, human insulin has been produced in bacteria through cloning of the insulin gene. The general experimental approach to gene cloning is described below. Refer also to **Figure 1.33**, which summarizes the steps in cloning a gene in bacteria.

1. Isolate the segment of DNA to clone, and choose a *vector* for cloning. Vectors act as carriers of the DNA to be cloned so that it can be copied in a foreign cell. One common vector for cloning in bacteria is called a *plasmid*. Plasmids are small, circular pieces of DNA that remain distinct from the bacterial chromosome.
2. Insert the chromosomal DNA into the vector. This relies on the use of enzymes that can cut DNA and help different pieces join together. The resulting DNA molecule, which includes genetic material from different sources, is called **recombinant DNA**.

3. Treat foreign cells, such as bacterial cells, so that they take in the recombinant DNA. This process is called *transformation*. Once the recombinant DNA plasmid is taken into the cell, many copies of the cloned gene or DNA fragment will be made by the host cell.

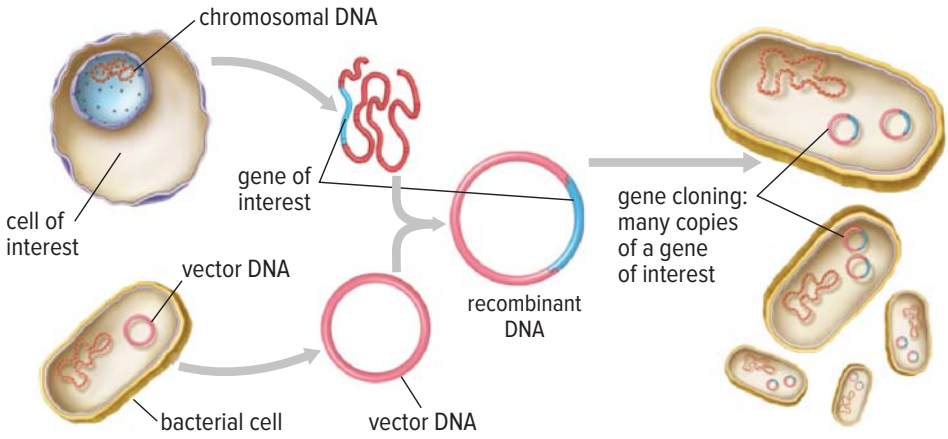


Figure 1.33 A gene or piece of DNA can be cloned. Many copies of it or the protein that the gene codes for can be produced and isolated. **Comparing: How does the recombinant DNA molecule differ from the vector DNA?**

Transgenic Organisms

Researchers have also developed techniques to investigate and alter the genetic material of many organisms. The process of specifically altering the genetic make-up of an organism is called *genetic engineering*. Genetic engineering involves making precise changes directed by the researcher (**Figure 1.34**). These include making specific changes to the sequence of DNA, such as introducing a mutation into a gene. Other kinds of changes are also possible. Genetic engineering involving the introduction of foreign DNA into an organism's genome, such as a gene from another species, results in a *transgenic organism*. Transgenic organisms are a type of genetically modified organism, or GMO.

Figure 1.34 This researcher is investigating ways to manipulate corn kernel traits such as starch and oil content.

Applications of Transgenic Plants

Transgenic crop plants account for more than half the corn and canola grown in North America. Many have been modified to increase their resistance to herbicides, insect pests, fungal infections, or viruses.

Transgenic Plants: Golden Rice

Scientists are also working to produce genetically modified plants with increased nutritional value. In many developing countries where rice is the main staple food, symptoms of iron and vitamin A deficiencies affect hundreds of thousands of people. In 2000, researchers in Switzerland developed a genetically modified strain of rice known as golden rice, shown in **Figure 1.35**. This rice has been genetically modified to increase its iron and vitamin A content. Golden rice is still in experimental stages, but it is considered to be the first GMO crop that was made to help reduce malnutrition.

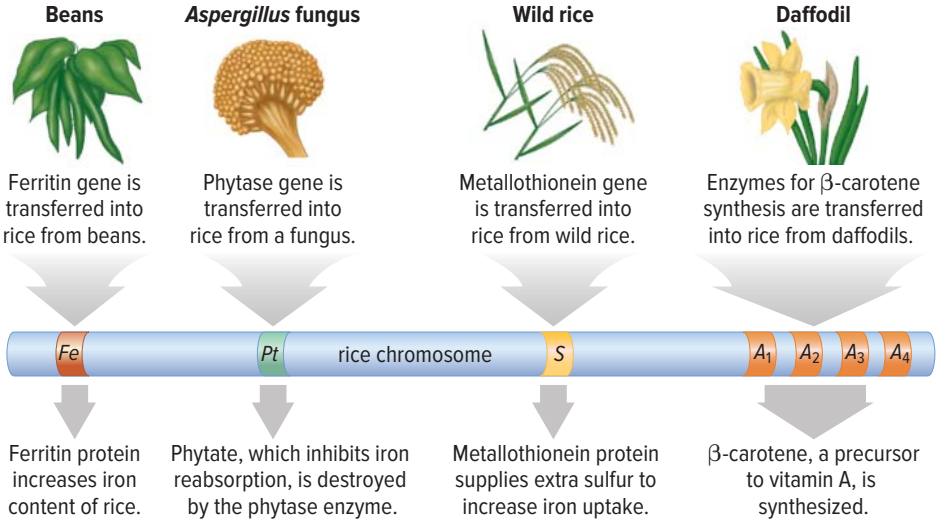


Figure 1.35 This transgenic product, golden rice, contains four different foreign genes. Three of these genes come from other plants, and one comes from a fungus. **Inferring: How could the development of such a disease-resistant plant be economically advantageous?**

Transgenic plants can also be used for medical purposes. In 2009, researchers used tobacco plants to produce virus-like particles that were used in vaccines against the A/H1N1 flu pandemic that hit the same year. Because the researchers used plants to produce the virus-like particles, they were able to develop a vaccine against the strain of virus causing the pandemic very quickly.

Activity

"Tough" Plants

One of Canada's most important crops is corn. European corn borers and corn earworms are insects that can destroy corn crops when they feed on them. A bacterium called *Bacillus thuringiensis*, makes a toxin that kills these insects when they ingest it. Scientists extracted the genes that control the production of the toxin from the bacteria and inserted them into the corn DNA. The genetically modified corn can now create the toxin. When the insects feed on the corn, they die shortly after being exposed to the toxin.

Many other crops, including soybean, potato, and strawberry, have been developed so they are resistant to diseases and insects. There is even a new apple that has been genetically modified so that its flesh does not turn brown if it is bruised or after it is cut or bitten into.

Suppose you are a transgenics scientist. Propose an idea for a genetically modified fruit or vegetable that most people eat. Write a paragraph explaining why you think you should look for a gene to alter that crop.

Applications of Transgenic Animals

Animals such as mice, fruit flies, and roundworms are widely used in research laboratories around the world to study diseases and ways to treat them. Transgenic milk-producing animals, such as goats, are being used to produce medical protein products that include human growth hormone and anti-clotting factors. **Figure 1.36** shows the main steps in creating a herd of goats that are genetically modified to secrete specific proteins in their milk. Recall also Pete and Webster in the opening to this Topic.

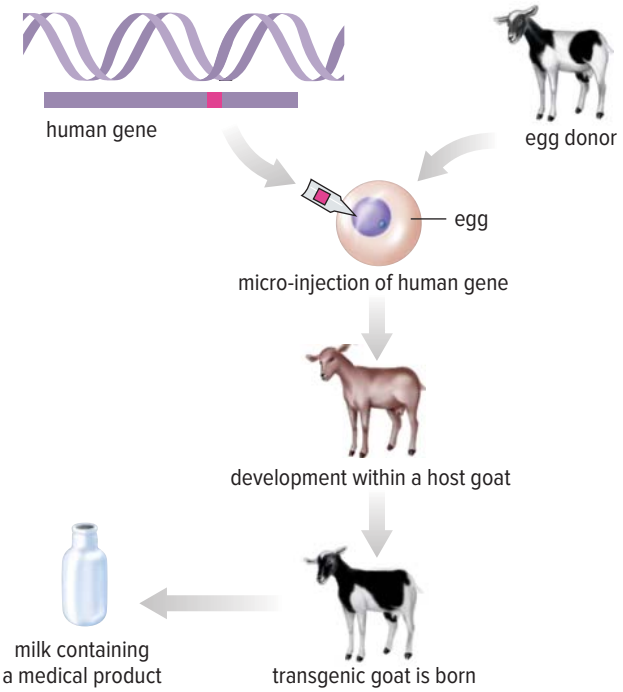


Figure 1.36 Genetic engineering can create transgenic animals that secrete human proteins or other substances in their milk. **Communicating: In your opinion, is it ethical to use animals in this way? Why or why not?**

Another area of research involves developing transgenic animals that can serve as organ donors for humans. Usually, transplanting organs from donor animals, such as pigs, into humans has very limited success because of tissue rejection. Some research teams are conducting work to develop transgenic pigs that are more compatible with human tissues. Research such as this also raises difficult issues, however. Some people are concerned about the risk of transferring diseases from pigs to humans. Other people ask whether it is ethical to create new kinds of animals purely for the purpose of harvesting their organs.

Before you leave this page . . .

1. What is the function of a vector in gene cloning?
2. Make a T-chart to list the different uses of transgenic plants and transgenic animals.

CONCEPT 2

DNA technology has many uses.

Advancements that have come from biotechnology can affect many aspects of our lives. Besides cloning and transgenic organisms, another example is a DNA profile, like the one shown in **Figure 1.37A**. A DNA profile determines the sequences of certain regions of a person's DNA that are unique to each individual. DNA profiles are used by law enforcement to try to match a person's DNA to a sample found at a crime scene. DNA profiles are also used to determine if people are related to each other.

Reproductive Technologies

Advancements in biotechnology and genetics also have touched one of the most basic biological activities—reproduction. These technologies have changed the way many people are conceiving children. They represent different options for people who want to have children but who are not able to conceive a child on their own.

In **artificial insemination**, sperm are collected and concentrated before being placed in the woman's uterus. This technique was originally developed to promote breeding success among domestic animals. Human couples have been using artificial insemination successfully for many years since it was first performed in the 1940s.

Another example of the use of biotechnology to help people conceive children is **in vitro fertilization (IVF)**. In IVF, the woman's eggs are retrieved and combined with sperm in laboratory glassware. (*In vitro* is Latin for "in glass," and refers to the petri dish in which fertilization takes place.) After fertilization, one or more of the developing embryos are placed in the woman's uterus. Once an embryo becomes implanted, the pregnancy proceeds. In 1978, the birth of Louise Brown, the first baby born as a result of IVF, offered hope to many couples whose inability to conceive a child was due to the woman having blocked fallopian tubes. This prevents the sperm and egg from coming into contact for fertilization. A type of IVF technique, called intracytoplasmic sperm injection (ICSI) is shown in **Figure 1.37B**.

artificial insemination
a process that involves collecting and concentrating sperm, and then placing it in the female's uterus

in vitro fertilization (IVF)
a process that results in a female's eggs being fertilized by sperm outside of the body

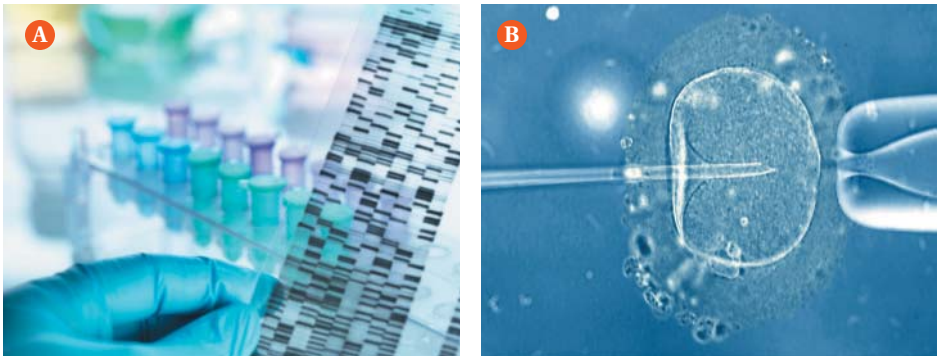


Figure 1.37 A DNA profiles are used by law enforcement to identify or eliminate perpetrators of crimes. B In a form of IVF called intracytoplasmic sperm injection (ICSI), the sperm is injected directly into the egg.

Gene Therapy

Understanding the role genes play in human diseases is an especially important part of biotechnology. This involves finding genes or genetic material that has been mutated in some way, and then identifying a link between those changes and a particular disease. Finding the genetic material that causes a disease enables doctors to make better diagnoses and to predict the likelihood of a person developing it.

gene therapy an experimental treatment to cure genetic disorders that involves inserting a healthy, normal form of a gene into the cells of tissues that are affected by a disorder

Gene therapy is an experimental treatment to cure genetic disorders. Its aim is to insert a healthy, normal form of a gene into the cells of tissues that are affected by a disorder. This gene can replace the mutated gene that causes the disorder. The approach to gene therapy for treating cystic fibrosis is shown in **Figure 1.38**. A normal gene is added to lung tissue, where it produces a normal protein. With a functioning protein, the thick mucus that builds up and harms people with cystic fibrosis is no longer produced, allowing them to breathe normally.

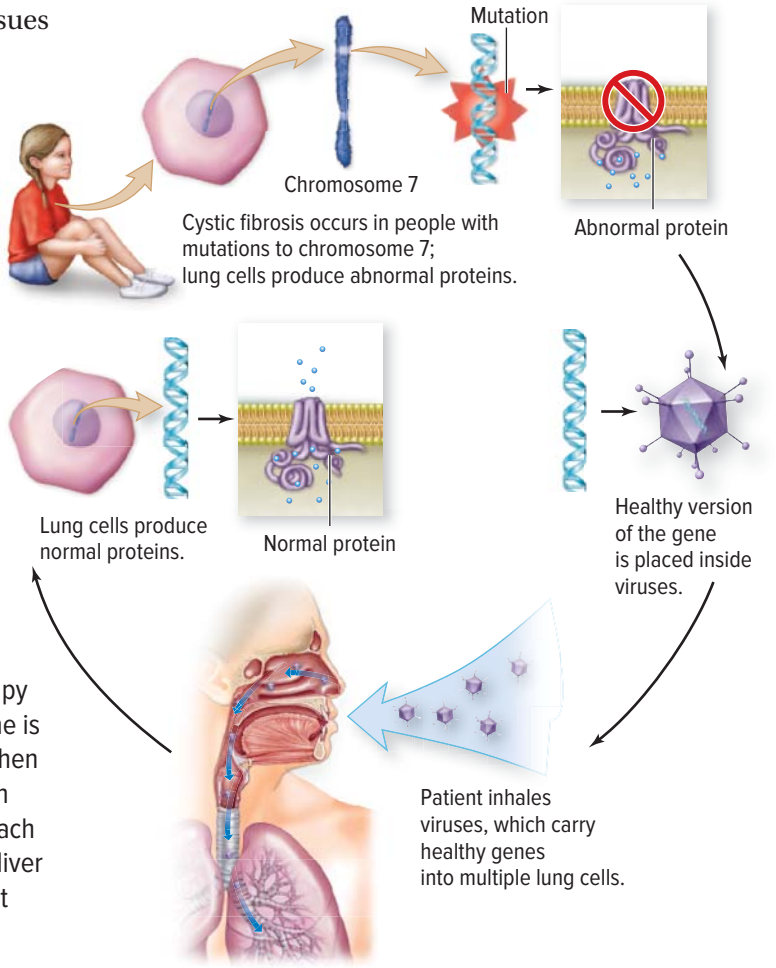


Figure 1.38 The strategy for using gene therapy to cure cystic fibrosis. A normal copy of the gene is taken up by cells in the lungs. These cells can then produce a normal protein from that gene, which can carry out its regular functions. In the approach shown, viruses act as vectors that carry and deliver the gene. The viruses have been treated so that they do not cause illness.

Extending the Connections

Gene Therapy for Donor Lungs

Scientists at the McEwen Centre for Regenerative Medicine in Toronto have developed a gene therapy technique to repair donor lungs before they are transplanted. The technique dramatically improves the success of transplants. As a result, more donor lungs are available to people who are waiting on transplant lists. Read the information provided by your teacher about this technique. Decide, from an ethics standpoint, whether this type of gene therapy is in the same category as treating the actual genetic material of an individual. Write a paragraph that summarizes your opinion, including supporting details.

Using DNA Technology in British Columbia

The use of DNA technology can benefit British Columbia both economically and ecologically. New DNA technologies are being used to help detect viruses in plants that are imported and exported to and from Canada. As well, biotechnology is applied to help fight invasive species in provincial forests.

Food Crops and Testing for Viruses

Exporting food crops is an important source of revenue for Canada. Exported strawberries bring in about $17 million per year, and tree fruits are worth over $240 million per year. As you might expect, when food crops are exported and imported to and from Canada they must be tested to make sure they are not carrying any viruses that could harm other crops. If food crops, such as those shown in **Figure 1.39**, are found to have viruses during testing, they are not accepted by the buyer. The loss of sales can be costly to growers. The earlier they can detect a virus in their plants, the better. Currently, the process of testing and quarantine can take up to three years. This can affect the speed with which products are traded, which can also cost growers.

Figure 1.39 Strawberries, blueberries, and cherries are just a few of the food crops grown in and exported from British Columbia.

In 2017, the Canadian Food Inspection Agency (CFIA) announced new projects that will use biotechnology to help reduce testing and quarantine time. In one project, scientists will use DNA-based technologies to test for all viruses normally associated with imported plants. This new testing process could reduce quarantine time to only six months. The second project specifically involves the testing of strawberry plants. The process will allow scientists to carry out a single test to check for multiple viruses in all exported strawberry plants. As with the first project, this will reduce the amount of time it takes for these plants to be sold.

Invasive Species and Forests of British Columbia

British Columbia's forests are important for many reasons. People use the forests for recreation and the trees and plants in the forests reduce soil erosion, filter water, and provide habitat. Timber is an important export for British Columbia and is a $33 billion industry across Canada.

When invasive species are introduced to forest ecosystems, they can cause great damage. An *invasive species* is a species that is not native to an ecosystem and causes harm to an ecosystem in which it is introduced. Examples of invasive species in B.C. forests include the Asian longhorned beetle, the Asian gypsy moth, and pathogens that cause sudden oak death and Dutch elm disease (**Figure 1.40**). Being able to identity the presence of an invasive species as early as possible can help reduce damage as well as reduce the risk that the exported timber will be rejected by the buyer.

Figure 1.40 As a caterpillar, the Asian gypsy moth eats the leaves of trees (left). Trees affected by sudden oak death (middle) develop cankers on their trunks. The leaves of trees with Dutch elm disease turn yellow, wilt, and then turn brown (right).

Scientists and CFIA agents can use a handheld device to test for invasive species. The device can extract DNA from samples of insect eggs or fungi. The DNA is then compared with a library of DNA from known invasive species and pathogens. This new device can reduce the time required to identify a sample from months to days. This device can also be used to test incoming wood and plant products for the presence of invasive species or infection. Early detection can prevent invasive species from entering B.C. ecosystems and reduce the damage they cause.

Activity

Asian Gypsy Moth

Your teacher will provide you with an information sheet about the Asian gypsy moth. Read the information, and then answer the questions on the worksheet provided by your teacher.

Before you leave this page . . .

1. Compare and contrast artificial insemination and in vitro fertilization.
2. Choose one of the uses of biotechnology discussed in the text and describe the benefits of its use. Do you think there are any disadvantages to its use? Explain.

CONCEPT 3

The use of biotechnology has some risks and raises some ethical issues.

Activity

Assessing the Use of Transgenic Plants

Different agencies oversee the development and use of transgenic products. These agencies consider criteria such as the potential social, economic, and environmental costs and benefits. Read the material provided by your teacher about a transgenic plant product or crop that has been approved for use in Canada. Describe the review process it has gone through for approval in Canada. What advantages does the product provide? Are there any negative consequences linked to its use?

Concerns about GMOs

The success in producing transgenic bacteria, plants, and animals has revolutionized health care and the ways that many plant crops are grown. However, there is controversy that surrounds making and using GMOs. Some of the risks and ethical issues are listed below.

Environmental threats

- The use of herbicide-resistant plants could encourage the use of stronger herbicides, which may get into the water or soil system and harm organisms that live there.
- There is evidence that genes can cross to other species, which may create "superweeds" and "superbugs" that cannot be controlled with pesticides.
- Another concern is that a GMO could out-compete or breed with species in the wild. This may endanger the natural populations.

Health effects

- Some scientists believe that not enough is known about the long-term effects of consuming genetically modified products such as food and medicine. Some people are concerned that GMOs are hazardous to our health or may produce allergic reactions in people. Some companies have chosen to make products that do not contain any GMO ingredients and are able to place a label on the product like the one shown in **Figure 1.41**.
- In Canada, up to 70% of processed foods could contain genetically modified ingredients. However, producers do not have to indicate this on their labels. Many international governments, including Canada's, continue to debate how to regulate the production, distribution, and labelling of GMOs and products that contain GMO ingredients.

Figure 1.41 Some products have a label that shows they do not contain any GMO ingredients.

Social and economic issues

- Although there are benefits to human health and reducing world hunger, the amount of money spent on genetics research may be greater than the overall benefits of the research.
- Some people wonder if private enterprise is having too much influence over the global food market.
- Other people question the ethics of using other species solely for human benefit.

Concerns about Gene Therapy

Scientists have carried out experimental treatments of genetic disorders aside from cystic fibrosis. These include treatments for sickle cell anemia (**Figure 1.42**) and some forms of inherited blindness. Although gene therapy has helped some people, others have experienced negative results. This caused most of the experimental treatments to be stopped until safer procedures could be developed. Nevertheless, gene therapy still holds great promise as a treatment for genetic disorders. As well, people are concerned about which genetic conditions should be considered "disorders" that deserve treatment.

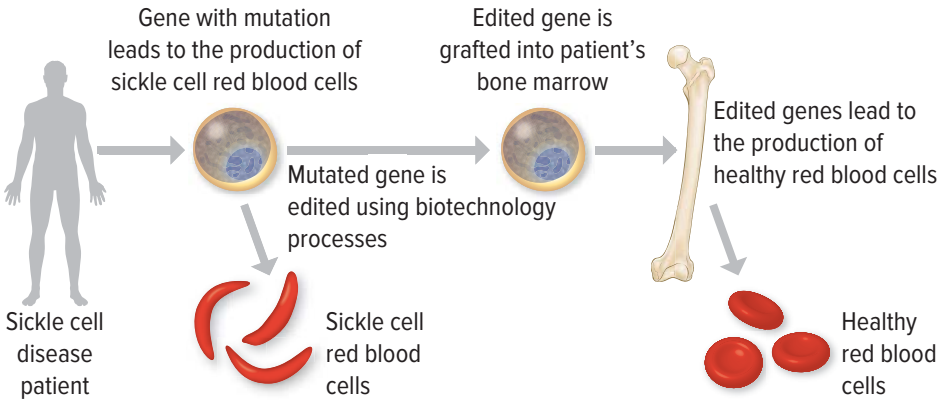


Figure 1.42 Gene therapy used to treat sickle cell anemia

Activity

Should we or shouldn't we?

Consider the scenario that has been presented by your teacher. In preparation for a debate, develop an argument for both sides of the issue. Your teacher will assign you a side to argue for in the debate. Carry out the debate according to the rules provided by your teacher.

Before you leave this page . . .

1. Why should environmental, social, and economic issues be considered when deciding how to use biotechnology?
2. Discuss one thing that concerns you about the use of biotechnology. Justify your concern with evidence collected from this concept.

AT ISSUE

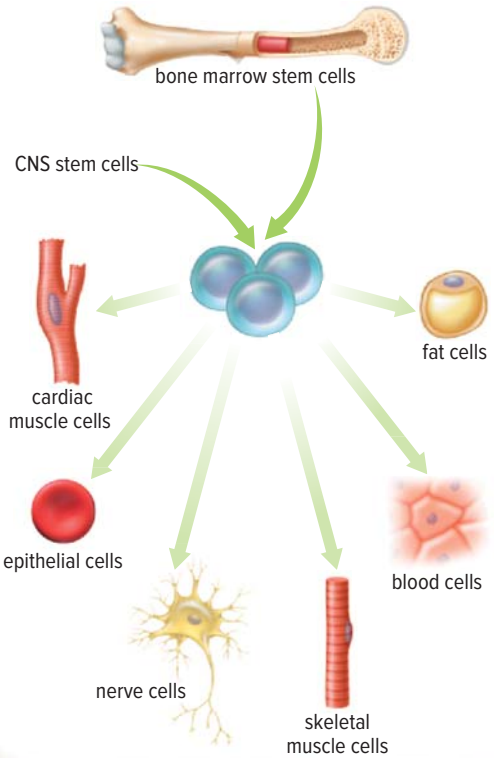
Stem Cells: Paralysis Cured

What's the Issue?

A race car driver is paralyzed in a crash. A teen is paralyzed after diving into shallow water. Until recently, these people would have little hope of regaining the full use of their bodies, but new research on adult stem cells shows promise for reversing paralysis.

What are stem cells? In animals, a cell that can differentiate into many different cell types is called a stem cell. A stem cell divides into two daughter cells through the processes of mitosis and cytokinesis. Each resulting daughter cell can develop into a different type of cell, based on which parts of its DNA are switched on. Stem cells generally occur in clumps that differentiate into different tissue layers, such as epithelial, muscle, and nerve tissues.

There are two types of stem cells. Embryonic stem cells can differentiate into any kind of cell. Adult stem cells exist within specialized tissue. They are only able to differentiate into certain types of cells. For example, tissue stem cells found in bone marrow can differentiate into white blood cells, red blood cells, or platelets.



Stem cells from bone marrow or the central nervous system (CNS) can be manipulated to generate many cell types that can then be transplanted to treat illness or repair damage.

How can stem cells be used? Scientists are trying to find ways to grow adult stem cells in cell cultures and manipulate them to generate specific cell types. For example, stem cells might be used to repair cardiac tissue after a heart attack, to restore vision in diseased or injured eyes, to treat diseases such as diabetes, or to repair spinal cells to reverse paralysis.

Stem Cells and Paralysis In Portugal, Dr. Carlos Lima and his team of researchers found that tissue taken from the nasal cavity is a rich source of adult stem cells. These stem cells become nerve cells when transplanted into the site of a spinal cord injury. The new nerve cells replace the cells that were damaged.

More than 40 people with paralysis due to accidents have undergone the Portuguese procedure. All have regained some sensation in paralyzed body areas. Most have regained some motor control. With intensive physical therapy, about 10 percent of them can now walk with the aid of supportive devices, such as walkers and braces. This is promising news to the many individuals facing illnesses or injuries that have robbed them of the full use of their bodies.

Stem Cells and the Future Scientists are eager to do the research necessary to make adult stem cell treatments a regular part of health care. Paralysis might not have to be permanent—stem cells could provide the cure.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. Create a pamphlet that explains the benefits to society of adult stem cell research. Conduct research in order to include information about the research methods, treatment, examples, cell physiology, and a brief history of adult stem cell research. Be sure to illustrate your pamphlet.
2. Legal, ethical, and social concerns surround human stem cell research. Investigate and summarize Canada's current guidelines on stem cell research.
3. Research the ethical arguments for and against stem cell research. Prepare an argument to present your opinion on this issue.

Biology Connections

Plant Pathologist

Bioinformatics Data Scientist

Fisheries Certification Manger

What kinds of jobs are there for people interested in the unity and diversity of life?

Soil Scientist

Animal Behaviourist

Bioethicist

If you like to ponder challenging issues, then keep reading. Bioethicists help researchers and healthcare workers make decisions about ethical dilemmas. They also help develop policies in hospitals and in research settings that involve human or other animal subjects.

Tree Breeder

Combine your interests in DNA and the great outdoors, and help manage and protect B.C.'s forests. Tree breeders help improve the growth, form, and health of trees to sustain forests for future generations.

Medical Illustrator

Where do you draw the line—literally? Medical illustrators use their knowledge of anatomy for advertising, textbooks, and other teaching tools. They work for medical schools, publishers, and companies that make pharmaceuticals and medical devices.

Questions

1. What other jobs and careers do you know or can you think of that involve biology?
2. Research a job or career related to Unit 1 that interests you. Explain what attracted you to it. What kinds of things do you have to know, do, and understand for this job or career?

Check Your Understanding of Topic 1.4

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. Use a flowchart with diagrams to summarize gene cloning. PA C
2. What is the benefit of producing insulin from transgenic plants rather than transgenic bacteria? PA
3. A company has developed a transgenic carrot that secretes toxins that kill damaging insects and worms. AI C
   a) What are some of the risks and benefits that you think the Canadian government should consider when deciding whether to approve this plant for agricultural use?
   b) If approved, what advantages will this transgenic carrot offer to farmers? What are some of the potential drawbacks to farmers?
   c) Do you think that foods produced with genetically modified ingredients should be labelled so that consumers can make informed choices? List your arguments.
4. Explain the steps involved in in vitro fertilization. PA C
5. Use a graphic organizer of your choice to help explain how gene therapy works. PA C
6. Copy the following table into your notebook and complete it. PA C

Applications of Biotechnology

Application	Benefits	Risks/ Concerns
Cloning		
Genetically modified organisms		
Gene therapy		

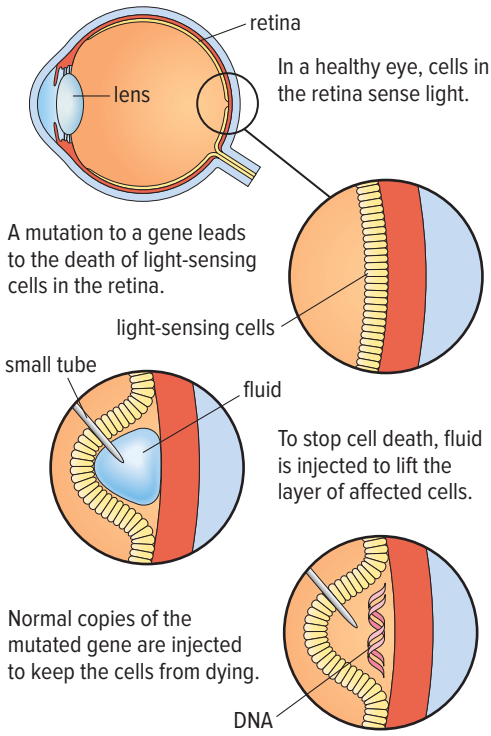
7. How can transgenic organisms help to achieve social, economic, or environmental goals? Give one example of a transgenic organism designed to meet one of these goals. E C

Connecting Ideas

8. Many people have life-threatening allergies to certain foods, such as nuts. Researchers are developing transgenic peanuts that will not produce allergic reactions. Do you think this is a good use of research money? Explain. E C

Making New Connections

9. Study the diagram below. What does it show? Explain your reasoning. PA C



INVESTIGATION 1-I

GUIDED INQUIRY

Owning and Controlling Genetic Information

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- access to online or print resources

As knowledge and technology related to genetic information continue to grow, more questions about how ownership and control of this information should be handled are being asked.

Question

How should ownership and control of genetic information be regulated?

Procedure

1. Work in small groups to conduct research on what laws or regulations different countries, such as Canada, the United States, and Great Britain, have regarding privacy of genetic information.
2. Why is privacy an issue of concern when it comes to personal genetic information? Research to find out how the privacy of genetic information relates to
   - potential employers
   - life insurance
   - medical drug plans
   - the health of family members
   - criminal cases
   - paternity testing
   - biobanks/stored DNA sequences
   - genetic research studies
3. Is a person's genetic information their own private property? Research to find different opinions about this issue.

Analyze and Interpret

1. Within your group, discuss whether there are any situations in which you think a person should be forced to share their genetic information. Defend your opinion.
2. Based on your research, how might someone be discriminated against because of his or her genetic profile? Include an example in your answer.
3. Why do you think the progress of government regulations is not able to keep up with scientific advancements in this area? What rules and policies would your group propose to deal with controlling genetic information?

Conclude and Communicate

4. As a group, present your list of rules and policies to the class.

INVESTIGATION
1-J

GUIDED INQUIRY

Skills and Strategies

- Planning and Conducting
- Processing and Analyzing Data
- Evaluating
- Communicating

What You Need

- access to online or print resources

The Effects of Biotechnology

Despite successes, controversy still surrounds making and using GMOs. Most of the concerns are about the "unknowns"—potential dangers that may occur.

Question

What positive and negative effects do genetically modified organisms (GMOs) have on the environment?

Procedure

1. Use the questions below to guide your research.
   - What are three examples of GMOs that have been developed?
   - Why was each of these GMOs developed? What advantage does each provide?
   - Are there any reports of GMOs having negative impacts on the environment? If so, what is the source for each report?
   - How well do scientists understand the effects of GMOs on the environment? Are additional data and further studies necessary? If so, what kind?
2. Some of the following topic and key word suggestions may help guide your research:
   - BT corn
   - herbicide-resistant plants
   - genetically modified wheat, canola, or insects
   - GMO effects on biodiversity
   - effects on "non-target organisms"
   - development of superweeds

Analyze and Interpret

1. What information do regulators need when they are assessing the effects of GMOs on the environment?
2. How can you tell which reports about GMOs are based on credible evidence and which are based on misconceptions or opinions?

Conclude and Communicate

3. Create a table to summarize the positive and negative effects of GMOs on the environment. Do you think the benefits outweigh any negative effects?
4. Based on your research, do you think GMOs are safe to use? Create an informational poster to promote your point of view.