15.1 Selective Breeding

Lesson Objectives

- Explain the purpose of selective breeding.
- Explain how people increase genetic variation.

Lesson Summary

**Selective Breeding** Through selective breeding, humans choose organisms with wanted characteristics to produce the next generation.

- This takes advantage of natural variation among organisms and passes wanted traits to offspring.
- The numerous breeds of dogs and varieties of crop plants and domestic animals are examples of selective breeding.

**Hybridization** crosses dissimilar individuals to bring together the best of both parents in the offspring. **Inbreeding** is the continued breeding of individuals with selected characteristics. It ensures that wanted traits are preserved, but can also result in defects being passed on.

**Increasing Variation** Mutations are the source of biological diversity. Breeders introduce mutations into populations to increase genetic variation. **Biotechnology** is the application of a technological process, invention, or method to living organisms. Selective breeding is one example of biotechnology.

- Radiation and chemicals can increase the mutation rate. Diverse bacterial strains have been bred from mutated lines.
- Drugs can prevent the separation of chromosomes during mitosis, leading to polyploidy in plants. Such plants may be larger or stronger than their diploid relatives.

**Selective Breeding**

*For Questions 1–5, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.*

1. Selective breeding works because of the natural genetic variation in a population.
2. Hybridization crosses similar individuals to bring together the best of both.
3. The individuals produced by crossing dissimilar parents are purebreeds.
4. The continued crossing of individuals with similar characteristics is hybridization.
5. Inbreeding increases the risk of genetic defects.
6. Complete the table describing the types of selective breeding.

<table>
<thead>
<tr>
<th>Selective Breeding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td>Crossing dissimilar individuals to bring together the best of both organisms</td>
</tr>
</tbody>
</table>

**Increasing Variation**

7. Complete this concept map about biotechnology.

Biotechnology

is

which can increase genetic variation through

- Radiation and chemicals increase the mutation rate in bacteria, producing new strains that can perform useful functions, such as cleaning up oil spills.
- an example of which is
For Questions 8–11, match the example with the probable method used to introduce the mutation. Each answer can be used more than once.

_____ 8. Bacteria that clean up radioactive substances
_____ 9. Larger, stronger banana trees
_____ 10. Bacteria that clean up metal pollution
_____ 11. Watermelons that grow faster and larger

A. radiation or chemicals
B. polyploidy

12. Is it easy for breeders to produce mutants with desirable mutations? Explain.

13. Why are radiation and chemicals useful techniques for producing mutant bacteria?

14. What technique do scientists use to produce mutant plants?

15. What are polyploid plants?

16. The muscles that racehorses use to move their legs are strong, heavy, and powerful. The bones of racehorses are very lightweight. How are these traits advantageous in racehorses? Describe a process that breeders might have used, over time, to produce racehorses with these characteristics.
15.2 Recombinant DNA

Lesson Objectives

- Explain how scientists manipulate DNA.
- Describe the importance of recombinant DNA.
- Define transgenic and describe the usefulness of some transgenic organisms to humans.

Lesson Summary

Copying DNA Genetic engineers can transfer a gene from one organism to another to achieve a goal, but first, individual genes must be identified and separated from DNA. The original method (used by Douglas Prasher) involved several steps:

- Determine the amino acid sequence in a protein.
- Predict the mRNA code for that sequence.
- Use a complementary base sequence to attract the predicted mRNA.
- Find the DNA fragment that binds to the mRNA.

Once scientists find a gene, they can use a technique called the polymerase chain reaction to make many copies.

- Heat separates the DNA into two strands.
- As the DNA cools, primers are added to opposite ends of the strands.
- DNA polymerase adds nucleotides between the primers, producing two complementary strands. The process can be repeated as many times as needed.

Changing DNA Recombinant DNA molecules contain DNA from two different sources. Recombinant-DNA technology can change the genetic composition of living organisms.

- Plasmids are circular DNA molecules found in bacteria and yeasts; they are widely used by scientists studying recombinant DNA, because DNA joined to a plasmid can be replicated.

- A genetic marker is a gene that is used to differentiate a cell that carries a recombinant plasmid from those that do not.

Transgenic Organisms Transgenic organisms contain genes from other species. They result from the insertion of recombinant DNA into the genome of the host organism. A clone is a member of a population of genetically identical cells.

Copying DNA

For Questions 1–5, complete each statement by writing in the correct word or words.

1. Genetic engineers can transfer ____________ from one organism to another.

2. As a first step toward finding a gene, Douglas Prasher studied the ____________ sequence of part of a protein.

3. Prasher next found the ____________ base sequence that coded for the protein.
4. Using the technique of ____________, Prasher matched the mRNA to a DNA fragment that contained the gene for GFP.

5. Southern blot analysis uses ____________ probes to bind to fragments with complementary base sequences.

6. **THINK VISUALLY** Make a sketch to show the steps in the polymerase chain reaction (PCR) method of copying genes. Label each part of your sketch.

---

**Changing DNA**

*For Questions 7–10, write the letter of the correct answer on the line at the left.*

7. Why is DNA ligase so important in recombinant DNA technology?
   - A. It causes DNA to make multiple copies of itself.
   - B. It joins two DNA fragments together.
   - C. It shapes bacterial DNA into a circular plasmid.
   - D. It cuts DNA into restriction fragments.

8. A recombinant plasmid can be used to
   - A. prevent nondisjunction at meiosis.
   - B. double the number of chromosomes in a plant cell.
   - C. cut DNA into restriction fragments.
   - D. transform a bacterium.
9. What do genetic engineers use to create the “sticky ends” needed to splice two fragments of DNA together?
   A. an amino acid sequence  
   B. DNA ligase  
   C. restriction enzymes  
   D. mRNA

10. Why must a genetically engineered plasmid contain a genetic marker?
   A. to prevent the construction of an artificial chromosome  
   B. to separate cells that contain recombinant DNA from those that do not  
   C. to produce multiple copies of the recombined plasmid after heat treatment  
   D. to break apart the circular plasmid and introduce another DNA fragment

11. Give a reason why a plasmid is useful for DNA transfer.

Transgenic Organisms

12. Complete the flowchart about how a transgenic plant is produced, using Agrobacterium as an example.

   Agrobacterium can cause tumors in plants. The part of the DNA that causes tumors is deactivated and replaced with __________ DNA.

   The __________ bacteria are placed in a dish with plant cells. The bacteria infect the plant cells.

   Inside a plant cell, Agrobacterium inserts part of its DNA into the host cell ________________.

   A ________________ is generated from the transformed cell.
13. What is a transgenic organism?

________________________________________________________________________

14. What can happen when DNA is injected into the nucleus of an animal’s egg cell?

________________________________________________________________________

15. How is a DNA molecule constructed so that it will eliminate a particular gene?

________________________________________________________________________

16. What is a clone?

________________________________________________________________________

17. What kinds of mammals have been cloned in recent years?

________________________________________________________________________

For Questions 18–22, write True if the statement is true. If the statement is false, change the underlined word to make the statement true.

_____________ 18. An organism that contains one or more genes from another species is inbred.

_____________ 19. Transgenic organisms can be made by inserting recombinant DNA into the genome of the host organism.

_____________ 20. Examining the properties of a transgenic organism allows scientists to discover the function of the transferred chromosome.

_____________ 21. Plant cells will sometimes take up DNA on their own if their cell walls are absent.

_____________ 22. Carefully designed DNA molecules can achieve gene replacement.

On the lines below, write T next to an example of a transgenic organism, and C next to an example of a clone.

_____________ 23. A goat that produces spider’s silk in its milk

_____________ 24. A plant that is grown from a cell into which Agrobacterium has incorporated recombinant DNA

_____________ 25. A lamb that is born with the same DNA as a donor cell

_____________ 26. A colony of bacteria that grows from one bacterium

_____________ 27. A bacterium that can produce human insulin
28. **THINK VISUALLY** Complete the sentences in the diagram below to show the steps in cloning a sheep.

- The egg cell is fused with a(n) __________________________ taken from another adult using an electric shock.
- The _______ of an egg cell is removed.
- The fused cell begins to __________________________ normally.
- The _______ is placed in the uterus of a foster mother, where it develops normally.

**Apply the Big idea**

29. The most successful heart transplants occur when proteins in the donor heart closely match those of the recipient’s original heart. If the proteins don’t match, the recipient’s immune system may reject the transplanted organ. Scientists would like to develop a strain of transgenic pigs that could provide donor hearts for humans. How might such an animal be developed? How might cloning help provide hearts for human recipients?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
15.3 Applications of Genetic Engineering

Lesson Objectives

- Describe the benefits of genetic engineering as they relate to agriculture and industry.
- Explain how recombinant DNA technology can improve human health.
- Summarize the process of DNA fingerprinting and explain its uses.

Lesson Summary

Agriculture and Industry Genetic engineers work to improve the products we get from plants and animals.

- Genetically modified crops may be more nutritious or higher yielding. They may be resistant to insects, diseases, or spoilage. Some can produce plastics.
- Genetically modified animals may produce more milk, have leaner meat, or contain higher levels of nutritious compounds. Transgenic salmon grow rapidly in captivity. Transgenic goats produce spider silk in their milk.

Health and Medicine Recombinant DNA studies are leading to advances in the prevention and treatment of disease.

- Examples include vitamin-rich rice, human proteins made in animals, animal models of human disease (for research), and bacteria that produce human insulin.
- Gene therapy is the process of changing a gene to treat a disorder. However, gene therapy is still an experimental and high-risk technique.
- Genetic testing can identify hundreds of inherited disorders.

Not all genes are active in every cell. DNA microarray technology lets scientists study thousands of genes at once to determine their activity level.

Personal Identification DNA fingerprinting analyzes sections of DNA that may have little or no function but that vary from one individual to another.

- DNA fingerprinting is used in forensics—the scientific study of crime-scene evidence—to identify criminals. It is also used to identify the biological father when paternity is in question.
- Common ancestry can sometimes be determined using mitochondrial DNA (mtDNA) and Y-chromosome analysis.

Agriculture and Industry

1. Give two examples of how genetically modified organisms lead to more environmentally friendly agricultural practices.
   a. 
   b. 

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2. Name two other benefits that may be gained from genetically engineering food crops.
   a. 
   b. 

3. Give two examples of how DNA modification has increased the importance of transgenic animals to our food supply.
   a. 
   b. 

**Health and Medicine**

For Questions 4–6, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

__________ 4. Human growth hormone is now widely available because it is mass produced by recombinant viruses.

__________ 5. In DNA fingerprinting, an absent or faulty gene is replaced by a normal, working gene.

__________ 6. Prospective parents can find out if they carry the alleles for a genetic disease through genetic testing.

7. Complete the flowchart to show the steps required to analyze gene activity using a microarray.

1. Preparing the cDNA Probe
   A. 
   B. 

2. Preparing Microarray
   A. 
   B. 

3. Combining the Probe and Microarray Samples
Personal Identification

8. Complete the flowchart about how DNA fingerprints are made.

Restriction _______ are used to cut the DNA into fragments containing genes and repeats.

The restriction fragments are separated according to size using gel _________.

The DNA fragments containing repeats are then labeled using radioactive _______. This labeling produces a series of bands—the DNA fingerprint.

9. Study the DNA fingerprint below. Which two samples may be from a set of identical twins? How do you know?

Apply the Big idea

10. In 2001, scientists reported the successful use of gene therapy to treat three dogs that had been born blind. The animals’ blindness was the result of a mutated gene. Explain the steps that the scientists probably would have used to restore sight to the dogs.
15.4 Ethics and Impacts of Biotechnology

Lesson Objectives

- Describe some of the issues that relate to biotechnology.
- Identify some of the pros and cons of genetically modified food.
- Describe some of the ethical issues relating to biotechnology.

Lesson Summary

Profits and Privacy Most of the research in genetic engineering is done by private companies.

- They patent their findings and inventions to protect their investment and make a profit.
- The patents block other scientists from pursuing certain lines of research.
- In 2007, the Genetic Information Nondiscrimination Act was signed into law in the United States. It prohibits discrimination based on genetic information.

Safety of Transgenics There is controversy about the safety of GM foods.

- Proponents of genetically modified foods argue that GM crops are better, safer, and higher yielding than conventional crops. GM crops require less land and energy to grow, and insecticides need not be applied to insect-resistant strains. Careful studies have provided no support for concerns about the safety of GM crops.
- Opponents argue that the safety of GM crops has been neither adequately tested for long-term use, nor regulated. Patents on GM seeds may force small farmers out of business. The resistance of GM plants to insects may harm beneficial insect species. Resistance to herbicides may result in the overuse of toxic chemicals.
- Some states have introduced legislation to require that GM foods be labeled.

Ethics of the New Biology Few argue that gene therapy for curing disease is ethically wrong, but many ask the question of how far genetic modification should go.

- Is it right to try to engineer children to have certain characteristics?
- Should human cloning be allowed?

Profits and Privacy

1. Should you be able to keep your genetic information confidential? State two answers: one giving a reason for a “yes” answer, and the other giving a reason for a “no” answer.

   Yes
   
   
   
   
   
   
   
   No
2. Explain what the Genetics Information Nondiscrimination Act is, and give an example of how it might protect people.

   __________________________________________________________
   __________________________________________________________

Safety of Transgenics

3. Complete the table to summarize the pros and cons of genetically modified foods. List at least four items in each column.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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For Questions 4–8, write True if the statement is true. If the statement is false, change the underlined word or words to make the statement true.

___________ 4. Most GM plants are grown in the United States.

___________ 5. Growing GM crops requires more energy resources than growing traditional crops.

___________ 6. With all the questions raised about GM agriculture, the wider use of biotechnology has been blocked.

___________ 7. Federal laws in the U. S. require that GM foods be labeled as such.

___________ 8. GM foods are required to undergo safety testing before they enter the U. S. market.
9. Some proponents of GM agriculture argue that GM crops are safer than others. Explain what they mean.

10. Some critics of GM agriculture fear that GM plants’ resistance to herbicides could result in the overuse of toxic chemicals. Explain why this may happen.

Ethics of the New Biology

11. It is easy to move genes from one species to another. Is it right to do this? Explain your position.

12. Recent developments have resulted in the ability to clone cats. Many people argue that cloning offers pet owners comfort in a time of need. Others argue that there are many homeless pets at shelters in need of homes, and that adopting one of these animals is a better solution for owners who have lost a pet. Do you think that the cloning of pets is acceptable? Explain why or why not.
Chapter Vocabulary Review

For Questions 1–8, complete each statement by writing in the correct word or words.

1. ___________ consists of allowing only those organisms with particular characteristics to produce the next generation.

2. In the process called ___________, dissimilar organisms are crossed in order to obtain bigger or stronger offspring.

3. When organisms that are genetically similar are crossed over and over to produce the next generation, the process is called ___________.

4. ___________ is the application of a technological process, invention, or method to living organisms.

5. The technology that makes copies of DNA is called ___________.

6. The DNA that results from the transfer of DNA from one organism into another is ___________.

7. The small, circular DNA molecule in a bacterial cell is a(n) ___________.

8. A gene that allows scientists to distinguish a cell that carries recombinant DNA from one that does not is a(n) ___________.

For Questions 9–15, match the term with its definition.

**Definition**

9. One of a population of genetically identical cells produced from a single cell

10. A technique that allows the identification of individuals using differences in their DNA

11. A technique that allows scientists to study thousands of genes at once

12. Containing genes from another species

13. Treating a disease by changing a gene

14. The scientific study of evidence from a crime scene

15. A gene that scientists use to find transformed bacteria

**Term**

A. transgenic
B. clone
C. gene therapy
D. DNA microarray
E. DNA fingerprinting
F. forensics
G. genetic marker

Write the letter of the correct answer on the line at the left.

16. Hybridization and inbreeding are both types of

   A. gene therapy.  C. transgenics.
   B. forensics.  D. selective breeding.

17. Because of their replication process, plasmids are excellent carriers of

   A. genetic markers.  C. clones.
   B. recombinant DNA.  D. transgenics.
CHAPTER MYSTERY

A CASE OF MISTAKEN IDENTITY

21st Century Learning

DNA Forensics: The Innocence Project

Many people in prison today were convicted of a crime before DNA fingerprinting was widely available. Should DNA forensic evidence be used to reopen such cases? At least one national legal group believes prisoners should have access to DNA testing. The Innocence Project has led the effort in the United States to use DNA forensic evidence to exonerate (or free from blame) and release wrongly convicted prisoners. They also work to improve evidence preservation techniques, to investigate possible wrongful executions based on DNA evidence, and to re-open cases based on today’s more sensitive and modern methods of testing DNA evidence.

The group still faces obstacles in its battle to gain acceptance for its methods. For instance, the laws in six states still will not allow newly discovered DNA evidence to be introduced after a trial. But the power of this technology has already worked in many states. In some cases where doubts about a conviction remain, or where prisoners have steadfastly maintained that they have been wrongly convicted, scientists and lawyers from the Innocence Project have worked together to subject the cases’ physical evidence to DNA forensic analysis. In more than 200 cases so far the DNA analysis has proved that innocent people have been mistakenly convicted and forced to spend many years in jail.

Learn more about the DNA exonerations by reading the fact sheet below, adapted from information provided by the Innocence Project.

THE INNOCENCE PROJECT:

Facts on Post-Conviction DNA Exonerations as of 2008

- Number of post-conviction DNA exonerations in the United States: 223
- The year the first DNA exoneration took place: 1989
- Number of states in which exonerations have been won: 32
- Number of exonerees who served time on death row before being freed: 17
- Average length of time served by exonerees: 12 years
- Total number of years served by exonerees: approximately 2754
- The average age of exonerees at the time of their wrongful convictions: 26
- Cases in which the true suspects and/or perpetrators have been identified: 88

In the Chapter Mystery, as in tens of thousands of real-life cases, police used DNA fingerprinting to avoid arresting the wrong suspect. However, DNA fingerprinting is a very new technology.
21st Century Themes  Science and Civic Literacy

1. What is the mission of the Innocence Project?

2. By 2008, how many times had DNA evidence been used successfully to exonerate prisoners in the United States?

3. In what portion of the cases of people exonerated by the Innocence Project have the true suspects and/or perpetrators been identified?

4. Considering the Innocence Project’s statistics, do you think prisoners jailed before DNA testing was widely available should be given access to the technology? Why or why not?

5. Do you think DNA evidence could be used to unintentionally convict an innocent person of a crime? Explain your answer.

21st Century Skills  Letter to a Lawmaker

The skills used in this activity include problem identification, formulation, and solution; critical thinking and systems thinking; and information and media literacy.

Search newspapers’ Web sites to read about cases in which the Innocence Project or DNA evidence has helped exonerate people. Then, find out about your own state’s position on prisoner access to DNA testing by contacting your state legislature or doing research online. Use the information you find to take the part of a citizen activist.

If your state allows access, then find out about a case in your state in which DNA testing was used after a conviction. Write a letter to a newspaper expressing your opinion on the outcome of the case. If the case is pending, you can discuss in your letter what you think should happen.

If your state does not allow post-conviction access, express your opinion in a letter to a state lawmaker. Explain how DNA fingerprinting works and what position you think the lawmaker should take regarding legislation allowing prisoners access to DNA testing.