CHAPTER

11 Gene Technology

Quick Review

Answer the following without referring to earlier sections of your book.

1. **Define** the term *gene*. *(Chapter 6, Section 1)*
2. **Describe** the structure of DNA. *(Chapter 9, Section 2)*
3. **State** the base-pairing rules that determine the structure of DNA. *(Chapter 9, Section 1)*
4. **Explain** why the genetic code is said to be universal. *(Chapter 10, Section 1)*

Did you have difficulty? *For help, review the sections indicated.*

Reading Activity

Before you read this chapter, write a short list of all the things you know about gene technology. Then, write a list of the things that you want to know about gene technology. Save your list, and to assess what you have learned, see how many of your own questions you can answer after reading this chapter.

Looking Ahead

Section 1

Genetic Engineering

Basic Steps of Genetic Engineering
Confirmation of a Cloned Gene

Section 2

Human Applications of Genetic Engineering

The Human Genome Project
Genetically Engineered Drugs and Vaccines
DNA Fingerprinting

Section 3

Genetic Engineering in Agriculture

Improving Crops
Risks of Genetically Modified Crops
Gene Technology in Animal Farming
Problems with Cloning

Internet connect

www.scilinks.org
National Science Teachers Association *sci*LINKS Internet resources are located throughout this chapter.

SCILINKS. Maintained by the National Science Teachers Association

Electrophoresis is a technique used in a laboratory that results in the separation of charged particles. DNA is a negatively charged molecule, and is moved by electric current through an electrophoresis gel.

Chapter Resource File

- Vocabulary Worksheets
- Concept Mapping

Transparencies

TR Bellringer
TR C34 Genetic Engineering
TR C32 Restriction Enzymes Cut DNA

Opening Activity — GENERA

Gene Technology Have students discuss why gene technology is con troversial. (Lead students to suggest that DNA technology allows researchers to produce new variants life forms with specific characteristics or abilities.) Students should understand that gene technology is a potentially powerful tool for fighti diseases and for understanding organisms. Explain that people are excited about the prospects of usin this tool, but concerned about its misuse. LS Verbal

Quick Review Answers

1. A gene is a segment of DNA that codes for a protein or RNA molecule.
2. DNA is constructed of nucleotide subunits made up of a phosphate group, a sugar molecule, and one of four nitrogen-containing bases. The nucleotides are linked end-to-end in two strands that are twisted into a double helix.
3. The base-pairing rules state that a purine base in one of the two strands of a DNA molecule always has across from it on the other strand a pyrimidine base. These rules further specify that the purine adenine always pairs with the pyrimidine thymine and the purine guanine always pairs with the pyrimidine cytosine.
4. The genetic code is universal because it is nearly the same in every living thing.

Reading Activity Answers

Instruct students to save their lists for use after they have finished reading the chapter.

Section 1

Focus

verview

efore beginning this section view with your students the bjectives listed in the Student dition. This section introduces udents to the techniques and tools ed to combine DNA from two or ore different organisms. Students arn how it is determined that dif- rent DNAs have been combined d the different uses for the combinant DNA.

Bellringer

sk students to imagine the appear- ce of an organism that has some netically determined characteristics om two different species. Ask them draw a picture of their imaginary ganism.

Motivate

iscussion — BASIC

ow students a bowl with various pes of fruits and vegetables. Ask udents to identify their favorite uits and vegetables. Ask students hat characteristics they would ange in their favorites, if they uld. (Answers may include making e fruit or vegetable sweeter, firmer, sier to bite into, or a different lor.) Discuss how scientists are le to manipulate many character- ics of fruits and vegetables using netic engineering techniques. nce the gene that controls a trait found and isolated, scientists can to manipulate it in various ways.

Visual

Section 1 Genetic Engineering

Objectives

- **Describe** four basic steps commonly used in genetic engineering experiments.
- **Evaluate** how restriction enzymes and the antibiotic tetracycline are used in genetic engineering.
- **Relate** the role of electrophoresis and probes in identifying a specific gene.

Key Terms

genetic engineering
recombinant DNA
restriction enzyme
vector
plasmid
gene cloning
electrophoresis
probe

Basic Steps of Genetic Engineering

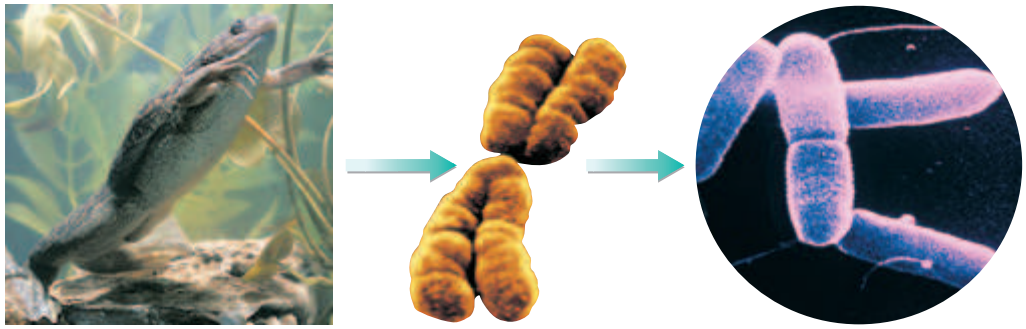
Not too long ago, using bacteria to produce human insulin and inserting genes into tomatoes and human cells were ideas that existed only in science fiction books and movies. But now, the techniques required to carry out these ideas have been developed and are used daily.

In 1973, Stanley Cohen and Herbert Boyer conducted an experiment that revolutionized genetic studies in biology. They isolated the gene that codes for ribosomal RNA from the DNA of an African clawed frog and then inserted it into the DNA of *Escherichia coli* bacteria, as summarized in **Figure 1.** During transcription, the bacteria produced frog rRNA, thereby becoming the first genetically altered organisms. The process of manipulating genes for practical purposes is called **genetic engineering.** Genetic engineering may involve building **recombinant DNA**—DNA made from two or more different organisms.

The basic steps in genetic engineering can be explored by examining how the human gene for insulin is transferred into bacteria. Insulin is a protein hormone that controls sugar metabolism. Diabetics cannot produce enough insulin, so they must take doses of insulin regularly. Before genetic engineering, insulin was extracted from the pancreases of slaughtered cows and pigs and then purified. Today, the human insulin gene is transferred to bacteria through genetic engineering. Because the genetic code is universal, bacteria can transcribe and translate a human insulin gene using the same code a human cell uses in order to produce human insulin.

Figure 1 Genetic alteration of an organism

Cohen and Boyer produced the first genetically engineered organisms.



1. Cohen and Boyer used an African clawed frog as their experimental organism.
2. They isolated an rRNA gene from one of its chromosomes.
3. They inserted the gene into bacteria. The bacteria produced frog rRNA.

Chapter Resource File

- Directed Reading BASIC
- Active Reading GENERAL
- Data Sheet for Quick Lab GENERAL

Transparencies

TR Bellringer
TR C33 Gel Electrophoresis

One-Stop Planner CD-ROM

- Reading Organizers BASIC
- Reading Strategies BASIC

Steps in a Genetic Engineering Experiment

Genetic engineering experiments use different approaches, but most share four basic steps, as illustrated in **Figure 2.**

Step 1 **Cutting DNA** The DNA from the organism containing the gene of interest (in our example, the insulin gene) is cut by restriction enzymes. **Restriction enzymes** are bacterial enzymes that recognize and bind to specific short sequences of DNA, and then cut the DNA between specific nucleotides within the sequences. The DNA from a vector also is cut. A **vector** is an agent that is used to carry the gene of interest into another cell. Commonly used vectors include viruses, yeast, and plasmids. **Plasmids,** shown in Figure 2, are circular DNA molecules that can replicate independently of the main chromosomes of bacteria.

Step 2 **Making recombinant DNA** The DNA fragments from the organism containing the gene of interest are combined with the DNA fragments from the vector. An enzyme called DNA ligase is added to help bond the ends of DNA fragments together. In our example, human DNA fragments are combined with plasmid DNA fragments. The host cells then take up the recombinant DNA.

Step 3 **Cloning** In a process called **gene cloning,** many copies of the gene of interest are made each time the host cell reproduces. Recall from your reading that bacteria reproduce by binary fission, producing identical offspring. When a bacterial cell replicates its DNA, its plasmid DNA also replicates.

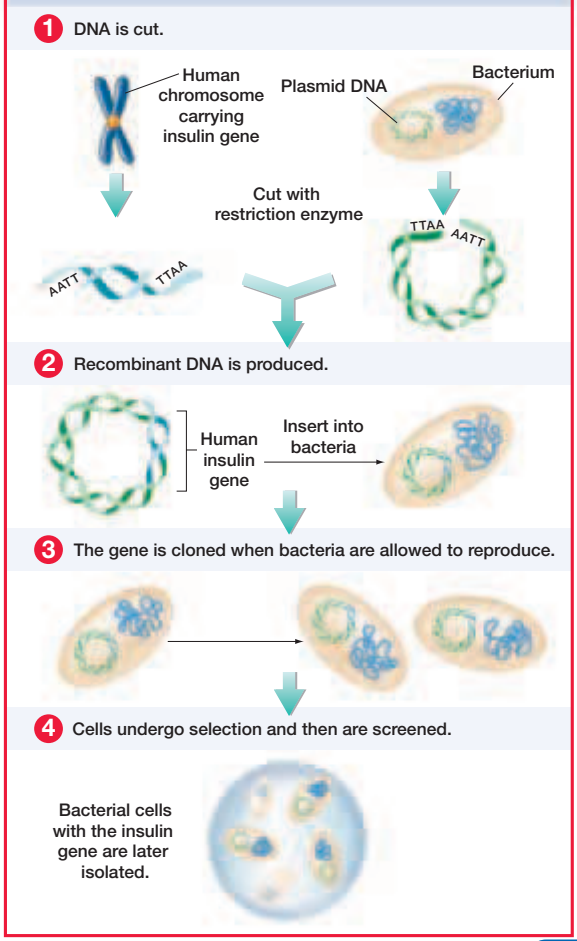
Step 4 **Screening** Cells that have received the particular gene of interest are distinguished, or separated, from the cells that did not take up the vector with the gene of interest. The cells can transcribe and translate the gene of interest to make the protein coded for in the gene.

Figure 2

BIO graphic

Genetic Engineering

Many genetic engineering experiments use one or more of these basic steps.



did you know?

Naming Restriction Enzymes Enzymes are named after the specific bacteria from which they are isolated. For example, the restriction enzyme *EcoRI* is named after the bacterium *Escherichia coli.* The first letter, "E," is the initial letter of the genus name of the organism from which the enzyme was isolated (*Escherichia*). The second and third letters, "co," are usually the first two letters of the species name (*coli*). These three letters are always italicized since they are part of the scientific name. The fourth letter, R, if present, represents the strain of the organism (strain RY 13). The Roman numerals (I) indicate the order of discovery (i.e. first endonuclease isolated in this strain of bacteria). LS Verbal

Teach

Using the Figure

Direct students' attention to **Figure 2.** Use this figure to review the steps used in many genetic engineering experiments. In step 4 emphasize that the bacterial cells with the insulin gene will later be isolated. These cells will transcribe and translate the insulin gene just as they would their own gene. Thus, scientists can isolate the insulin from the cells, purify it, and then use it for medical purposes. LS Visual

READING SKILL BUILDER

Assign Chapter 11 of the *Holt Biology* Guided Audio CD Program to help students achieve greater success in reading the chapter.

Activity

GENERAL

Recombinant DNA Give pairs of students a piece of yarn (to represent a human chromosome), a long pipe cleaner a different color from the yarn (to represent plasmid DNA), and some tape. Ask the students to form a circle with the pipe cleaner, and twist the ends once to secure the circle. Have students use scissors to cut a "gene" from the yarn and to untangle the twisted end of the pipe cleaner. Ask the students what the scissors represent. (restriction enzymes) Tell the students to insert the human gene (piece of yarn) into the opening of the plasmid and secure the ends with tape. Ask the students the following: What does the tape represent? (DNA ligase as it helps bond the DNA pieces together) What does the plasmid represent? (a vector) Why is this recombinant DNA? (The plasmid now contains foreign DNA.) What is the next step in genetic engineering? (The plasmid is inserted into a host cell, typically a bacterium.) Why? (The host cell will reproduce; each time it does, all the genetic material will be copied, including the human gene.) LS Visual

Teach, *continued*

eaching Tip

atural Selection and Screening iscuss with students how screen- g cells involves events similar to ose of natural selection. Only cer- in organisms will survive in a ven environment. In screening, ly bacteria with the gene for tibiotic resistance will survive in culture medium containing an tibiotic. In natural selection, the cteria with the successful trait sur- ve and produce future generations. Verbal

sing the Figure

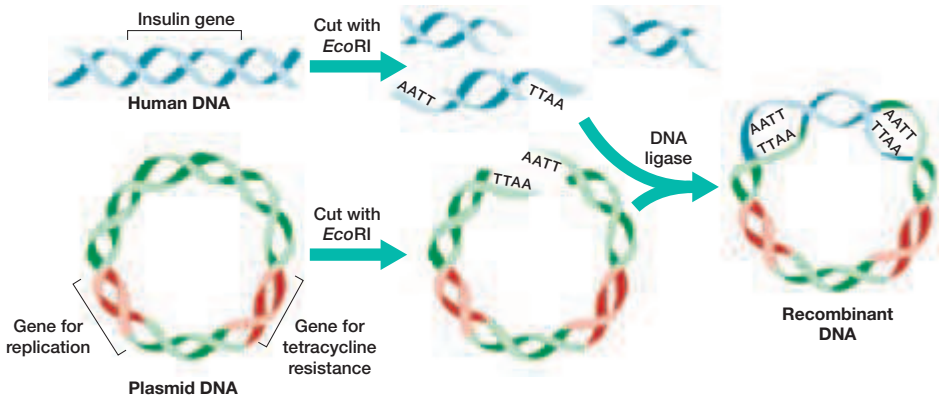
ave students examine **Figure 3.** einforce the importance of sticky ds and how sticky ends are com- ementary. Ask students why the nes for replication and tetracy- ne resistance must be present in e vector. (replication gene—so that e plasmid can replicate; tetracycline sistance gene—to screen the bacter- cells that take up the recombined ctor) There are thousands of dif- rent restriction enzymes, and each e recognizes a different DNA quence. LS Verbal

SKILL BUILDER

ocabulary Tell students that the ord clone comes from the Greek *on* meaning "twig." Pieces of a ant can be cut off and rooted, oducing a new and identical ant—a clone. LS Verbal

Figure 3 **Restriction enzymes cut DNA**

The restriction enzyme *Eco*RI recognizes the nucleotide sequence GAATTC and makes its cut between the G and the A.

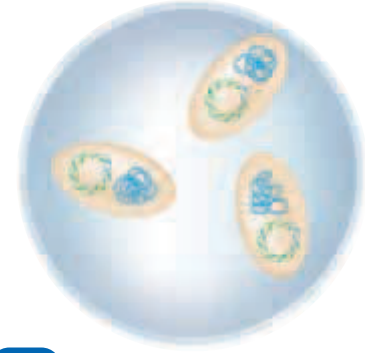


Cutting DNA and Making Recombinant DNA

An example of how restriction enzymes work is shown in **Figure 3.** The enzyme recognizes a specific sequence of DNA. The sequence the enzyme recognizes and the sequence on the complementary DNA strand are palindromes—they read the same backward as they do forward (such as the word *noon*).

The cuts of most restriction enzymes produce pieces of DNA with short single strands on each end that are complementary to each other. The ends are called *sticky ends*. As illustrated in Figure 3, the vectors that are used contain only one nucleotide sequence that the restriction enzyme recognizes. Thus, vectors such as the circular plasmids "open up" with the same sticky ends as those of the cut human DNA. The two DNA molecules bond together by means of complementary base pairing at the sticky ends. The plasmid DNA has both the gene for plasmid DNA replication and the gene that makes the cell carrying the plasmid resistant to the antibiotic tetracycline.

Figure 4 **Screening.**
Only the cells that take up the vectors are resistant to tetracycline and survive when tetracycline is added.



Cloning, Selecting, and Screening Cells

One difficult part in a genetic engineering experiment is finding and isolating the cells that contain the gene of interest. First, the cells that have taken up the plasmid must be identified. The bacterial cells that have taken up the plasmid are identified by growing the bacteria on plates that contain the antibiotic tetracycline. As shown in **Figure 4,** only the cells that have taken up the vectors (which contain the gene for tetracycline resistance) survive when exposed to tetracycline. Each surviving cell makes a copy of the vector every time the cell reproduces. Eventually, each surviving cell forms a colony of genetically identical cells, or clones. Some vectors contain the gene of interest, and some do not.

Attention Grabber

Molecular Scissors Restriction enzymes are often described as being like molecular scissors because they cut a specific nucleotide sequence at the first nucleotide. Many teaching aids developed for classroom use actually depict a small pair of scissors snipping the DNA. Of course, teachers will state that these aren't really microscopic scissors. Scientists have recently discovered that one restriction enzyme's structure actually does resemble a tiny pair of scissors! BGLII is a restriction endonuclease that recognizes and cleaves the DNA sequence AGACTC. Using X-ray crystallography, the scientists found that the enzyme's two subunits swing away from each other in a dramatic scissorslike motion. The sliding of the subunits past each other results in cutting of the DNA.

Confirmation of a Cloned Gene

The surviving bacterial colonies are tested for the presence of the gene of interest. One method used to identify a specific gene is a technique called a Southern blot, as summarized in **Figure 5.**

Step 1 In a Southern blot, the DNA from each bacterial clone colony is isolated and cut into fragments by restriction enzymes.

Step 2 The DNA fragments are separated by gel **electrophoresis** *(ee LEK troh fuh REE sis)*, a technique that uses an electric field within a gel to separate molecules by their size. The gel is a rectangular slab of gelatin with a line of little rectangular wells near the top edge. The DNA sample is placed in the pits. Because DNA is negatively charged, it migrates toward the positive pole when the electric field is applied. The DNA fragments move through the gel, with the smallest DNA fragments moving fastest. A pattern of bands is formed. The gel is soaked in a chemical solution that separates the double strands in each DNA fragment into single-stranded DNA fragments.

Step 3 The DNA bands are then transferred (blotted) directly onto a piece of filter paper. The filter paper is moistened with a probe solution. **Probes** are radioactive- or fluorescent-labeled RNA or single-stranded DNA pieces that are complementary to the gene of interest.

Step 4 Only the DNA fragments complementary to the probe will bind with the probe and form visible bands.

WORD Origins

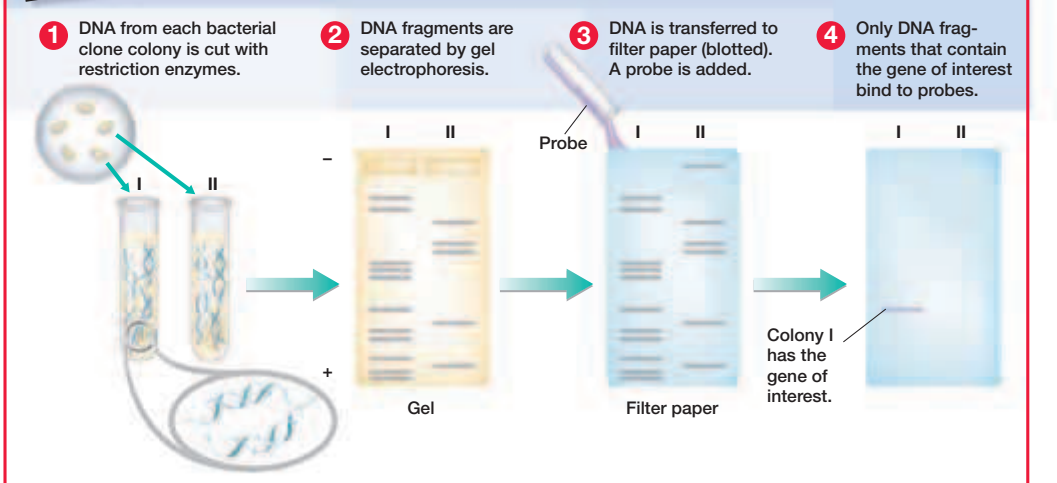
The word *electrophoresis* is from the Latin *electrocus,* meaning "electricity," and the Greek *phoresis,* meaning "to carry." Knowing this makes it easier to remember that electrophoresis uses electricity to separate DNA fragments.

Figure 5

BIO graphic

Southern Blot: Identifying a Gene of Interest

A DNA or RNA probe can be used to identify a cloned gene.



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Integrating Physics and Chemistry

Help students make the connection between electrophoresis and electrolytic behavior of solutions. Inform them that when an electric current is applied to the gel, which is an electrolytic solution, electrolytes or dissolved ions are attracted to the electrodes that are introducing the electric field into the gel. In a Southern blot, the negatively charged DNA molecules migrate toward the positive electrode and as a result are separated from other molecules.

Teaching Tip

Discovery of Restriction Enzymes Tell students that the first restriction endonuclease (restriction enzyme) was purified 1972 by Hamilton Smith, a mole ular biologist who was working with *Haemophilus influenzae* and a bacteriophage that naturally infects *Salmonella*.

Using the Figure

Direct students' attention to **Figure 5.** Remind them that the bacterial colonies in Step 1 were produced from the basic genetic engineering steps described in **Figure 2.** Point out that the fragments on the gel in Step 2 are a of different sizes, with the smalles fragments closest to the positive pole. The transfer or blotting of t DNA fragments that occurs in Step 3 is the reason for the second part of the name of this technique—Southern blot. The first part of the name, Southern, is named after E. M. Southern, who developed the technique. In Step 4, the colony that contains the gene of interest is actually ide tified. Because the original Petri dish (from Step 1) is stored whi the researcher conducts the Southern blot, the researcher can then return to the original Petri dish and conduct further research on the colony containing the gene

LS Visual

Once the bacterial colonies containing the gene of interest are identified, the researcher can manipulate the genetically engineered bacteria in many different ways. For example, the gene of interest can be isolated so that the researcher has pure DNA to use in genetic studies. The researcher can then study how the gene is controlled. Pure DNA allows the researcher to determine the sequence of nucleotides that make up the gene. By comparing the nucleotide sequence of several different organisms, researchers can study the evolution of a particular gene.

The gene of interest can also be isolated and then transferred to other organisms. The bacterial colonies can be used to produce large quantities of the protein coded for by the gene so that the protein can be studied further or used to make drugs, such as insulin.

QUICK LAB

Modeling Gel Electrophoresis

You can use beads to model how DNA fragments are separated in a gel during electrophoresis.

Materials

500 mL beaker, large jar, 3 sets of beads—each set a different size and different color

Procedure

1. Fill a large jar with the largest beads. The filled jar represents a gel.
2. Mix the two smaller beads in the beaker and then pour them slowly on top of the "gel." The two smaller size beads represent DNA fragments of different sizes.
3. Observe the flow of the beads through the "gel." Lightly agitate the jar if the beads do not flow easily.

Analysis

1. **Identify** which beads flowed through the "gel" the fastest.
2. **Relate** the sizes of the beads to the sizes of DNA fragments.
3. **Determine** whether the top or the bottom of the jar represents the side of the gel with the positively charged pole.
4. **Critical Thinking Forming Conclusions** Why do the beads you identified in Analysis question 1 pass through the "gel" more quickly?

Section 1 Review

1. **Apply** the four steps commonly used in genetic engineering experiments to describe the cloning of a human gene.
2. **Relate** the role of DNA "sticky ends" in the making of recombinant DNA.
3. **Summarize** how cells are screened in genetic engineering experiments.
4. **Evaluate** the role of probes in identifying a specific gene.
5. **Critical Thinking Evaluating Conclusions** A student performing electrophoresis on a DNA sample believes that her smallest DNA fragment is the band nearest the negative pole of the gel. Do you agree with her conclusion? Explain.
6. **Standardized Test Prep** Many genetic engineering experiments are performed in bacteria using circular DNA molecules called
   A phages. **C** probes.
   B promoters. **D** plasmids.

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Answers to Section Review

1. Human and vector DNA are cut and then combined to produce recombinant DNA. The recombinant DNA is inserted into host cells. The host cells reproduce, cloning the human gene. The host cells are screened for the gene.
2. The bases of the sticky ends are complementary, which allows the DNA from the two different organisms to combine.
3. The plasmids contain the gene for tetracycline resistance. Bacteria with the recombined plasmid are grown in the presence of tetracycline. Only bacteria with the plasmid survive.
4. Probes are pieces of single-stranded DNA or RNA complementary to the gene of interest. The DNA fragments on the gel are made single stranded. The probe will bind to any complementary fragments. The genes are identified because the probes are made with radioactive or fluorescent-labeled tags.
5. No, disagree. DNA is negatively charged and opposite charges attract. The smallest fragments will move fastest through the gel.
6. **A.** Incorrect. Phages are viruses. **B.** Incorrect. Promoters are individual genes. **C.** Incorrect. Probes are radioactive or fluorescent labeled RNA or DNA pieces. **D.** Correct.

Modeling Gel Electrophoresis

Skills Acquired
Modeling, relating information, forming conclusions

Teacher's Notes
The large beads should be big enough so that when placed in the jar there are spaces between them. The smallest beads should flow through the spaces of the large beads.

Answers to Analysis
1. the smallest beads
2. The smaller beads represent the smaller DNA fragments.
3. bottom; DNA is negatively charged and will flow to the pole with the opposite charge.
4. The smaller size allows them to flow through the space in between the large beads.

Close

Reteaching — BASIC

Ask students to rewrite each objective as a question. Then ask the students to answer each question.
Verbal

Quiz — GENERAL

What is recombinant DNA? (DNA made from two or more different organisms)

What is the role of gel electrophoresis in genetic engineering? (It separates DNA fragments according to their size.)

Human Applications of Genetic Engineering

Section 2

The Human Genome Project

In February of 2001, scientists working on the Human Genome Project published a working draft of the human genome sequence. The sequence of an organism's genome is the identification of all base pairs that compose the DNA of the organism. The **Human Genome Project** is a research project that has linked over 20 scientific laboratories in six countries. Teams of scientists, such as those shown in **Figure 6,** cooperated to identify all 3.2 *billion* base pairs of the DNA that makes up the human genome. Scientists were surprised by some of the discoveries they made.

The Geography of the Genome

One of the most surprising things about the human genome is the large amount of DNA that does *not* encode proteins. In fact, only 1 to 1.5 percent of the human genome is DNA that codes for proteins. Each human cell contains about six feet of DNA, but less than 1 inch of that is devoted to exons. Recall that exons are sequences of nucleotides that are transcribed and then translated. Exons are scattered about the human genome in clumps that are not spread evenly among chromosomes. For example, chromosome number 19 is small and is packed with transcribed genes. The much larger chromosomes 4 and 8, by contrast, have few transcribed genes. On most human chromosomes, great stretches of untranscribed DNA fill the chromosomes between scattered clusters of transcribed genes.

The Number of Human Genes

When they examine the complete sequence of the human genome, scientists were surprised at how few genes there actually are. Human cells contain only about 30,000 to 40,000 genes. This is only about double the number of genes in a fruit fly. And it is only one-fourth of the 120,000 genes that scientists had expected to find. How had scientists made this prediction of the number of human genes, and why was it wrong? When scientists had counted unique human messenger RNA (mRNA) molecules, they had found over 120,000. Each of these different forms of mRNA molecules can, in turn, be translated into a unique protein. So the scientists expected to find as many genes as there are types of mRNA molecules.

- **Summarize** two major goals of the Human Genome Project.
- **Describe** how drugs produced by genetic engineering are being used.
- **Summarize** the steps involved in making a genetically engineered vaccine.
- **Identify** two different uses for DNA fingerprints.

Key Terms

Human Genome Project
vaccine
DNA fingerprint

Figure 6 **Genetic Research.** Hundreds of scientists around the world worked to identify the human genome sequence.

Chapter Resource File

- Directed Reading BASIC
- Active Reading GENERAL

Transparencies

TR Bellringer
TR C35 Genetically Engineered Medicine
TR C38 Making a Genetically Engineered Vaccine

One-Stop Planner CD-ROM

- Reading Organizers BASIC
- Reading Strategies BASIC

Section 2

Focus

Overview

Before beginning this section review with your students the objectives listed in the Student Edition. This section discusses the efforts and discoveries of the Human Genome Project, drugs an vaccines that have been produced using the techniques of genetic eng neering, and the techniques and applications of DNA fingerprintin

Bellringer

Ask students to make a list of cha acteristics they possess that are determined by genes. (Answers wil vary but may include eye color, skin color, enzymes that catalyze differen reactions in the body, specific protei such as hormones and antibodies, height, and intelligence.)

Motivate

Demonstration — BASI

Use an inkpad and white paper to take a fingerprint of each student. Display the prints. Ask the class what is special about each print. (They are all different.) Explain tha just as everyone (except identical twins) has different fingerprints, we all have different DNA prints. Inform students that the DNA prints are called DNA fingerprints because they create a pattern simil to the way that the ridges on the fi gers leave a pattern in a fingerprin Display autoradiographs of DNA fingerprints from science journals or magazines.

LS Intrapersonal

English Language Learners

Teach

eaching Tip

ınk DNA Tell students that the ndings of the Human Genome oject indicate that at least 50 per- nt of the human genome is made o of repeated sequences of DNA at do not code for proteins. This NA is often referred to as "junk NA" because scientists have not en able to determine that it has y function. Recent research sug- sts that these repeats are involved reshaping the genome by rear- nging it, creating entirely new nes, and modifying and reshuf- ng existing genes.

eaching Tip — GENERAL

raphic Organizer Have students ake a Graphic Organizer to out- ne how genetically engineered ugs are made. LS Visual

roup Activity — BASIC

enetic Privacy By 2010, scien- ts predict, $100 will buy a test at effectively identifies genetic arkers for a myriad of conditions d diseases. Have students work in oups of five to discuss genetic formation and privacy by reacting questions such as: Should nployers have access to genetic formation? Should health and life surance companies? Should school ficials? Should anyone except you r your parents, as a child) know ur genetic predispositions and ur genetic potential or lack ereof? Moreover, should they ow your genetic information even you choose not to know it?

Interpersonal Co-op Learning

Genetically Engineered Drugs and Vaccines

Much of the excitement about genetic engineering has focused on its potential uses in our society. The possibilities for the applications of these techniques in medicine and research are endless. Many applications are already commonplace, such as the production of genetically engineered proteins used to treat illnesses and the creation of new vaccines used to combat infections.

Drugs

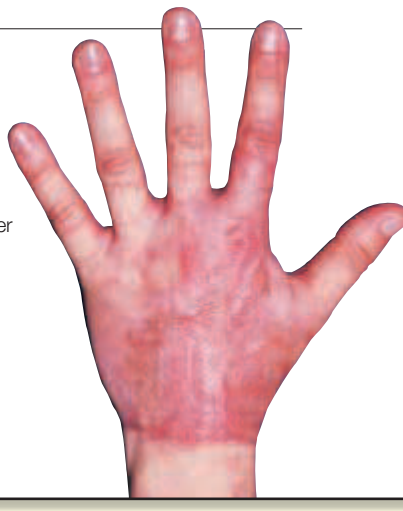
Many genetic disorders and other human illnesses occur when the body fails to make critical proteins. Juvenile diabetes is such an illness. The body is unable to control levels of sugar in the blood because a critical protein, insulin, cannot be made. These failures can be overcome if the body can be supplied with the protein it lacks. The proteins that regulate the body's functions are typically present in the body in very low amounts. Today hundreds of pharmaceutical companies around the world produce medically important proteins in bacteria using genetic engineering techniques as summarized in **Figure 7.**

Factor VIII, a protein that promotes blood clotting, is an example of a GM medicine (**g**enetically **m**odified; a drug manufactured by genetic engineering). A deficiency in factor VIII leads to one type of hemophilia, an inherited disorder characterized by prolonged bleeding. For a long time, hemophiliacs received blood factors that had been isolated from donated blood. Unfortunately, some of the donated blood was infected with viruses such as HIV and hepatitis B. The viruses were sometimes unknowingly transmitted to people who received blood transfusions. Today, the use of genetically engineered factor VIII eliminates these risks.

Figure 7 Use of genetically engineered medicines. Many medicines, such as medicines used to treat burns, are produced by genetic engineering techniques.

Genetically Engineered Medicines

Product:	Used for treatment of:
• Erythropoetin	Anemia
• Growth factors	Burns, ulcers
• Human growth hormone	Growth defects
• Insulin	Diabetes
• Interferons	Viral infections and cancer
• Taxol	Ovarian cancer



Graphic Organizer

Use this graphic organizer with **Teaching Tip: Graphic Organizer** on this page.

Desired gene identified → Gene transferred to bacterial plasmid → Plasmid containing desired gene introduced into bacteria → Bacteria grown in large numbers to produce needed drug

Vaccines

Many viral diseases, such as smallpox and polio, cannot be treated effectively by existing drugs. Instead they are combated by prevention—using vaccines. A **vaccine** is a solution containing all or part of a harmless version of a pathogen (disease-causing microorganism). When a vaccine is injected, the immune system recognizes the pathogen's surface proteins and responds by making defensive proteins called antibodies. In the future, if the same pathogen enters the body, the antibodies are there to combat the pathogen and stop its growth before it can cause disease.

Traditionally, vaccines have been prepared either by killing a specific pathogenic microbe or by making the microbe unable to grow. This ensures that the vaccine itself will not cause the disease. The problem with this approach is that there is a small but real danger that a failure in the process to kill or weaken a pathogen will result in the transmission of the disease to the very patients seeking protection. This danger is one of the reasons why, for example, rabies vaccines are administered only when a person has actually been bitten by an animal suspected of carrying rabies.

Vaccines made by genetic engineering techniques avoid this danger. As illustrated in **Figure 8,** the genes that encode the pathogen's surface proteins can be inserted into the DNA of harmless viruses such as cowpox (Vaccinia). The modified but harmless cowpox virus becomes an effective and safe vaccine, as illustrated in Figure 8. The surfaces of the modified virus display herpes surface proteins in addition to the virus's own surface proteins. When the modified virus is injected into a human body, the body's immune system quickly responds to this challenge. The immune system makes antibodies that attack any virus displaying the herpes surface protein. As a result, the body is thereafter protected against infection by the herpes virus.

Real Life

You might get a vaccine in a banana.

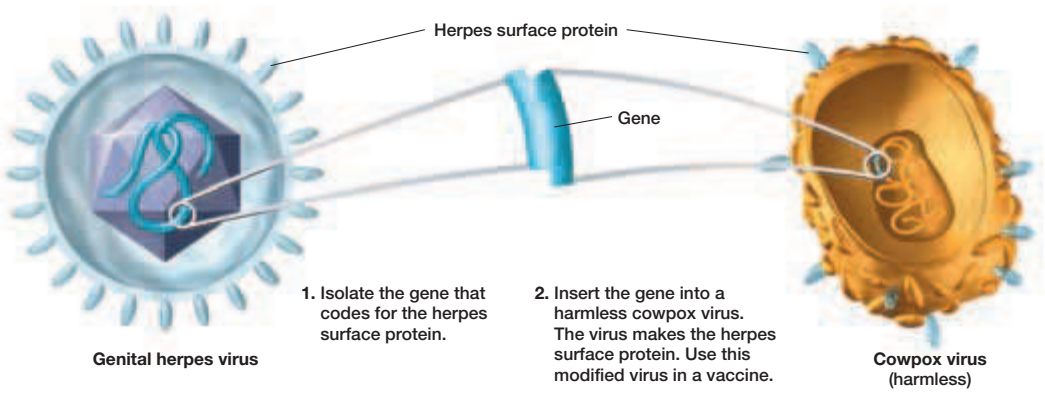
Genetic engineers are putting genes from disease-causing microbes into fruits and vegetables to create vaccines that are inexpensive and easy to take. Clinical trials using different foods, including potatoes, are underway.

Finding Information

What are the most common ways vaccines are now administered?

Figure 8 **Making a genetically engineered vaccine**

A person vaccinated with a genetically engineered vaccine, such as the genital herpes vaccine, will make antibodies against the virus.



Real Life — GENERAL

Answer

Nearly all vaccines are currently administered by injection. Most vaccines are injected into muscle tissue or under the skin.

Group Activity — GENERAL

Genetic Diseases of Different Ethnicities Have students work in small groups to conduct research on diseases that are more common in people of specific ethnic backgrounds. Some examples they could research are sickle cell anemia, thalassemia, Tay-Sachs disease, and tyrosinemia. Have each group prepare an oral report on the disease, including its prevalence in the specific population and the general population, its symptoms and severity, current treatments available, and current genetic engineering research being conducted as part of efforts to prevent, control, and/or treat the disease.

LS Verbal Co-op Learning

Group Activity — ADVANCED

Smallpox Have students work in small groups to conduct library and Internet research on smallpox. Assign one group to research the history of smallpox and its control, including its status as the first vaccine-preventable disease and its eradication in the 1970s. Assign another group to research the only approved smallpox vaccine, which is made from a virus called Vaccinia which is a live "pox"-type virus related to smallpox. Assign another group to research the development of new smallpox vaccines, the testing and approval processes for new vaccines, and the current status of smallpox vaccine. Assign a final group to research the potential use of smallpox as a bioterrorism agent and the public health system's current plans for controlling a possible bioterrorist attack using the smallpox virus.

LS Verbal Co-op Learning

TECHNOLOGY CONNECTION

Gene therapy is a novel approach to treat, cure, or ultimately prevent disease by changing the expression of a person's genes. Gene therapy is in its infancy and current gene therapy is primarily experimental, with most human clinical trials only in the research stages. Gene therapy can be targeted to somatic (body) or germ (egg and sperm) cells. In somatic gene therapy the recipient's genome is changed, but the change is not passed along to the next generation. Thus the gene therapy may have to be repeated in future generations. There are several diseases for which gene therapy is currently being investigated using somatic gene therapy, with mixed results to date. In germline gene therapy, the parents' egg and sperm cells are changed with the goal of passing on the changes to their offspring. Germline gene therapy prevents the trait from being passed on to further generations. Germline gene therapy is not being actively investigated, at least in larger animals and humans, although a lot of discussion is being conducted about its value and desirability.

Vaccines for the herpes II virus and for the hepatitis B virus are now being made through genetic engineering. The herpes II virus produces small blisters on the genitals (the external sex organs). The hepatitis B virus causes an inflammation of the liver that can be fatal. A major effort is underway to produce a vaccine that will protect people against malaria, a protozoan-caused disease for which there is currently no effective protection.

Polymerase Chain Reaction (PCR)

A detective finds a single hair as the only evidence left behind at a crime scene. Will this hair provide enough DNA to analyze? For DNA fingerprinting and many of the genetic engineering uses discussed throughout this chapter, a certain amount of DNA is needed. Sometimes, however, only a very tiny amount of DNA is available.

Today scientists use a technique called the polymerase chain reaction (PCR) to quickly make many copies of selected segments of the available DNA. With PCR, a scientist can produce a billionfold increase in DNA material within a few hours!

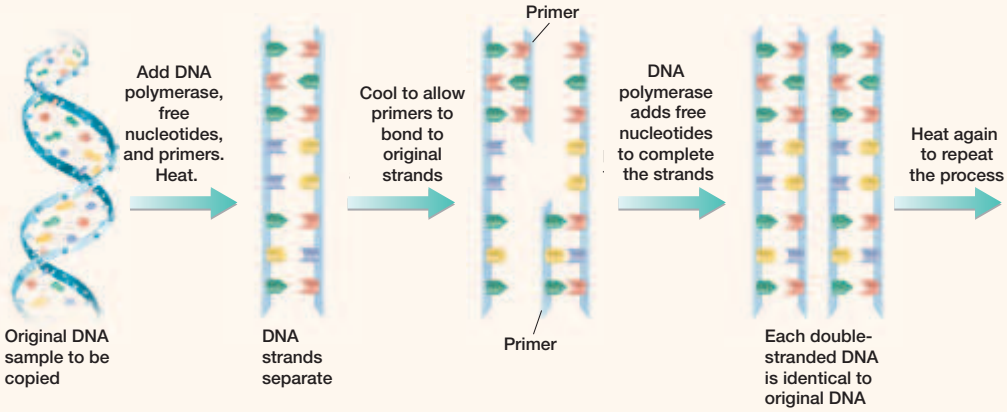
Heating and Replication Cycles

In PCR the double-stranded DNA sample to be copied is heated, which separates the strands. The mixture is cooled, and short pieces of artificially made DNA called primers are added. The primers bind to places on the DNA where the copying can begin.

DNA polymerase and free nucleotides are added to the mixture. The DNA polymerase extends the DNA by attaching complementary free nucleotides to the primer. The result is two strands of DNA that are identical to each other and to the original strand. The heating and replication process is repeated over and over again. Every 5 minutes, the sample of DNA doubles again, resulting in many copies of the sample in a short amount of time. Today, scientists use PCR machines, which automatically cycle the reaction temperature.

PCR's Many Uses

PCR can duplicate DNA from as few as 50 white blood cells, which might be found in a nearly invisible speck of blood. PCR is important for diagnosing genetic disorders and for solving crimes. PCR is also used in different types of research and for studying ancient fragments of DNA found in fossils or in preserved material.



REAL WORLD CONNECTION

In cases of bioterrorist attack such as the anthrax mail incidents, officials need to understand the situation quickly. Early detection and identification of the biological organism and its source are crucial for minimizing the potentially catastrophic human and economic costs. Clues may lie hidden in the weapon itself. Does the bacterium or virus harbor information in its DNA that could lead to its source? Is it resistant or sensitive to vaccines and antibiotics? To find answers to these questions, revolutionary new approaches are being developed. Intensive research on *Bacillus anthracis* and *Yersinia pestis* (causes of anthrax and plague, respectively) has led to a wealth of genetic information and unique technologies for detecting and identifying these organisms. The studies have focused on tracking selected, highly variable, or very specific DNA signatures in the microbes. These analyses may offer clues to the agents' genetic identity, geographic origin, and genetic modification to enhance its resistance to antibiotics and vaccines.

BIOWatch

Polymerase Chain Reaction (PCR)

Teaching Strategies

- Let students know that PCR is now a very common technique used to obtain sufficient DNA samples not just in criminal cases but for basic research as well.
- When the source of DNA is meager or impure, PCR is a quicker and more selective method than gene cloning. Because PCR is performed completely *in vitro* (in test tubes), cells are not used as with gene cloning. Billions of copes of DNA can be made in a few hours with PCT, whereas gene cloning would take days.

Discussion

- If most proteins (such as enzymes) denature or break down with high heat, how can the DNA polymerase used in PCR withstand the heating cycles? (The DNA polymerase is isolated from bacteria living in hot springs. The DNA polymerase from these bacteria can withstand the heat needed to separate the DNA strands.)
- Under conditions of PCR amplification, DNA replicates about every 5 minutes. Determine how many copies of a DNA fragment will result from 85 minutes of PCR. ([85 min] / [5 min/cycle] = 17 cycles; 2^{17} or 1.31×10^5 copies.)

Forensics Labs Appendix

Turn to pp. 1048–1071 for forensics lab activities and more student information on forensics techniques.

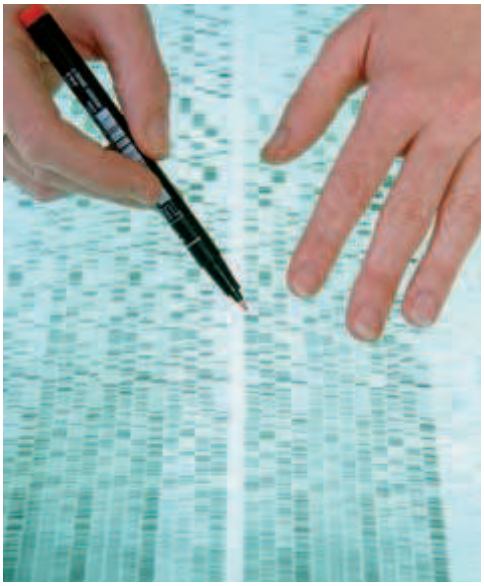
DNA Fingerprinting

Other than identical twins, no two individuals have the same genetic material. Scientists use DNA sequencing gel technology to determine a DNA fragment's nucleotide sequence, as shown in **Figure 9.** Because the places a restriction enzyme can cut depend on the DNA sequence, the lengths of DNA restriction fragments will differ between two individuals. Such DNA fragments of different lengths (polymorphisms) are called restriction fragment length polymorphisms, or RFLPs.

RFLPs can be used to identify individuals and to determine how closely related members of a population are to one another. The Southern blot technique, shown in Figure 5, is used to show an individual's RFLP profile. The result is called a *DNA fingerprint*. A **DNA fingerprint** is a pattern of dark bands on photographic film that is made when an individual's DNA restriction fragments are separated by gel electrophoresis, probed, and then exposed to an X-ray film. Because restriction enzymes cut the DNA from different individuals into DNA fragments of different lengths (RFLPs), each individual (other than identical twins) has a unique pattern of banding, or DNA fingerprint.

The banding patterns from two individuals can be compared to establish whether they are related, such as in a paternity case. Because it can be performed on a sample of DNA found in blood, semen, bone, or hair, DNA fingerprinting is useful in forensics. Forensics is the scientific investigation of the causes of injury and death when criminal activity is suspected. DNA fingerprints are also valuable for identifying the genes that cause genetic disorders, such as Huntington's disease and sickle cell anemia.

Figure 9 DNA sequence. The nucleotide sequence of DNA fragments can be determined using DNA sequencing gel technology.



Section 2 Review

1. **Relate** the use of genetic engineering to the treatment of human illnesses such as hemophilia.
2. **Relate** genetic engineering techniques to the making of vaccines.
3. **List** two ways in which DNA fingerprinting has been useful to society.
4. **Critical Thinking Distinguishing Relevant Information** A student states that genetic engineering is "perfectly safe and sound." What safety and ethical issues do you think might arise over the use of genetic engineering?
5. **Standardized Test Prep** One medicine made in bacteria using genetic engineering techniques is insulin, which is used to treat

   A heart attacks **C** diabetes
   B smallpox **D** cystic fibrosis

Answers to Section Review

1. Many genetically engineered proteins are used to treat illnesses. For example, factor VIII, a protein that promotes blood clotting, is now made by genetic engineering and sold as a drug to hemophiliacs. Genetic engineers are also attempting to replace defective human genes with healthy ones.
2. Instead of using a killed or weakened pathogen, the genes that code for the proteins found on the surface of the pathogen are inserted into the DNA of harmless bacteria or viruses. People are then vaccinated with the modified virus or bacteria.
3. DNA fingerprinting has been useful in forensics, in paternity suits, and in identifying the genes that cause genetic disorders.
4. Answers may include concerns about who has access to personal genetic information and how they might use that information and whether gene technologies are safe to individuals and to the human population as a whole.
5. **A.** Incorrect. Insulin is not used to treat heart attacks. **B.** Incorrect. Insulin is not used to treat smallpox. **C.** Correct. **D.** Incorrect. Insulin is not used to treat cystic fibrosis.

Close

Reteaching — BASI

Have students write one sentence for each of the Key Terms. Each sentence should demonstrate the meaning of the term as it is defined in the text. LS Verbal

Quiz — GENERA

1. What is the Human Genome Project? (a multinational scientif research project that has elucidated the DNA sequence of the entire human genome)
2. Provide an example of a genetically engineered medicine (erythropoetin, growth factors, human growth hormone, insulin, interferons, and taxol)
3. What is the polymerase chain reaction, or PCR? (a laboratory technique used to quickly make multiple copies of selected segments of a DNA sample)

Alternative Assessment — ADVANC

Instruct students to prepare themselves for a visit to a university or pharmaceutical company that use genetic engineering techniques. Have them prepare a list of questions about the research conducte at the facility, the staff and financia resources available, the techniques and equipment used, and any appl cations of their research that are currently in use.

Section 3

Focus

verview

efore beginning this section view with your students the bjectives listed in the Student dition. This section discusses the netic engineering of crop plants d animals to improve yield and uality and reviews concerns about e safety of this kind of engineering.

Bellringer

ave students write the name of a uit or vegetable that they don't ke to eat and explain why they on't like it. Then ask them to rite about ways in which the fruit vegetable could possibly be anged by genetic engineering so at they would like it.

Motivate

iscussion — GENERAL

he Flavr-Saver™ tomato was the rst genetically altered fruit to ach supermarket shelves. It was tered to last longer and taste bet- r than other types of tomatoes. enetically engineered crops also esent an alternative to the use of sticides. A large percentage of the orld's food supply is lost to pests. sticide use, though effective, has disadvantages. Ask students hat some of the disadvantages ight be. (Over time the pests become sistant to the pesticide; other plant d animal life may be harmed) Ask udents to discuss concerns about ing genetically engineered crops. he genetically engineered plant may ss the genes on to close relatives in e wild.) LS Verbal

Section 3 Genetic Engineering in Agriculture

Objectives

- **Describe** three ways in which genetic engineering has been used to improve plants.
- **Summarize** two ways in which genetic engineering techniques have been used to modify farm animals.
- **Summarize** the cloning of sheep through the use of differentiated cells.

Key Terms

transgenic animal

Improving Crops

Farmers began primitive genetic breeding by selecting seeds from their best plants, replanting them, and gradually improving the quality of successive generations. In the twentieth century, plant breeders started using the principles of genetics to select plants. Today, genetic engineers can add favorable characteristics to a plant by manipulating the plant's genes, as shown in **Figure 10.**

Genetic engineers can change plants in many ways, including making crop plants more tolerant to drought conditions and creating plants that can adapt to different soils, climates, and environmental stresses.

Genetic engineers have developed crop plants that are resistant to a biodegradable weedkiller called *glyphosate*. This has enabled farmers to apply glyphosate to kill weeds without killing their crops. Because the field does not need to be tilled to control weeds, less topsoil is lost to erosion. Half of the 72 million acres of soybeans planted in the United States in 2000 were genetically modified to be glyphosate resistant.

Scientists have also developed crops that are resistant to insects by inserting a certain gene isolated from soil bacteria into crop plants. This gene makes a protein that injures the gut of chewing insects. Crops that are resistant to insects do not need to be sprayed with pesticides, many of which can harm the environment.

More Nutritious Crops

Genetic engineers have been able, in many instances, to improve the nutritional value of crop plants. For example, in Asia many people use rice as a major source of food, yet rice has low levels of iron and beta carotene, which your body uses to make vitamin A (necessary for vision). As a result, millions suffer from iron deficiency and poor vision. Genetic engineers have added genes to rice from other plants, as shown in **Figure 11,** to overcome this deficiency.

Figure 10 **Genetically engineered plants.** At least 50 plants have been genetically engineered, including potatoes, soybeans, and corn. The researcher Athanasios Theologis genetically engineered tomatoes to ripen without becoming soft.

Chapter Resource File

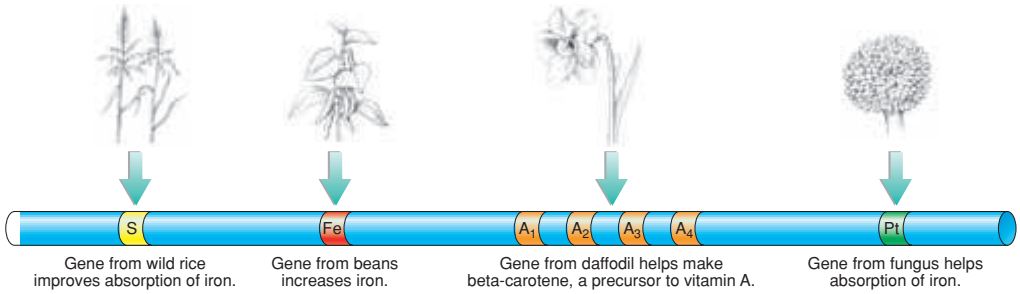
- Directed Reading BASIC
- Active Reading GENERAL

Transparencies

TR Bellringer

One-Stop Planner CD-ROM

- Reading Organizers BASIC
- Reading Strategies BASIC
- Supplemental Reading Guide *The Double Helix* ADVANCED



Risks of Genetically Modified Crops

Many people, including influential scientists, have expressed concern that genetically modified crops (GM crops) might turn out to be dangerous. What kind of unforeseen negative effects might "improved" GM crops have?

Figure 11 Rice enriched with iron and vitamin A. Genetically modified "golden" rice offers the promise of improving the diets of people in rice-consuming countries, where iron and vitamin A deficiencies are a serious problem.

Potential Problems

Some food crops, such as corn and soybeans, have been genetically rendered resistant to glyphosate, a weed killer that is harmless to humans. Glyphosate, when used on a food crop, will kill the weeds but will not harm the GM crop, thus increasing food crop yields. Some scientists are concerned that the use of GM crops and the subsequent use of glyphosate will eventually lead to glyphosate-resistant weeds. This will leave farmers with few weed-control alternatives.

Some GM crops have genes added to improve nutritional character, as was done in rice. It is important to check that consumers are not allergic to the product of the introduced gene. For this reason, screening of GM crops for causes of allergy problems is now routine.

Are GM Crops Harmful to the Environment?

Will introduced genes pass from GM crops to their wild or weedy relatives? This sort of gene flow happens naturally all the time, so this concern is legitimate. For most crops, no closely related wild plant is around to receive the gene. The GM gene cannot pass to a nonrelative, because crop plants cannot successfully reproduce with unrelated species, any more than a cat can breed with a giraffe. There are wild relatives of corn in Mexico and Guatamala, which frequently exchange genes with corn crops. Scientists are divided about whether it makes any difference if one of the genes is a GM gene.

Might pests become resistant to GM toxins? Pests are becoming resistant to GM toxins just as they have become resistant to the chemical pesticides that are sprayed on crops.

Scientists, the public, and regulatory agencies must work together to evaluate the risks and benefits of GM products.

REAL WORLD CONNECTION

The Green Revolution of the 1960s and 1970s, with its package of improved seeds, farm technology, better irrigation, and chemical fertilizers was highly successful at meeting its primary objective of increasing crop yields and augmenting food supplies. In Asia, where the package was the most widely adopted, food production increased substantially. Yet, despite its success at increasing aggregate food supply, the Green Revolution has not translated into benefits for most of the lower strata of the rural poor.

Poor nutrition and poverty are still prevalent, and the distribution of food remains skewed. This has led to the recognition by development agencies of the need to formulate a more equitable and sustainable Green Revolution aimed at improving food security for the poorest people in rural areas. Much of the success of this new approach will depend on its ability to respond to the realities of women farmers, who are the critical people involved in producing, providing, and managing food supplies in the poorest rural households.

Teach

Teaching Tip

Plants of The Green Revolution In the 1950s, Norman Borlaug of the International Maize and Whea Research Centre, Mexico, crossed short-stem wheat plants with Mexico's best wheat plants. In 1963, Borlaug responded to an urgent request from the government of India to provide them wi seeds of his dwarfed, high-yieldin plants. The tall native wheat plan of India were growing too high when heavily fertilized with nitrogen and would fall over from the weight of their seed heads. The short wheat plants Borlaug provided, along with fertilizer and irrigation, increased wheat produ tion from 12 million metric tons i 1965 to over 20 million in 1970 and over 37 million in 1982. Sinc the new wheat plants were broadl adapted, Green Revolutions also took hold in countries sharing sim lar latitudes, such as Pakistan, Turkey, and Afghanistan. For his contributions, Borlaug was awarded the Nobel Prize.

Group Activity — GENERA

Genetically Engineered Crop Plants Have students work in small groups to conduct library a Internet research on genetically engineered crop or ornamental plants. Assign different groups to research one of the following kin of plants: One that has been engineered to enhance its nutritional value, another engineered to mak it resistant to an herbicide, anothe engineered to enhance its resistan to an insect or other pest, and another engineered to enhance its aesthetic value. Have each group prepare a written report of their findings, including a description and picture or drawing of the plant, the methods used to develo it, the cost and time involved in engineering it, the public's acceptance of the plant, and any problem associated with producing or mar keting the plant. Co-op Learning

Teach, *continued*

READING SKILL BUILDER — GENERAL

rainstorming Lead students in a scussion comparing food crops d farm animals produced by lective breeding and by genetic gineering. (A new variety is devel-ed in a shorter period of time using NA technology instead of selective eeding. You can also insert medically eful human proteins into animals that they produce the protein in lk.) Emphasize that the develop-ent of organisms to enhance rtain features has been occurring r many years through selective eeding. Ask students to envision ays in which genetic engineering ight not be beneficial. (may lead a loss of biodiversity or create nforeseen problems) LS Verbal

roup Activity — ADVANCED

ds for Gene Products Have oups of students choose and then search a genetically engineered oduct such as human insulin. Ask udents to create a full-page adver-ement. The ad must be creative, me the product and its use, list de effects, and include a well-ought-out effort to convince the blic that the genetically engi-ered product is safe.

Visual Co-op Learning

internet connect
www.scilinks.org
Topic: Cloning
Keyword: HX4047
SCILINKS Maintained by the National Science Teachers Association

Gene Technology in Animal Farming

Farmers have long tried to improve farm animals and crops through traditional breeding and selection programs. In the past, the cow that produced the most milk on a farm may have been mated to male offspring of high producers in hopes that the cow's offspring would also produce a lot of milk. But these traditional processes were slow and inefficient.

Now, many farmers use genetic-engineering techniques to improve or modify farm animals. Some farmers add growth hormone to the diet of cows to increase milk production. Previously, the growth hormone was extracted from the brains of dead cows. But now the cow growth hormone gene is introduced into bacteria. The bacteria produce the hormone so cheaply that it is practical to add it as a supplement to the cows' diet.

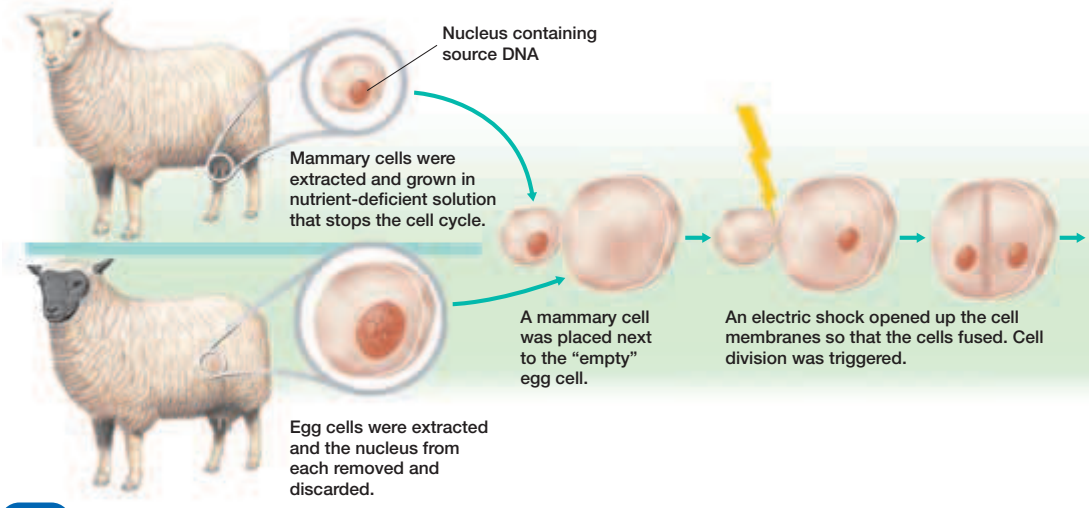
By altering the gene responsible for GH production, scientists have stimulated natural GH in pigs, increasing their weight. Though these procedures are still new, they may lead to the creation of new breeds of very large and fast-growing cattle and hogs.

Making Medically Useful Proteins

Another way in which gene technology is used in animal farming is in the addition of human genes to the genes of farm animals in order to get the farm animals to produce human proteins in their milk. This is used especially for complex human proteins that cannot be made by bacteria through gene technology. The human proteins are

Figure 12 **Cloning a sheep from mammary cells**

In 1997 scientists announced the first successful cloning using differentiated cells—a lamb named Dolly.



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TECHNOLOGY CONNECTION

Having already cloned cattle, pigs and goats, researchers at Texas A&M University have moved on to house pets, with the first successful cloning of a common house cat. The fact that the cloned kitten was one of only 87 cloned cat embryos to survive underscores obstacles still remaining in this area of research. In a process similar to that used with Dolly the cloned sheep, the researchers transplanted DNA derived from the nuclei of cumulus cells (near the ova) of a calico cat into the empty (i.e. nucleus removed) egg cell of another cat, then transplanted the embryo into a third cat.

Genetic tests confirm that the kitten is indeed a genetic copy of the original calico cell donor. Interestingly, the kitten does not have the same coloring as the genetic parent, a fact the researchers attribute to the play of dueling X chromosomes and developmental factors outside the control of the nucleic DNA.

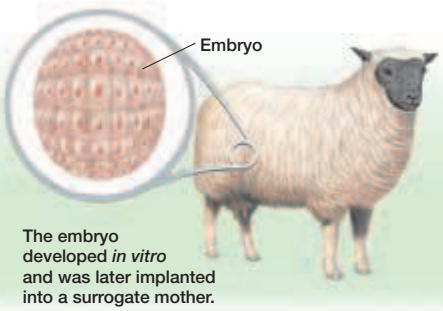
extracted from the animals' milk and sold for pharmaceutical purposes. The animals are called **transgenic animals** because they have foreign DNA in their cells.

Most recently, scientists have turned to cloning animals as a way of creating herds of identical animals that can make medically useful proteins. The intact nucleus of an embryonic or fetal cell (whose DNA has been recombined with a human gene) is placed into an egg whose nucleus has been removed. The egg with the new nucleus is then placed into the uterus of a surrogate, or substitute, mother and is allowed to develop.

Cloning From Adult Animals

In 1997, a scientist named Ian Wilmut captured worldwide attention when he announced the first successful cloning using differentiated cells from an adult animal. A differentiated cell is a cell that has become specialized to become a specific type of cell (such as a liver or udder cell). As summarized in **Figure 12,** a lamb was cloned from the nucleus of a mammary cell taken from an adult sheep. Previously, scientists thought that cloning was possible only using embryonic or fetal cells that have not yet differentiated. Scientists thought that differentiated cells could not give rise to an entire organism. Wilmut's experiment proved otherwise.

An electric shock was used to fuse mammary cells from one sheep with egg cells without nuclei from a different sheep. The fused cells divided to form embryos, which were implanted into surrogate mothers. Only one embryo survived the cloning process. Dolly, born on July 5, 1996, was genetically identical to the sheep that provided the mammary cell.



The embryo developed *in vitro* and was later implanted into a surrogate mother.

After a 5-month pregnancy, a lamb was born that was genetically identical to the sheep from which the mammary cell was extracted.

Teaching Tip

Technology Terminology Tell st dents that the terms *genetic modi cation* (GM) and biotechnology a often used interchangeably. GM i a special set of technologies that alter the DNA of such living orga isms as animals, plants, or bacteri Biotechnology, a more general term, refers to using natural livin organisms or their components. Combining DNA from different organisms is known as recombinant DNA technology, and the resulting organism is said to be "genetically modified," "genetica engineered," or "transgenic."

READING SKILL BUILDER — ADVANC

Discussion Dolly, the lamb clon from undifferentiated cells, developed some unforeseen problems as she grew older. Her chromosomes began showing signs of premature aging. In 2002 she was diagnosed with arthritis, a condition of aging that normally develops in sheep older than her 5 years. Dolly was euthanized in 2003. Ask students why the chromosomes could appear abnormally old when Dol was relatively young. (Dolly was cloned from mammary cells from a adult sheep.) How does this information affect other cloning experiments? (It appears that when organisms are cloned from adult cells, their chromosomes may age prematurely. These findings suggest that Dolly's cellular aging clock wa not reset at her own "birth" but tha her clock is actually set at her age plus 6 years, the age of the sheep from which she was cloned. This in turn may eventually affect the meta olism of the organism.) LS Verbal

did you know?

Genetically Modified Foods Genetically modified (GM) crops are grown in over 40 countries and on 6 continents. In 2000, about 109.2 million acres were planted with transgenic crops, the principal ones being herbicide- and insecticide-resistant soybeans, corn, cotton, and canola. Other crops grown commercially or field tested are a sweet potato resistant to a virus that could decimate most of the African harvest, rice with increased iron and vitamins that may alleviate chronic malnutrition in Asian countries, and a variety of plants able to survive weather extremes. On the horizon are bananas that produce human vaccines against infectious diseases such as hepatitis B, fish that mature more quickly, fruit and nut trees that yield years earlier, and plants that produce new unique plastics.

In 2000, countries that grew 99% of the global transgenic crops were the United States (68%), Argentina (23%), Canada (7%), and China (1%). Although growth is expected to plateau in industrialized countries, it is increasing in developing countries.

Close

eteaching — BASIC

sk students to create a table summarizing the ways in which genetic gineering has been used to prove food crops and farm animals and to make medically useful oteins in the milk of farm animals. LS Verbal

uiz — GENERAL

Why is glyphosate a valuable weedkiller? (it is biodegradable and crop plants can be genetically engineered to resist its toxic effects)

What is an animal called that has foreign DNA in its cells? (a transgenic animal)

What is genomic imprinting and what are the implications of this process for cloning? (Genomic imprinting is the process of conditioning DNA to the early stage of development of an embryo. Because cells divide rapidly during the cloning process, there is not enough time for reconditioning of the DNA to occur.)

lternative ssessment — GENERAL

ll students to return to the list of ings they want to know about ne technology from the previous ctive Reading exercise. Have em place check marks next to the uestions they can now answer. udents should finish by making a t of what they have learned. onduct a discussion of the maining questions that have gone nanswered. LS Verbal

Problems With Cloning

Since Dolly's birth in 1996, scientists have successfully cloned animals. Only a few of the cloned offspring survived for long, however. Many become fatally oversized. Others encounter problems in development. For example, three cloned calves were born healthy in March, 2001, only to die a month later of immune system failure.

The Importance of Genomic Imprinting

Technical problems in reproductive cloning lie within a developmental process that conditions eggs and sperm so that the right combination of genes are turned "on" or "off" during early development. When cloned offspring become adults, a different combination of genes is activated. The process of conditioning the DNA during an early stage of development is called genomic imprinting.

In genomic imprinting, chemical changes made to DNA prevent a gene's expression without altering its sequence. Usually, a gene is locked into the "off" position by adding methyl ($-CH_3$) groups to its cytosine nucleotides, as shown in **Figure 13.** The bulky methyl groups prevent polymerase enzymes from reading the gene, so the gene cannot be transcribed. Later in development, the methyl groups are removed and the gene is reactivated.

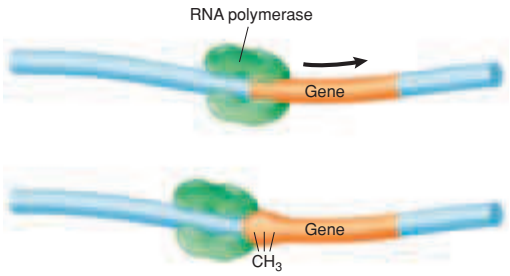


Figure 13 Methylated gene. In one model of genomic imprinting, methyl groups attached to a gene prevent the gene from being expressed.

Why Cloning Fails

Normal vertebrate development depends on precise genomic imprinting. This process, which takes place in adult reproductive tissue, takes months for sperm and years for eggs. Reproductive cloning fails because the reconstituted egg begins to divide within minutes. There is simply not enough time in these few minutes for the reprogramming to process properly. Key genes fail to become properly methylated, and this leads to critical errors in development.

Because of these technical problems, and because of ethical problems, efforts to clone humans are illegal in most countries.

Section 3 Review

1. **List** three ways in which food crops have been improved through genetic engineering.
2. **Compare** the cloning of sheep through the use of differentiated cells with the cloning of sheep through the use of embryonic cells.
3. **Critical Thinking Analyzing Methods** In the movie *Jurassic Park*, scientists used DNA to bring back extinct species. How is that different from the creation of cloned sheep using differentiated cells?
4. **Critical Thinking Forming Reasoned Opinions** List reasons you would or would not be concerned about consuming milk from cows treated with growth hormone.
5. **Standardized Test Prep** Using genetic engineering to produce rice with high levels of beta-carotene should help people who suffer from a deficiency in
   A vitamin A. **C** glyphosate.
   B growth hormone. **D** complex proteins.

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Answers to Section Review

1. making food crops more tolerant to drought conditions, different soils, or climates; enhancing their nutritional value; controlling the process by which fruit ripens; making them resistant to the weedkiller glyphosate
2. Cloning with embryonic cells allows an organism to develop from cells that have not undergone specialization. Cloning with differentiated cells requires that the cell be manipulated so that the cell cycle is stopped.
3. The DNA used in Jurassic Park was fragmented. The researchers filled it in with DNA from other species. Thus, the dinosaurs had foreign DNA and were not truly clones.
4. Answers will vary. Students may not be concerned if evidence provided by the company indicates the hormone is safe. Concerns may include that the hormone may contribute to breast and prostate cancer and that cows get more infections and have to be given antibiotics, which could enter the milk.
5. **A.** Correct. **B.** Incorrect. Beta-carotene would not alleviate a deficiency of growth hormone. **C.** Incorrect. Humans do not require glyphosate. **D.** Incorrect. Beta-carotene would not alleviate a deficiency of complex proteins.

Study ZONE CHAPTER HIGHLIGHTS

Key Concepts

1 Genetic Engineering

- Genetic engineers manipulate DNA for practical purposes.
- Restriction enzymes cleave DNA into fragments that have short sticky ends. Sticky ends allow DNA fragments from different organisms to join together to form recombinant DNA.
- Recombinant DNA is inserted into host cells. The cells are screened to identify cells that have the recombinant DNA. Each time the cells reproduce, the gene of interest is cloned.
- Electrophoresis uses an electric field within a gel to separate DNA fragments by their size.
- Specific genes can be identified with the Southern blot technique.

2 Genetic Engineering in Medicine and Society

- Genetic engineering is used to manufacture human proteins for use as drugs and to make safer and more effective vaccines.
- Some human genetic disorders are being treated with gene therapy.
- DNA fingerprinting is used to identify individuals and determine relationships between individuals.
- The Human Genome Project is an effort to determine the nucleotide sequence of and map the location of every gene on each human chromosome by the year 2003. The sequence of the genomes of many organisms has already been determined.

3 Genetic Engineering in Agriculture

- Crop plants can be genetically engineered to have favorable characteristics, including improved yields and resistance to herbicides and destructive pests.
- Genetically engineered growth hormone increases milk production in dairy cows and weight gain in cattle and hogs.
- Success in cloning animals using differentiated cells was announced in 1997. In addition, transgenic animals can be cloned and used to make proteins that are useful in medicine.

Key Terms

Section 1

genetic engineering (228)
recombinant DNA (228)
restriction enzyme (229)
vector (229)
plasmid (229)
gene cloning (229)
electrophoresis (231)
probe (231)

Section 2

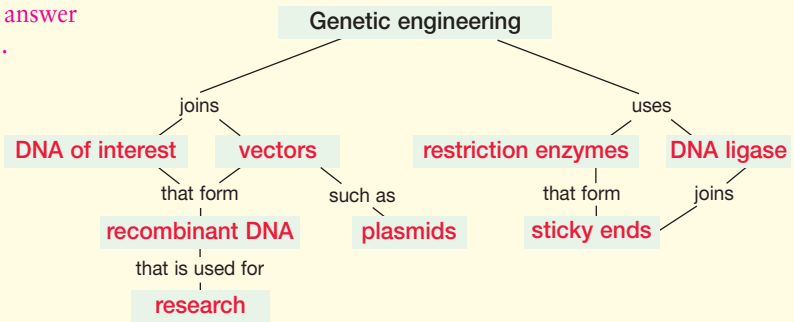
Human Genome Project (233)
vaccine (235)
DNA fingerprint (237)

Section 3

transgenic animal (241)

Answer to Concept Map

The following is one possible answer to Performance Zone item 15.



Study ZONE

Alternative Assessment — ADVANC

The use of DNA technology presents many ethical and moral issue Divide your class into two groups Ask one group to prepare informa tion that supports DNA technolo development, including specifics about the benefits of genetic engineering to society. Have the other group prepare information that demonstrates the negative aspects of these technologies. Have the tw groups debate their stands on the issue. LS Verbal

Chapter Resource Fil

- Science Skills Worksheet GENERAL
- Critical Thinking Worksheet ADVANCED
- Test Prep Pretest GENERAL
- Chapter Test GENERAL

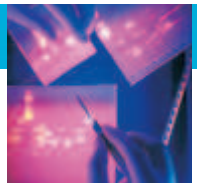
ANSWERS

Understanding Key Ideas

1. a
2. b
3. b
4. c
5. b
6. a
7. d
8. Molecule A was produced through genetic engineering. Plasmid DNA and DNA from a different organism are cut with restriction enzymes and then combined to produce recombinant plasmid DNA. The recombinant plasmid DNA molecules are then inserted into bacterial cells.
9. DNA is extracted from the bone. DNA primers, DNA polymerase, and nucleotides are added. The DNA is heated and then cooled. In a short time the original DNA from the fossilized bone is replicated. The sample is heated again to repeat the process until an adequate sample size is obtained.
10. The answer to the concept map is found at the bottom of the Study Zone page.

Critical Thinking

11. Answers will vary. The regulations were prompted by concerns that genetically engineered organisms might cause disease or have harmful effects on the environment. By limiting their survival outside the laboratory, scientists are preventing the organism from possibly harming people or other organisms and interfering in food chains.
12. Students should disagree. A match of DNA fingerprints from two different samples has only two explanations—the prints are from the same person or from identical twins.
13. Answers will vary. For example: Will genetically engineered foods contain new proteins that are allergenic or toxic to some people? Will genetically engineered crops pass their new genes to close relatives in nearby wild areas and create weeds that are very difficult to control?



Understanding Key Ideas

1. Gel electrophoresis is used to _____ DNA fragments.
a. separate **c.** cut
b. join **d.** copy

2. Which of the following human illnesses can be treated using a product of genetic engineering?
a. malaria **c.** flu
b. hemophilia **d.** a sinus cold

3. Injecting a healthy copy of a gene into a person who has a defective gene is called
a. probing.
b. gene therapy.
c. PCR.
d. DNA cloning.

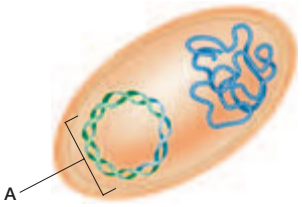
4. The major effort to map and sequence all human genes is called
a. the RFLP Project.
b. the PCR Project.
c. the Human Genome Project.
d. DNA fingerprinting.

5. A transgenic organism is produced as a result of
a. hybridization.
b. recombinant DNA.
c. mutation.
d. RFLPs.

6. The process of making recombinant DNA is *least* related to
a. clones.
b. DNA fragments.
c. restriction enzymes.
d. sticky ends.

7. Genetic engineers can make plants
a. resistant to insects.
b. more tolerant to droughts.
c. that are adapted to different soils.
d. All of the above

8. Describe how molecule *A* was produced.



9. BIOWatch You have discovered a fossilized bone. How can you use PCR to obtain sufficient DNA for DNA analysis?

10. **Concept Mapping** Make a concept map about genetic engineering. Try to include the following words in your map: *DNA of interest, vectors, recombinant DNA, plasmids, restriction enzymes, sticky ends,* and *research.*

Critical Thinking

11. Forming Reasoned Opinions In the United States, government regulations require researchers to contain experimental genetically engineered organisms inside a laboratory and to ensure that the organisms could not survive outside the laboratory. Why do you think these strict regulations are necessary?

12. Distinguishing Fact from Opinion A judge presiding over a highly publicized murder trial dismissed the prosecution's request to admit DNA fingerprints as evidence, calling it "unproven." Do you agree with the judge? Explain your answer.

13. Distinguishing Relevant Information Organize and videotape a class debate about the safety questions raised by the potential release of genetically engineered plants, bacteria, and animals into the environment. Use library references and on-line databases to back up your arguments.

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Assignment Guide

Section	Questions
1	1, 6, 8, 10, 11
2	2, 3, 4, 9, 12
3	5, 7, 13

Standardized Test Prep

Understanding Concepts

***Directions (1–4):* For *each* question, write on a separate sheet of paper the letter of the correct answer.**

1. What term describes a molecule containing DNA from two different organisms?
   A. plasmid
   B. probe
   C. recombinant DNA
   D. RFLP DNA

2. Which of the following is an extra ring of DNA in bacteria?
   F. clone
   G. plasmid
   H. probe
   I. restriction enzyme

3. What agent allows genetic engineers to cut DNA at specific sites?
   A. DNA ligase
   B. DNA polymerase
   C. plasmid DNA
   D. restriction enzyme

4. What technique is used to identify individuals in paternity cases and criminal cases?
   F. DNA fingerprinting
   G. gene therapy
   H. genomic imprinting
   I. vaccination

***Directions (5–6):* For *each* question, write a short response.**

5. Examine how natural selection could be affected by genetic engineering.

6. Analyze the difference in the meanings of the terms recombinant DNA and restriction enzyme.

Test TIP

When answering short-response questions, be sure to write in complete sentences.

Reading Skills

***Directions (7):* Read the passage below. Then answer the question.**

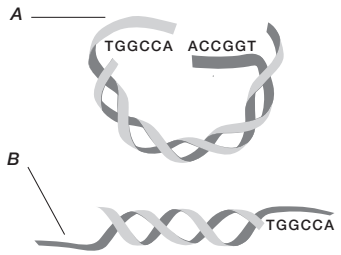
The question of awarding patents on genetically engineered organisms arose when a microbiologist named Ananda Chakrabarty filed for a patent on a bacterium capable of digesting the components of crude oil. Chakrabarty identified enzymes that degrade different components of crude oil and added the enzymes to *Pseudomonas* bacteria. His patent request was brought before the U. S. Supreme Court, which ruled in 1980 that human-engineered organisms are patentable under federal law.

7. What type of genetic engineering did Chakrabarty use to add enzymes to *Pseudomonas* bacteria?
   A. DNA fingerprinting
   B. gel electrophoresis
   C. human cloning
   D. recombinant DNA

Interpreting Graphics

***Directions (8):* Base your answer to question 8 on the diagram below.**

DNA Cut with a Restriction Enzyme



8. The diagram above shows two pieces of DNA that have been cut with the same restriction enzyme. What nucleotide sequence must the sticky end labeled *B* have if it is to bond with the sticky end labeled *A*?
   F. ACCGGT
   G. CTTAAG
   H. TCCGGA
   I. UGGCCU

Answers

1. C
2. G
3. D
4. F
5. Fit organisms that have naturally evolved might not be able to compete with genetically modified organisms.
6. Recombinant DNA is DNA made from two or more different organisms. Restriction enzymes are enzymes used to cut DNA.
7. D
8. F

TEST DOCTOR

Question 3 Answer D is the correct choice. Answer A is incorrect because DNA ligase is used to bond together fragments of DNA not cut them. Answer B is incorrect because DNA polymerase is used in the replication of DNA, not in the cutting of DNA. Answ C is incorrect because plasmid DNA are circular forms of DNA and are the molecules that are acted upon by restriction enzyme and DNA ligase.

Question 5 If the genetically modified organisms are fitter tha naturally evolved organisms, the genetically modified organisms would be naturally selected.

Question 6 Recombinant DNA i a nucleic acid, while restriction enzymes are proteins; restriction enzymes are often used to produc recombinant DNA.

Question 7 Answer D is the correct choice. Answer A is incorrect because DNA fingerprinting is used to identify and compare DN sequences. not insert DNA into genome. Answer B is incorrect because gel electrophoresis is use to separate molecules by their siz which allows for techniques such as DNA fingerprinting. Answer C is incorrect because bacteria, not humans, were the transgenic organism that would be cloned i this application.

Question 8 Answer F is the correct choice. Answer G is incorrect because the complementary sequence would be GAATTC. Answer H is incorrect because th complementary sequence would AGGCCT. Answer I is incorrect because this is an RNA sequence Its complementary DNA sequenc would be ACCGGA.