

# Genetic Technology

### What You'll Learn

- You will evaluate the importance of plant and animal breeding to humans.
- You will summarize the steps used to engineer transgenic organisms.
- You will analyze how mapping the human genome is benefitting human life.

### Why It's Important

Genetic technology will continue to impact every aspect of your life, from producing improved foods to treating diseases.

### Understanding the Photo

DNA technology makes it possible to monitor wildlife populations without handling the animals. Researchers with The Greater Glacier Area Bear DNA Project are identifying and tracking grizzlies, as well as black bears, by analyzing the DNA in hair and bear feces.



### Biology Online

Visit [ca.bdol.glencoe.com](http://ca.bdol.glencoe.com) to

- study the entire chapter online
- access Web Links for more information and activities on genetic technology
- review content with the Interactive Tutor and self-check quizzes

# Section 13.1

## SECTION PREVIEW

### Objectives

**Predict** the outcome of a test cross.

**Evaluate** the importance of plant and animal breeding to humans.

### Review Vocabulary

**hybrid:** an organism whose parents have different forms of a trait (p. 255)

### New Vocabulary

inbreeding  
test cross

# Applied Genetics

**California Standards** Standard 5c Students know how genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products.

## FOLDABLES<sup>®</sup> Study Organizer

**Selective Breeding** Make the following Foldable to help you illustrate the pros and cons of selective breeding.

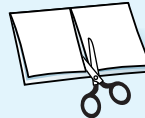
**STEP 1** **Fold** a vertical sheet of paper in half from top to bottom.



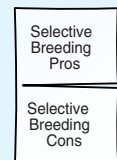
**STEP 2** **Fold** in half from side to side with the fold at the top.



**STEP 3** **Unfold** the paper once. **Cut** only the fold of the top flap to make two tabs.



**STEP 4** **Turn** the paper vertically and **label** the front tabs as shown.



**Illustrate and Label** As you read Chapter 13, list the pros and cons of selective breeding under the appropriate tab.

## Selective Breeding

For thousands of years, humans have selected plants and animals with certain qualities, and selectively bred them so that the qualities were common and of more use to humans. The same principle of selective breeding is still used today, in the food we eat and the animals we raise.

From ancient times, breeders have chosen plants and animals with the most desired traits to serve as parents of the next generation. Farmers select seeds from the largest heads of grain, the juiciest berries, and the most disease-resistant clover. They raise the calves of the best milk producer and save the eggs of the best egg-laying hen for hatching. Breeders of plants and animals want to be sure that their populations breed consistently so that each member shows the desired trait. You can read about the selective breeding of domesticated cats on pages 1066–1067 in the *Focus On*.

The process of selective breeding requires time, patience, and several generations of offspring before the desired trait becomes common in a population. Although our ancestors did not realize it, their efforts at selective breeding increased the frequency of a desired allele within a population. Increasing the frequency of desired alleles in a population is the essence of genetic technology.

 **Reading Check** **Explain** selective breeding in terms of alleles.

**Figure 13.1**

A pure breed, such as this German shepherd dog, is homozygous for the particular characteristics for which it has been bred. Infer **What characteristics might have been bred into this German shepherd dog?**



One example of the effectiveness of selective breeding is seen in a comparison of milk production in cattle in 1947 and 1997. In 1947, an average milk cow produced 4997 pounds of milk per year. In 1997, 50 years later, an average milk cow produced 16 915 pounds of milk in a year, more than three times more milk per cow. Fewer than half the number of cows are now needed to produce the same amount of milk, resulting in savings for dairy farmers.

**Figure 13.2**

These different cultivars of roses have been hybridized to combine traits such as color, scent, and flower shape.



## Inbreeding develops pure lines

To make sure that breeds consistently exhibit a trait and to eliminate any undesired traits from their breeding lines, breeders often use the method of inbreeding. **Inbreeding** is mating between closely related individuals. It results in offspring that are homozygous for most traits. However, inbreeding can bring out harmful, recessive traits because there is a greater chance that two closely related individuals both may carry a harmful recessive allele for the trait.

Horses and dogs are two examples of animals that breeders have developed as pure breeds. A breed (called a cultivar in plants) is a selected group of organisms within a species that has been bred for particular characteristics. For example, the pure breed German shepherd dog in *Figure 13.1* has long hair, is black with a buff-colored base, has a black muzzle, and resembles a wolf.

## Hybrids are usually bigger and better

Selective breeding of plants can increase productivity of food for humans. For example, plants that are disease resistant can be crossed with others that produce larger and more numerous fruit. The result is a plant that will produce a lot of fruit and be more disease resistant. Recall that a hybrid is the offspring of parents that have different forms of a trait. When two cultivars or closely related species are crossed, their offspring will be hybrids. Hybrids produced by crossing two purebred plants are often larger and stronger than their parents. Many crop plants such as wheat, corn, and rice, and garden flowers such as roses and dahlias have been developed by hybridization. *Figure 13.2* shows some examples.

## Determining Genotypes

A good breeder must be careful to determine which plants or animals will have the greatest chances of transmitting a desired trait to the next generation. Choosing the best parents may be difficult. The genotype of an organism that is homozygous recessive for a trait is obvious to an observer because the recessive trait is expressed. However, organisms that are either homozygous dominant or heterozygous for a trait controlled by Mendelian inheritance have the same phenotype. How can a breeder learn which genotype should be used for breeding?

### Test crosses can determine genotypes

One way to determine the genotype of an organism is to perform a test cross. A **test cross** is a cross of an individual of unknown genotype with an individual of known genotype. The pattern of observed phenotypes in the offspring can help determine the unknown genotype of the parent. Usually, the parent with the known genotype is homozygous recessive for the trait in question.

Many traits, such as disease vulnerability in roses and progressive blindness in German shepherd dogs, are inherited as recessive alleles. These traits are maintained in a population by carriers of the trait. A carrier, or heterozygous individual, has the same phenotype as an individual that is homozygous dominant.

What are the possible results of a test cross? If a known parent is homozygous recessive and an unknown parent is homozygous dominant for a trait, all of the offspring will be heterozygous and show the dominant trait (be phenotypically dominant), as shown in **Figure 13.3B** on the next page. However, if the organism being

## Problem-Solving Lab 13.1

### Design an Experiment

#### When is a test cross practical?

How can you tell the genotype of an organism that has a dominant phenotype? There are two ways. The first is through the use of pedigree studies. This technique works well as long as a family is fairly large and records are accurate. The second technique is a test cross. Test crosses help determine whether an organism is homozygous or heterozygous for a dominant trait.



### Solve the Problem

Your pet guinea pig has black hair. This trait is dominant and can be represented by a  $B$  allele. Your neighbor has a white guinea pig. This trait is recessive and can be represented by a  $b$  allele. You want to breed the two guinea pigs but want all offspring from the mating to be black. You are not sure, however, of the genotype of your black guinea pig and want to find out before starting the breeding program.

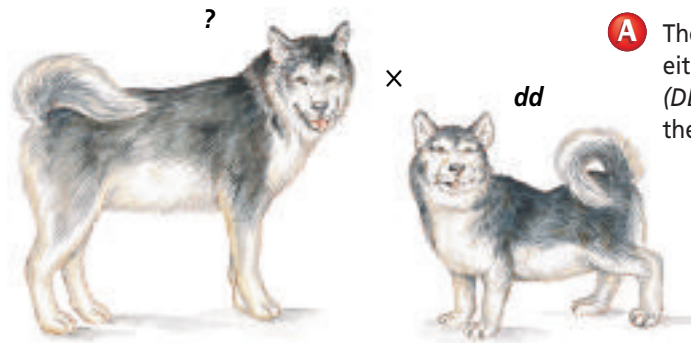
### Thinking Critically

- Infer** What may be the possible genotypes of your black guinea pig? Explain.
- Infer** What is the genotype of the white guinea pig? Explain how you are able to tell.
- Outline** Outline a procedure that will determine the coat color genotype for your black guinea pig. Include Punnett squares to illustrate the conclusions that you will reach. (Hint: You will be doing a test cross.)
- Analyze** What options do you have for breeding all black offspring if you determine that your guinea pig is heterozygous for black color?
- Think Critically** Explain why a test cross is not practical when trying to determine human genotypes.

tested is heterozygous, the expected 1:1 phenotypic ratio will be observed, **Figure 13.3C**. If any of the offspring have the undesired trait, the parent in question must be heterozygous. Doing the *Problem-Solving Lab* will show you how to set up and analyze a test cross.

**Figure 13.3**

In this test cross of Alaskan malamutes, the known test dog is homozygous recessive for a dwarf allele ( $dd$ ), and the other dog's genotype is unknown.



**A** The unknown dog can be either homozygous dominant ( $DD$ ) or heterozygous ( $Dd$ ) for the trait.

**B** If the unknown dog's genotype is homozygous dominant, all of the offspring will be phenotypically dominant.

**Homozygous  $\times$  Homozygous**

	$DD$	$dd$
	$d$	$d$
$D$	$Dd$	$Dd$
$D$	$Dd$	$Dd$

Offspring: all dominant



**C** If the unknown dog's genotype is heterozygous, half the offspring will express the recessive trait and appear dwarf. The other half will express the dominant trait and be of normal size.

**Heterozygous  $\times$  Homozygous**

	$Dd$	$dd$
	$d$	$d$
$D$	$Dd$	$Dd$
$d$	$dd$	$dd$

Offspring: 1/2 dominant  
1/2 recessive



## Section Assessment

### Understanding Main Ideas

1. A test cross made with a cat that may be heterozygous for a recessive trait produces ten kittens, none of which has the trait. What is the presumed genotype of the cat? Explain.
2. Suppose you want to produce a plant cultivar that has red flowers and speckled leaves. You have two cultivars, each having one of the desired traits. How would you proceed?
3. Why is inbreeding rarely a problem among animals in the wild?
4. Hybrid corn is produced that is resistant to bacterial infection and is highly productive. What might have been the phenotypes of the two parents?

### Thinking Critically

5. What effect might selective breeding of plants and animals have on the size of Earth's human population? Why?

### SKILL REVIEW

6. **Make and Use Tables** A bull is suspected of carrying a rare, recessive allele. Following a test cross with a homozygous recessive cow, four calves are born, two that express the recessive trait and two that do not. Draw a Punnett square that shows the test cross, and determine the genotype of the bull. For more help, refer to *Make and Use Tables* in the **Skill Handbook**.



## Section 13.2

### SECTION PREVIEW

#### Objectives

**Summarize** the steps used to engineer transgenic organisms.

**Give examples** of applications and benefits of genetic engineering.

#### Review Vocabulary

**nitrogenous base:** a carbon ring structure found in DNA and RNA that is part of the genetic code (p. 282)

#### New Vocabulary

genetic engineering  
recombinant DNA  
transgenic organism  
restriction enzyme  
vector  
plasmid  
clone

# Recombinant DNA Technology

**California Standards Standard 5d\***  
Students know how basic DNA technology is used to construct recombinant DNA molecules.

## Cut 'n Paste

**Using an Analogy** You have learned that DNA can function like a zipper, opening up to allow replication and transcription. Scientists have found a series of enzymes, from bacteria, that can cut DNA at specific locations, sometimes unzipping the strands as they cut. These enzymes allow scientists to insert genes from other sources into DNA. The glowing plant shown here was created by inserting a firefly gene into the DNA of a tobacco plant.

**Think Critically** Predict why a gene from a firefly can function in a tobacco plant.



Tobacco plant that contains a gene from a firefly

## Genetic Engineering

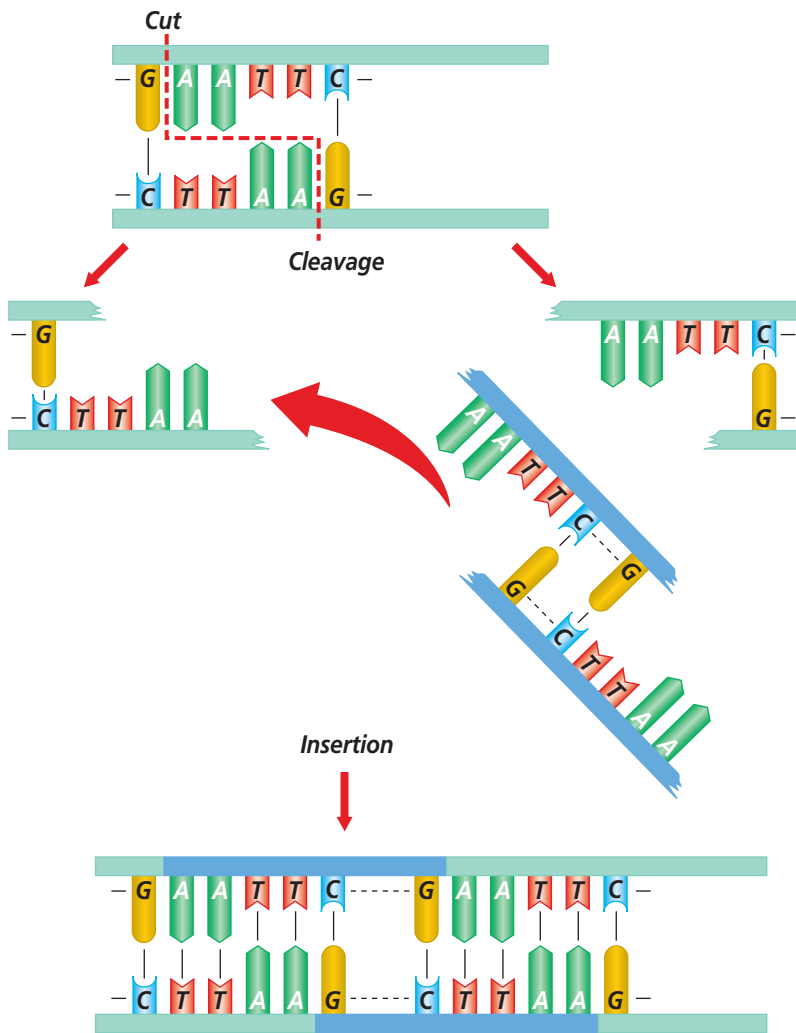
You learned that selective breeding increases the frequency of an allele in a population. You also learned that it may take many generations of breeding for a trait to become homozygous and consistently expressed in the population. **Genetic engineering** is a faster and more reliable method for increasing the frequency of a specific allele in a population. This method involves cutting—or cleaving—DNA from one organism into small fragments and inserting the fragments into a host organism of the same or a different species. You also may hear genetic engineering referred to as recombinant (ree KAHM buh nunt) DNA technology. **Recombinant DNA** is made by connecting, or recombining, fragments of DNA from different sources.

### Transgenic organisms contain recombinant DNA

Recombinant DNA can be inserted into a host organism's chromosomes and that organism will use this foreign DNA as if it were its own. Plants and animals that contain functional recombinant DNA from an organism of a different genus are known as **transgenic organisms** because they contain foreign DNA. The glowing tobacco plant shown above contains foreign DNA and is the result of a three-step process that produces a transgenic organism.

### Word Origin

**transgenic** from the Latin word *trans*, meaning "across," and the Greek word *genos*, meaning "race"; A transgenic organism contains genes from another species.



**Figure 13.4**  
 In the presence of the restriction enzyme *EcoRI*, a double strand of DNA containing the sequence—GAATC—is cleaved between the G and the A on each strand. **Interpret Scientific Illustrations**  
*What is the sequence of each sticky end?*

The first step of the process is to isolate the foreign DNA fragment that will be inserted. The second step is to attach the DNA fragment to a carrier. The third step is the transfer into the host organism. Each of these three steps now will be discussed in greater detail.

### Restriction enzymes cleave DNA

To isolate a DNA fragment, small pieces of DNA must be cut from a chromosome. In the example of the glowing tobacco plant, the fragment is a section of firefly DNA that codes for a light-producing enzyme. The discovery in the early 1970s of DNA-cleaving enzymes called restriction enzymes made it possible to cut DNA.

**Restriction enzymes** are bacterial proteins that have the ability to cut both strands of the DNA molecule at a specific nucleotide sequence. There are hundreds of restriction enzymes; each can cut DNA at a specific point in a specific nucleotide sequence. The resulting DNA fragments are different lengths. Cutting DNA with restriction enzymes is similar to cutting a zipper into pieces by cutting only between certain teeth of the zipper. Note in *Figure 13.4* that the same sequence of bases is found on both DNA strands, but in opposite orders. This arrangement is called a palindrome (PA luhn drohm). Palindromes are words or sentences that read the same forward and backward. The words *mom* and *dad* are two examples of palindromes.

Some enzymes produce fragments in which the DNA is cut straight across both strands. These are called blunt ends. Other enzymes, such as the enzyme called *EcoRI*, cut palindromic sequences of DNA by unzipping them for a few nucleotides, as shown in *Figure 13.4*. When this DNA is cut, double-stranded fragments with single-stranded ends are formed. The single-stranded ends have a tendency to join with other single-stranded ends to become double stranded, so they attract DNA they can join with. For this reason, these ends are called sticky ends. This is the key to recombinant DNA because if the same enzyme is used to cleave DNA from two organisms, such as firefly DNA and bacterial DNA, the two pieces of DNA will have matching sticky ends and will join together at these ends. When the firefly DNA joins with bacterial DNA, recombinant DNA is formed. The *MiniLab* on the opposite page models the way restriction enzymes work.

## Vectors transfer DNA

Loose fragments of DNA do not readily become part of a host organism's chromosomes, so the fragments are first attached to a carrier that will transport them into the host organism's cells. A **vector** is the means by which DNA from another species can be carried into the host cell. In the case of the transgenic tobacco plant, the light-producing firefly DNA had to be inserted into bacterial DNA before it could be placed inside the plant. The bacterial DNA is the vector.

Vectors may be biological or mechanical. Biological vectors include viruses and plasmids. A **plasmid**, shown in *Figure 13.5*, is a small ring of DNA found in a bacterial cell. The genes it carries are different from those on the larger bacterial chromosome.

Two mechanical vectors carry foreign DNA into a cell's nucleus. One, a micropipette, is inserted into a cell; the other is a microscopic metal bullet coated with DNA that is shot into the cell from a gene gun.

**Figure 13.5**

Plasmids are small rings of DNA. The large ring is the bacterium's chromosome.

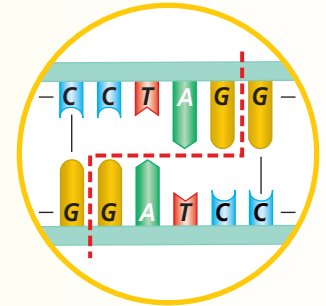


Magnification: unavailable

## MiniLab 13.1

### Apply Concepts

**Matching Restriction Enzymes to Cleavage Sites** Many restriction enzymes cut palindromic sequences of DNA that result in single-stranded, dangling sequences of DNA. These sticky ends can pair with complementary bases in a plasmid or a piece of viral DNA.



DNA fragment

### Procedure

**1** Copy the data table and DNA sequences below.

#### Data Table

Restriction Enzyme	Cutting Pattern of Enzyme	Cleaved Fragments of DNA	DNA Sequence this Enzyme Will Cut
<i>EcoRI</i>	<pre>           -G A A T T C-                                 -C T T A A G-           </pre>	<pre>           -G      AATTC-                                -CTTAA      G-           </pre>	
<i>BamHI</i>	<pre>           -G G A T C C-                                 -C C T A G G-           </pre>		
<i>HindIII</i>	<pre>           -A A G C T T-                                 -T T C G A A-           </pre>		
<i>KpnI</i>	<pre>           -G G T A C C-                                 -C C A T G G-           </pre>		

#### DNA Sequences

- A.**

```
-CAGGATCCCATG-
      | | | | |
      -CTCCTAGGGTAC-
```
- B.**

```
-GACTAGGTACCAA-
      | | | | |
      -CTGATCCATGGTT-
```
- C.**

```
-GCAGAATTGATC-
      | | | | |
      -CGTCTTAAGCTAG-
```
- D.**

```
-AAGCTTGACTA
      | | | | |
      -TTCGAACTGAT
```

**2** Fill in the third column. *EcoRI* is done for you. Then, fill in the letter of the DNA sequence that each restriction enzyme will cut.

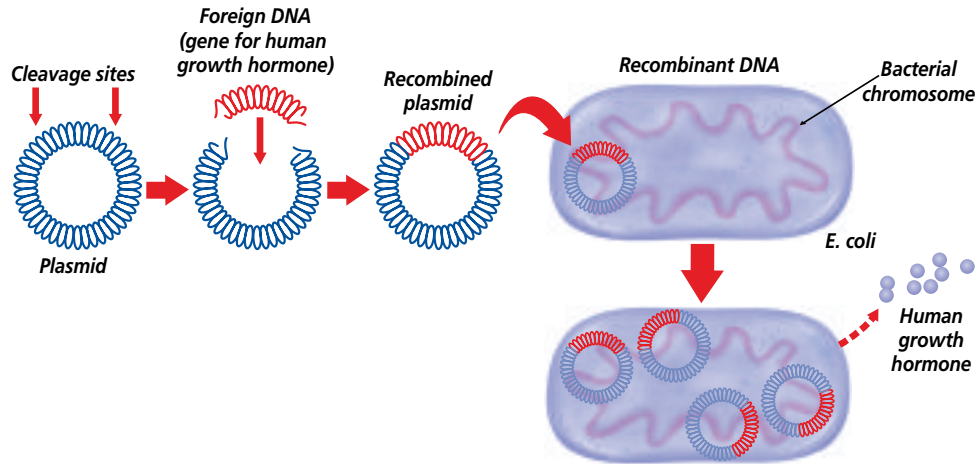
### Analysis

- Use Models** Construct a DNA sequence that would be cut twice by *HindIII*.
- Analyze** Record the DNA sequence of a piece of viral DNA if its ends would "stick to" a piece of DNA that was cut with *BamHI*.
- Draw Conclusions** Are restriction enzymes specific as to where they cleave DNA? Explain and give an example.



**Figure 13.6**

Foreign DNA is inserted into a plasmid vector. The recombinant plasmid then carries the foreign DNA into the bacterial cell, where it replicates independently of the bacterial chromosome. If the foreign DNA contained a gene for human growth hormone, each cell will make the hormone, which can be used to treat patients with dwarfism.



### Insertion into a vector

As you have learned, if a plasmid and foreign DNA have been cleaved with the same restriction enzyme, the ends of each will match and they will join together, reconnecting the plasmid ring. The foreign DNA is recombined into a plasmid or viral DNA with the help of a second enzyme. You can model this process in the *BioLab* at the end of this chapter.


### Gene cloning

After the foreign DNA has been inserted into the plasmid, the recombinant DNA is transferred into a bacterial cell. The plasmid is capable of replicating separately from the bacterial host and can produce up to 500 copies per bacterial cell. An advantage to using bacterial cells to clone DNA is that they reproduce quickly; therefore, millions of bacteria are produced and each bacterium contains hundreds of recombinant DNA molecules. **Clones** are genetically identical copies. Each identical recombinant DNA molecule is called a gene clone.

Plasmids also can be used to deliver genes to animal or plant cells, which incorporate the recombinant DNA. Each time the host cell divides it copies the recombinant DNA along with its own. The host cell can produce the protein encoded on the

recombinant DNA. Scientists can study the function of this protein in cells that don't normally produce such proteins. Scientists also can produce mutant forms of a protein and determine how that mutation alters the protein's function within the cell.

Using other vectors, recombinant DNA can be inserted into yeast, plant, and animal cells. *Figure 13.6* summarizes the formation and cloning of recombinant DNA in a bacterial host cell.

 **Reading Check** Explain what is meant by a gene clone.

### Cloning of animals

So far, you have read about cloning one gene. For decades, scientists attempted to expand the technique from a gene to an entire animal. The most famous cloned animal is Dolly, the sheep, first cloned in 1997. Since then, various mammals including goats, mice, cattle, and pigs have been cloned. Although their techniques are inefficient, scientists are coming closer to perfecting the process of cloning animals. One of the benefits for humans in cloning animals is that ranchers and dairy farmers could clone particularly productive, healthy animals to increase yields.

## Polymerase chain reaction

In order to replicate DNA outside living organisms, a method called polymerase chain reaction (PCR) has been developed. This method uses heat to separate DNA strands from each other. An enzyme isolated from a heat-loving bacterium is used to replicate the DNA when the appropriate nucleotides are added in a PCR machine. The machine repeatedly replicates the DNA, making millions of copies in less than a day. Because the machine uses heat to separate the DNA strands and cycles over and over to replicate the DNA, it is called a thermocycler.

PCR has become one of the most powerful tools for molecular biologists. The technique is essential to the analysis of bacterial, plant, and animal DNA, including human DNA. PCR has helped bring molecular genetics into crime investigations and the diagnosis of infectious diseases such as AIDS. PCR can help doctors identify extremely small amounts of HIV in blood or the lymphatic system.

## Sequencing DNA

Another application of genetic engineering is to provide pure DNA for use in determining the sequence or correct order of the DNA bases. This information can allow scientists to identify mutations.

In DNA sequencing, millions of copies of a double-stranded DNA fragment are cloned using PCR. Then, the strands are separated from each other. The single-stranded fragments are placed in four different test tubes, one for each DNA base. Each tube contains four normal nucleotides (A,C,G,T) and an enzyme that can catalyze the synthesis of a complementary strand. One nucleotide in each tube is tagged with a different fluorescent color. The reactions produce complementary strands

of varying lengths. These strands are separated according to size by gel electrophoresis (ih lek troh fuh REE sus), producing a pattern of fluorescent bands in the gel. The bands are visualized using a laser scanner or UV light. How do the DNA fragments separate from each other in the gel? See *Figure 13.8* on the next page to find out.

## Applications of DNA Technology

Once it became possible to transfer genes from one organism to another, large quantities of hormones and other products could be produced. How is this technology of use to humans? The main areas proposed for recombinant bacteria are in industry, medicine, and agriculture.

### Recombinant DNA in industry

Many species of bacteria have been engineered to produce chemical compounds used by humans. Scientists have modified the bacterium *E. coli* to produce the expensive indigo dye that is used to color denim blue jeans, like those shown in *Figure 13.7*.

**Figure 13.7**

Genetically modified bacteria produce the blue dye that colors denim blue jeans.

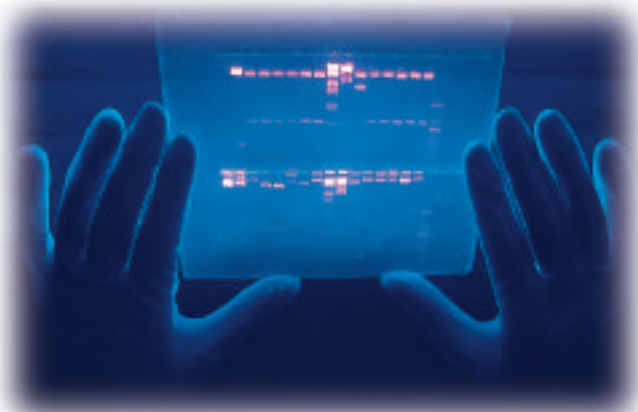


# Gel Electrophoresis

**Figure 13.8**

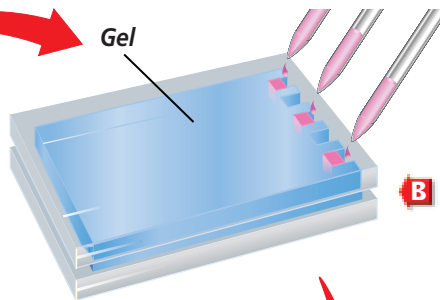
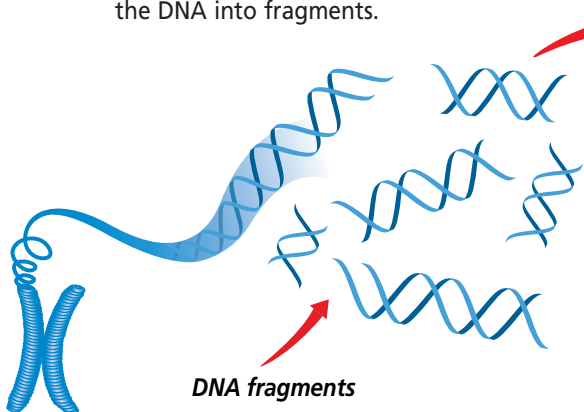
Restriction enzymes are the perfect tools for cutting DNA. However, once the DNA is cut, a scientist needs to determine exactly what fragments have been formed. After DNA fragments have been separated on a gel, many other techniques, such as DNA sequencing, can be used to specifically identify a DNA fragment.

**Critical Thinking** *Why might gel electrophoresis be an important step before DNA sequencing can be done?*



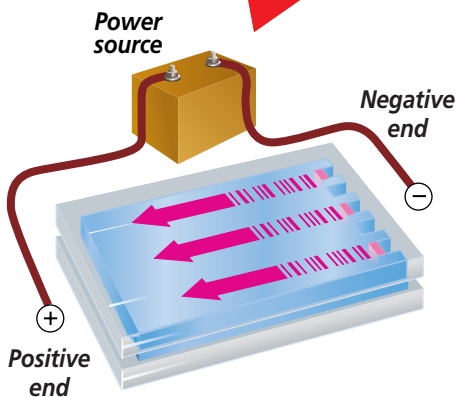
The gel that contains separated DNA fragments is treated with a dye that glows under ultraviolet light, allowing the bands to be studied.

**A Restriction enzymes** Either one or several restriction enzymes is added to a sample of DNA. The enzymes cut the DNA into fragments.



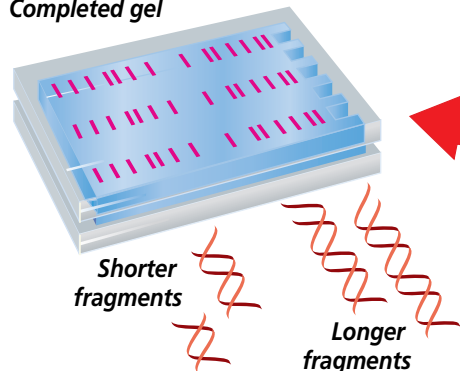
**B The gel** With a consistency that is firmer than dessert gelatin, the gel is molded so that small wells form at one end. Small amounts of the fragmented DNA are placed into these wells.

**D The fragments move** The negatively charged DNA fragments travel toward the positive end. The smaller the fragment, the faster it moves through the gel. The smallest fragments move the farthest from the well.



**C An electric field** The gel is placed in a solution and an electric field is applied making one end of the gel positive and the other end negative.

Completed gel



The production of cheese, laundry detergents, pulp and paper production, and sewage treatment have all been enhanced by the use of recombinant DNA techniques that increase enzyme activity, stability, and specificity. Research is currently going on to develop high-protein corn with protein levels comparable to beef and to develop a process for making automobile fuel from discarded cornstalks.

### Recombinant DNA in medicine

Pharmaceutical companies already are producing molecules made by recombinant DNA to treat human diseases. Recombinant bacteria are used in the production of human growth hormone to treat pituitary dwarfism. Also, the human gene for insulin is inserted into a bacterial plasmid by genetic engineering techniques. Recombinant bacteria produce large quantities of insulin. Human antibodies, hormones, vaccines, enzymes, and various compounds needed for diagnosis and treatment have been made using recombinant DNA. Read about engineered vaccines in *Biotechnology* at the end of this chapter.

### Transgenic animals

Scientists can study diseases and the role specific genes play in an organism by using transgenic animals. Because mice reproduce quickly, they often are used for transgenic studies. Mouse chromosomes also are similar to human chromosomes. In addition, scientists know the locations of many genes on mouse chromosomes. The roundworm *Caenorhabditis elegans* is another organism with well-understood genetics that is used for transgenic studies. A third animal commonly used for transgenic studies is the fruit fly, *Drosophila melanogaster*.

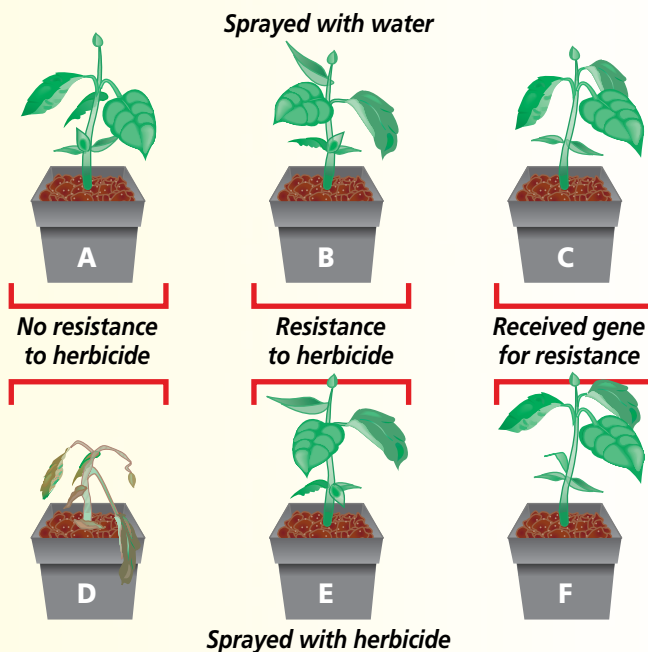
## Problem-Solving Lab 13.2

### Think Critically

**How might gene transfer be verified?** When you spray weeds with a chemical herbicide, they die. The problem with herbicides, however, is that they often get sprayed accidentally onto crops, and they also die. Glyphosate is the active ingredient in some herbicides. A certain gene will confer resistance to glyphosate. If this gene can be genetically engineered into crop plants, they will survive when sprayed with this herbicide.

### Solve the Problem

In the diagram below, plants A and D are sensitive to glyphosate and plants B and E are naturally resistant. Plants C and F have been treated with recombinant DNA, but it isn't known if the treatment worked. Plants A, B, and C are sprayed with water. Plants D, E, and F are sprayed with a herbicide containing glyphosate.



### Thinking Critically

- Predict** Assume that the transfer of glyphosate resistance was successful in plant F. Predict whether each of plants D, E, and F will remain healthy after being sprayed with glyphosate. Explain your prediction.
- Infer** Will plant F remain healthy if the transfer of glyphosate resistance was not successful?
- Define Operationally** Which plants are transgenic organisms? Explain your answer.
- Use Variables, Constants, and Controls** Why were plants A, B, and C sprayed with water?

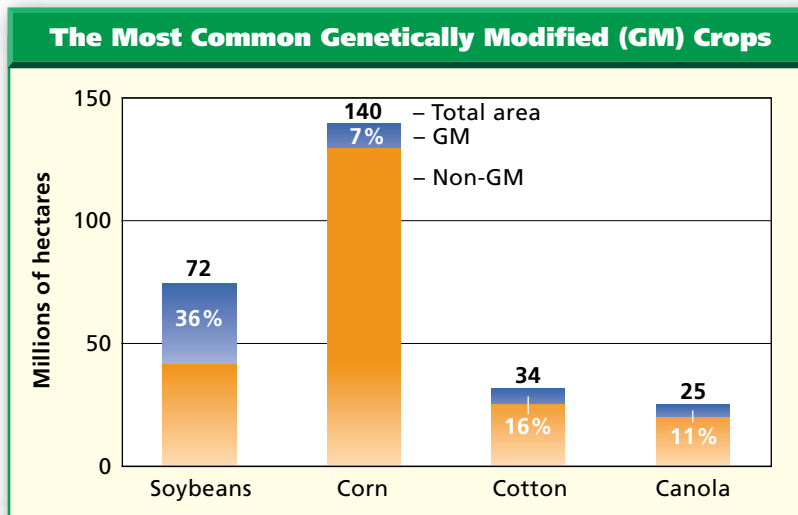
On the same farm in Scotland that produced the cloned sheep Dolly, a transgenic sheep was produced that contained the corrected human gene for hemophilia A. Recall from Chapter 12 that people with hemophilia are missing a protein-clotting factor in their blood. This human gene inserted into the sheep chromosomes allows the production of the clotting protein in the sheep's milk. The protein then can be separated for use by patients with hemophilia. This farm also has produced transgenic sheep which produce a protein that helps lungs inflate and function properly. The protein is given to people with emphysema, a lung disease associated mainly with cigarette smoking.

## Recombinant DNA in agriculture

Recombinant DNA technology has been highly utilized in the agricultural and food industries. Crops have been developed that are better tasting, stay fresh longer, and are protected from disease and insect infestations. Corn, broccoli, cotton, and potatoes have been developed to produce *Bt* toxin from a bacterial gene, which makes them resistant to certain insect pests. Various plants have been made resistant to a herbicide used to rid the fields of unwanted weeds. You can learn more about this herbicide in the *Problem-Solving Lab* on the previous page. Canola plants have been modified so they make a higher yield of oil. Currently, research is increasing the amounts of various vitamins in certain crops. These plants could be grown and used in developing countries to supplement local diets that are vitamin deficient. Other research includes the development of peanuts and soybeans that do not cause allergic reactions, a problem for a significant number of people. *Figure 13.9* shows a graph of production acreage for the most common genetically modified crops.

**Figure 13.9**

Soybeans, corn, cotton, and canola were the most frequently grown, genetically modified (GM) crops in 2000, covering 16 percent of the 271 million hectares devoted to those four crops.



**Reading Check** Explain why high-nutrient crops are important to humans.

## Section Assessment

### Understanding Main Ideas

1. How are transgenic organisms different from natural organisms of the same species?
2. How are sticky ends important in making recombinant DNA?
3. How does gel electrophoresis separate fragments of DNA?
4. Explain two ways in which recombinant bacteria are used for human applications.

### Thinking Critically

5. Many scientists consider genetic engineering to be simply an efficient method of selective breeding. Explain.

### SKILL REVIEW

6. **Get the Big Picture** Order the steps in producing recombinant DNA in a bacterial plasmid. For more help, refer to *Get the Big Picture* in the **Skill Handbook**.



# Section 13.3

## SECTION PREVIEW

### Objectives

**Analyze** how the effort to completely map and sequence the human genome will advance human knowledge.

**Predict** future applications of the Human Genome Project.

### Review Vocabulary

**mutation:** a change in the DNA sequence of an individual (p. 296)

### New Vocabulary

human genome  
linkage map  
gene therapy

### Word Origin

**genome** from the Greek word *genos*, meaning “race”; A genome is the total number of genes in an individual.

# The Human Genome

**California Standards** Standard 3d\* Students know how to use data on frequency of recombination at meiosis to estimate genetic distances between loci and to interpret genetic maps of chromosomes.

## On the Cutting Edge

**Using Prior Knowledge** You have already learned about several genetic disorders that affect humans—Huntington’s disease, cystic fibrosis, Tay Sach’s disease, and sickle-cell anemia. In the last section, you learned that transgenic bacteria are being designed to treat disorders such as hemophilia and dwarfism. Scientists hope someday to be able to treat more disorders. To accomplish this, they are sequencing the entire human genome.

**Research** As a class, build a reference file of the latest discoveries by the Human Genome

Project. Use library resources or visit [ca.bdol.glencoe.com](http://ca.bdol.glencoe.com)

to collect information. Update the file throughout the school year.

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Sickled red blood cells

## Mapping and Sequencing the Human Genome

In 1990, scientists in the United States organized the Human Genome Project (HGP). It is an international effort to completely map and sequence the **human genome**, the approximately 35 000–40 000 genes on the 46 human chromosomes. In February of 2001, the HGP published its working draft of the 3 billion base pairs of DNA in most human cells. The sequence of chromosomes 21 and 22 was finished by May 2000. The *MiniLab* on the next page gives you an idea of the size of the human genome.

### Linkage maps

The locations of thousands of the total number of genes have been mapped to particular chromosomes, and half of the genome has been completely sequenced. However, scientists still don’t know the exact locations of all the genes on the chromosomes.

The genetic map that shows the relative locations of genes on a chromosome is called a **linkage map**. The historical method used to assign genes to a particular human chromosome was to study linkage data from human pedigrees. Recall from your study of meiosis that crossing over occurs during prophase I. As a result of crossing over, gametes and, thus, offspring can have a combination of alleles not found in either parent.

## MiniLab 13.2

### Use Numbers

#### Storing the Human Genome

It has been estimated that the human genome consists of three billion nitrogenous base pairs. How much room would all of the genetic information in one cell take up if it were printed in a 400-page novel?



#### Procedure

- 1 Copy the right column of the data table marked "Letters and Numbers."
- 2 Select a random page from a novel.
- 3 Follow the directions in the table. Record your calculations in your data table.

#### Data Table

Directions	Letters and Numbers
A. Count the number of characters (letters, punctuation marks, and spaces) across one entire line of your selected page.	
B. Count the number of lines on the page.	
C. Calculate the number of characters on the page. (Multiply A $\times$ B.)	
D. Let one nitrogenous base equal one character. Knowing that DNA is made of nitrogenous base pairs, divide C by 2.	
E. Record the number of pages in your novel.	
F. Calculate the number of base pairs in your novel. (Multiply E $\times$ D.)	
G. Calculate the number of books the size of your novel needed to hold the human genome. (Divide 3 billion by F.)	

#### Analysis

1. **Critique** What changes could be taken to improve the accuracy of this activity at steps A–C?
2. **Think Critically** What assumption is being made at step G?
3. **Analyze** Explain the logic for step D.
4. **a. Use Numbers** How many books the size of your novel would be needed to store the human genome?  
**b. Use Numbers** How many books the size of your novel would be needed to store a typical bacterial genome? Assume there are three million base pairs in the genome of a bacterium.

The frequency with which these alleles occur together is a measure of the distance between the genes. Genes that cross over frequently must be farther apart than genes that rarely cross over. Recall from Chapter 10 that the percentage of crossed-over traits appearing in offspring can be used to determine the relative position of genes on the chromosome, and thus, to create a linkage map.

Because humans have only a few offspring compared with the larger numbers of offspring in some other species, and because a human generation time is so long, mapping by linkage data is extremely inefficient. Biotechnology now has provided scientists with new methods of mapping genes. Using polymerase chain reaction (PCR), millions of copies of DNA fragments are cloned in a matter of a few hours. These fragments contain genetic markers that are spread throughout the genome. A genetic marker is a segment of DNA with an identifiable physical location on a chromosome and whose inheritance can be followed. A marker can be a gene, or it can be some section of DNA with no known function. Because DNA segments that are near each other on a chromosome tend to be inherited together, markers are often used as indirect ways of tracking the inheritance pattern of a gene that has not yet been identified, but whose approximate location is known.

#### Sequencing the human genome

The difficult job of sequencing the human genome is begun by cleaving samples of DNA into fragments using restriction enzymes, as described earlier in this chapter. Then, each individual fragment is cloned and sequenced. The cloned fragments are aligned in the proper

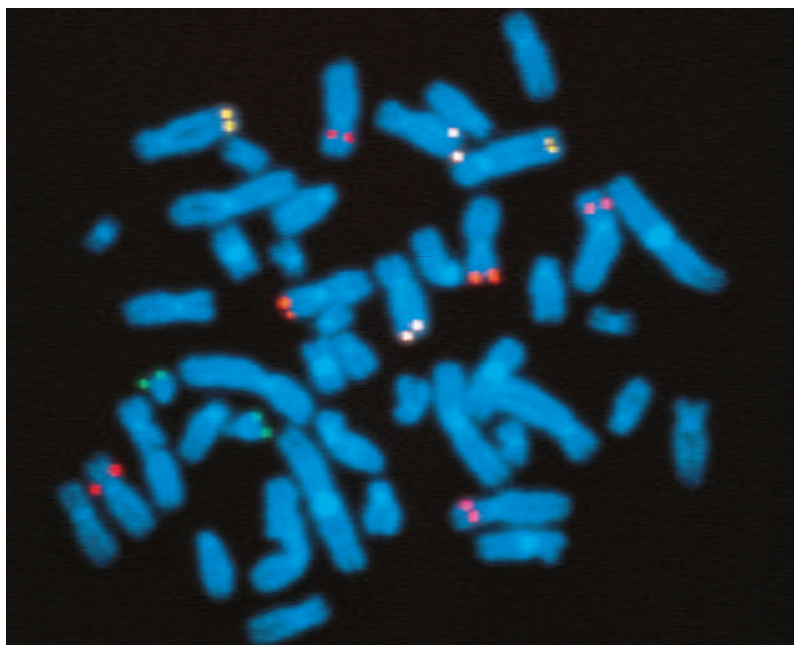
order by overlapping matching sequences, thus determining the sequence of a longer fragment. Automated machines can perform this work, greatly increasing the speed of map development.

## Applications of the Human Genome Project

As chromosome maps are made, how can they be used? Improved techniques for prenatal diagnosis of human disorders, use of gene therapy, and development of new methods of crime detection are areas currently being researched.

### Diagnosis of genetic disorders

One of the most important benefits of the HGP has been the diagnosis of genetic disorders. The DNA of people with and without a genetic disorder is compared to find differences that are associated with the disorder. Once it is clearly understood where a gene is located (see *Figure 13.10*) and that a mutation in the gene causes the disorder, a diagnosis can be made for an individual, even before birth. Cells are obtained from the fluid surrounding the fetus. DNA is isolated and PCR is used to analyze the area where the mutation is found. If the gene is normal, the PCR product will be a standard size—a deviation means a mutation is present. For some diagnostic tests, the DNA must be analyzed using gel electrophoresis only. This is usually when the disease-causing mutation alters a restriction enzyme-cutting site, producing DNA fragments of different sizes than normal. Thus, when DNA from fetal cells is examined and found to have the mutation associated with the disorder, the fetus will develop the disorder.



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**Figure 13.10**

Fluorescently labeled complementary DNA for the gene to be mapped is made and added to metaphase chromosomes. The labeled DNA binds to the gene and its location is shown as a glowing spot. In this photo, six genes are mapped simultaneously. A karyotype can be made for clarity.

## BIOTECHNOLOGY CAREERS

### Forensic Analyst

**W**ould you like to work in a crime laboratory, helping police and investigators figure out “who done it?” Then consider a career as a forensic analyst.

#### Skills for the Job

Forensic analysts include identification technicians (who work with fingerprints), crime lab technologists (who use microscopes, lasers, and other tools to analyze tissue samples and other evidence), and medical examiners (who perform autopsies to determine the cause of death). Most forensic analysts work in labs operated by the federal, state, or local government. Requirements include on-the-job training for technicians, one or more college degrees that include crime lab work for technologists, and a medical degree for medical examiners. Analysts hired by the FBI complete an additional 14-week training program.



For more careers in related fields, visit [ca.bdol.glencoe.com/careers](http://ca.bdol.glencoe.com/careers)



## Gene therapy

Individuals who inherit a serious genetic disorder may now have hope—gene therapy. **Gene therapy** is the insertion of normal genes into human cells to correct genetic disorders. This technology is still experimental, but ongoing trials involving over 3000 patients are attempts to treat genetic and acquired diseases. Trials that treat SCID (severe combined immunodeficiency syndrome) have been the most successful. In this disorder, a person's immune system is shut down and even slight colds can be life-threatening. In gene therapy for this disorder, the cells of the immune system are removed from the patient's bone marrow, and the functional gene is added to them. The modified cells are then injected back into the patient. *Figure 13.11* shows this process.

Other trials involve gene therapy for cystic fibrosis, sickle-cell anemia, hemophilia, and other genetic disorders. Research is also going on to use gene therapy to treat cancer, heart disease, and AIDS. It is hoped

that in the next decade DNA technology that uses gene therapy will be developed to treat many different disorders.

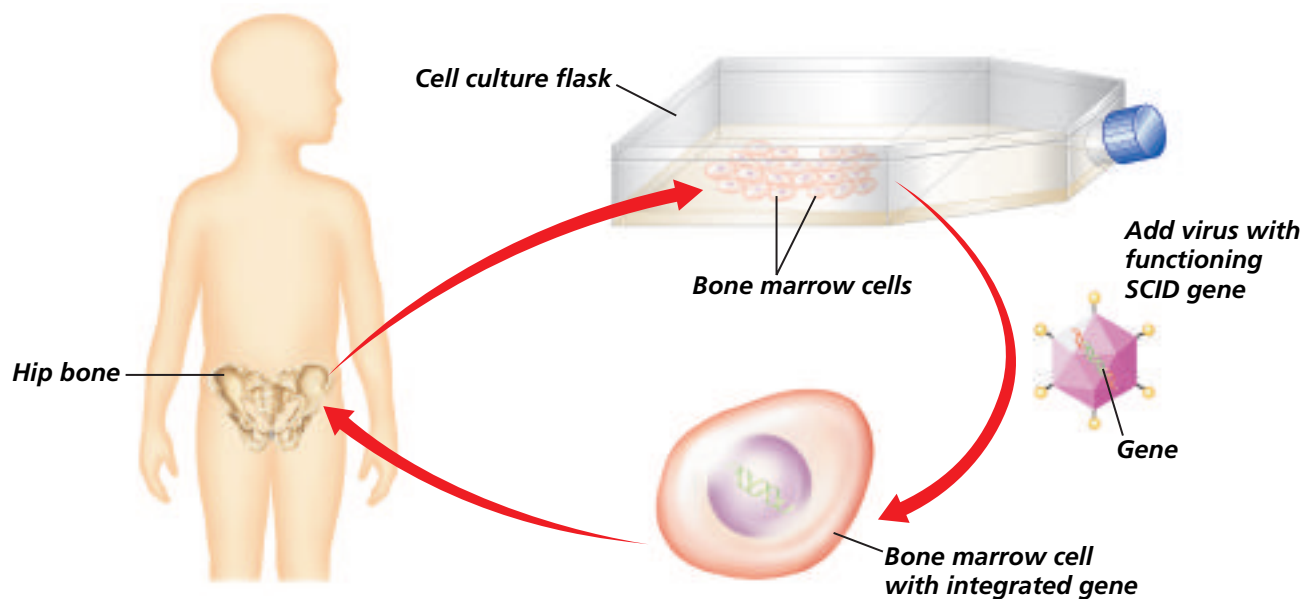
## DNA fingerprinting

Law-enforcement workers use unique fingerprint patterns to determine whether suspects have been at a crime scene. In the past ten years, biotechnologists have developed a method that determines DNA fingerprints. DNA fingerprinting can be used to convict or acquit individuals of criminal offenses because every person is genetically unique.

Chromosomes consist of genes that are separated by segments of noncoding DNA, DNA that doesn't code for proteins. The genes follow fairly standard patterns from person to person, but the noncoding segments produce distinct combinations of patterns unique to each individual. In fact, DNA patterns can be used like fingerprints to identify the person (or other organism) from whom they came. DNA fingerprinting works because no

**Figure 13.11**


In SCID gene therapy, bone marrow cells are removed from a patient's hipbone and grown in a flask. Genetically engineered viruses containing a normal SCID gene are added. The bone marrow cells insert the normal gene into their DNA. When the modified cells are returned to the patient's bone marrow, the gene begins to function. **Think Critically** *Why doesn't the virus cause disease in the patient?*



two individuals (except identical twins) have the same DNA sequences, and because all cells (except gametes) of an individual have the same DNA. You can read about a real example of DNA fingerprinting in the *Problem-Solving Lab*.

In a forensic application of DNA fingerprinting, a small DNA sample is obtained from a suspect and from blood, hair, skin, or semen found at the crime scene. The DNA, which includes the unique noncoding segments, is cut into fragments with restriction enzymes. The fragments are separated by gel electrophoresis, then further analyzed. If the samples match, the suspect most likely is guilty.

DNA technology has been used to clone DNA from many sources. Geneticists are using PCR to clone DNA from mummies and analyze it in order to better understand ancient life. Abraham Lincoln's DNA has been taken from the tips of a lock of his hair and studied for evidence of a possible genetic disorder. The DNA from fossils has been analyzed and used to compare extinct species with living species, or even two extinct species with each other. The uses of DNA technology are unlimited.

 **Reading Check** Explain why an individual's DNA fingerprint is so unique if humans all have similar genes.

## Problem-Solving Lab 13.3

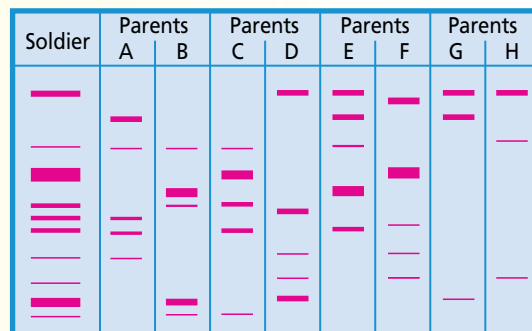
### Apply Concepts

**How is identification made from a DNA fingerprint?** DNA fingerprint analysis requires a sample of DNA from a person, living or dead. First the DNA is cut into smaller segments with enzymes. Then the segments are separated according to size using gel electrophoresis. When stained, the DNA segments appear as colored bands that form a DNA fingerprint.

### Solve the Problem

A U.S. soldier from the Vietnam War who had been placed in the Tomb of the Unknowns at Arlington National Cemetery was identified through

DNA fingerprinting. The soldier could have been one of four individuals. A DNA sample from his body was analyzed. The DNA from the parents of the four possible soldiers was analyzed. The diagram



shows a DNA fingerprint pattern analysis similar to the one that was actually done. Find the match between the soldier's DNA fingerprint pattern and those of his parents.

### Thinking Critically

- Draw Conclusions** Which parental DNA matched the soldier's DNA? Explain.
- Use Numbers** What percent of the soldier's DNA matched his father's DNA? His mother's? Explain.
- Think Critically** Could an exact identification have been made with only one parent's DNA? Explain.

## Section Assessment

### Understanding Main Ideas

- What is the Human Genome Project?
- Compare a linkage map and a sequencing map.
- What is the goal of gene therapy?
- Explain why DNA fingerprinting can be used as evidence in law enforcement.

### Thinking Critically

- Describe some possible benefits of the Human Genome Project.

### SKILL REVIEW

- Get the Big Picture** Suppose a SCID patient has been treated with gene therapy. The therapy has involved the insertion of a normal allele into the patient's bone marrow cells using a virus vector. If successful, does this person still run the risk of passing the disorder to his or her offspring? Explain. For more help, refer to *Get the Big Picture* in the **Skill Handbook**.



# INVESTIGATE BioLab

## Before You Begin

Experimental procedures have been developed that allow recombinant DNA molecules to be engineered in a test tube. From a wide variety of restriction enzymes available, scientists choose one or two that recognize particular sequences of DNA within a longer DNA sequence of a chromosome. The enzymes are added to the DNA, which is cleaved at the recognition sites. Because the cleaved fragments have ends that are available for attachment to complementary strands, the fragments can be added to plasmids or to viral DNA that has been similarly cut. When the DNA fragment has been incorporated into the plasmid or virus, it is called recombinant DNA.



# Modeling Recombinant DNA

## PREPARATION

### Problem

How can you model recombinant DNA technology?

### Objectives

*In this BioLab, you will:*

- **Model** the process of preparing recombinant DNA.
- **Analyze** a model for preparation of recombinant DNA.

### Materials

white paper  
colored pencils (red and green)

tape  
scissors

### Safety Precautions

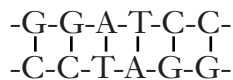
**CAUTION:** *Always wear goggles in the lab. Be careful with sharp objects.*

### Skill Handbook

If you need help with this lab, refer to the **Skill Handbook**.

## PROCEDURE

1. Cut a 3-cm × 28-cm strip from a sheet of white paper. This strip of paper represents a long sequence of DNA containing a particular gene that you wish to combine with a plasmid.
2. Cut a 3-cm × 10-cm strip of paper. When taped into a ring in step 5, this piece of paper will represent a bacterial plasmid.
3. Use your colored pencils to color the longer strip red and the shorter strip green.
4. Write the following DNA sequence once on the shorter strip of paper, and write it two times about 5 cm apart on the longer strip of paper.



5. After coloring the shorter strip of paper and writing the sequence on it, tape the ends together.

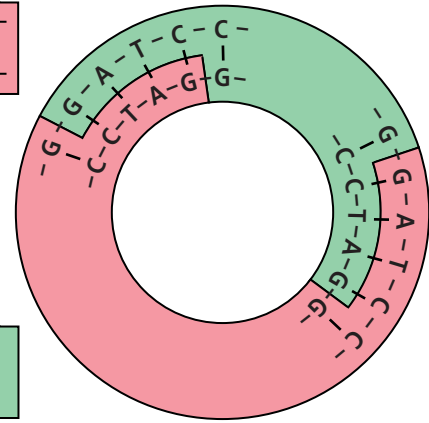
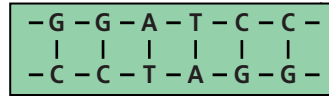


6. Assume that a particular restriction enzyme is able to cleave DNA in a staggered way as illustrated here.



Cut the longer strand of DNA in both places as shown above. You now have a cleaved foreign DNA fragment containing a gene that can be inserted into the plasmid.

7. Once the sequence containing the foreign gene has been cleaved, cut the plasmid in the same way.
8. Insert the foreign gene into the plasmid by taping the paper together where the sticky ends pair properly. The new plasmid represents recombinant DNA.
9. Copy the data table. Relate the steps of producing recombinant DNA to the activities of the modeling procedure by explaining how the terms relate to the model.



**Data Table**

Term	BioLab Model
Gene insertion	
Plasmid	
Restriction enzyme	
Sticky ends	
Recombinant DNA	

## ANALYZE AND CONCLUDE

- Compare and Contrast** How does the paper model of a plasmid resemble a bacterial plasmid?
- Compare and Contrast** How is cutting with the scissors different from cleaving with a restriction enzyme?
- Think Critically** Enzymes that modify DNA, such as restriction enzymes, have been discovered and isolated from living cells. What functions do you think they have in living cells?
- Critique** Does the model accurately represent the process of producing recombinant DNA?

## Apply Your Skill

**Project** Design and construct a three-dimensional model that illustrates the process of preparing recombinant DNA. Consider using clay or other materials in your model. Label the model and explain it to your classmates.



**Web Links** To find out more about recombinant DNA, visit [ca.bdol.glencoe.com/genetic\\_engineering](http://ca.bdol.glencoe.com/genetic_engineering)

## New Vaccines

**G**reater understanding of how the immune system works and rapid advances in gene technology have paved the way for the development of new types of vaccines that offer hope in the fight against some of the world's most deadly and widespread diseases.

Traditionally, most vaccines have been made from weakened or killed forms of a disease-causing virus or bacterium, or from some of its cellular components or toxins. Although these types of vaccines have helped to prevent disease, they sometimes cause severe side effects. Furthermore, it hasn't been possible to create vaccines for diseases such as malaria and AIDS using traditional methods. With the help of genetic engineering technology, researchers can now manipulate microbial genes to create entirely new kinds of vaccines.

**Recombinant vaccines** One revolutionary approach to developing vaccines uses recombinant DNA technology, a process in which genes from one organism are inserted into another organism. The hepatitis B virus vaccine was the first genetically engineered vaccine to be produced in this way. Researchers isolated the gene in the hepatitis virus that codes for the production of an antigen, a protein that stimulates an immune response. Then they inserted that gene into yeast cells. Like tiny microbial machines, the genetically engineered yeast cells produce great quantities of pure hepatitis B antigen, which is then used to make a vaccine.

**Live vector vaccines** An antigen-coding gene from a disease-causing virus such as HIV can be inserted into a harmless "carrier" virus such as cowpox virus. When a vaccine made from the carrier virus is injected into a host, the virus replicates and in the process produces the antigen protein, which causes an immune response. This type of vaccine, called a live vector vaccine, shows promise against AIDS.



Researchers who work with viruses must wear protective clothing.

**DNA vaccines** DNA vaccines differ from other vaccines in that only the cloned segment of DNA that codes for a disease-causing antigen is injected into a host—the DNA itself is the vaccine. The DNA can be injected through a hypodermic needle into muscle tissue, or microscopic DNA-coated metal beads can be fired into muscle cells using a "gene gun." Once in the cells, the foreign DNA is expressed as antigen protein that induces an immune response. Researchers currently are working on DNA vaccines for cancer and tuberculosis.

### Applying Biotechnology

**Think Critically** It is possible to insert antigen-coding genes for several different diseases into one virus carrier that can be used to make a vaccine. What would be an advantage of such a vaccine?



To find out more about vaccines, visit [ca.bdol.glencoe.com/biotechnology](http://ca.bdol.glencoe.com/biotechnology)

# Chapter 13 Assessment

## STUDY GUIDE

### Section 13.1

## Applied Genetics

### Key Concepts

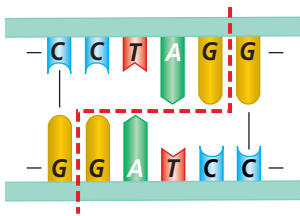
- Test crosses determine the genotypes of individuals and the probability that offspring will have a particular allele.
- Plant and animal breeders selectively breed organisms with a desirable trait which increases the frequency of a desired allele in a population.

### Vocabulary

inbreeding (p. 338)  
test cross (p. 339)

### Section 13.2

## Recombinant DNA Technology



### Key Concepts

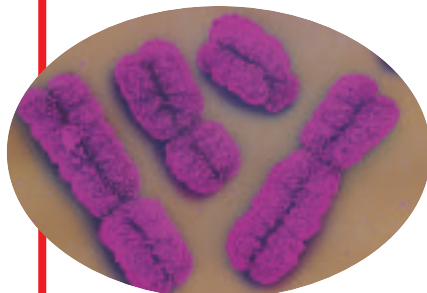
- Scientists have developed methods to move genes from one species into another. These processes use restriction enzymes to cleave DNA into fragments and other enzymes to insert a DNA fragment into a plasmid or viral DNA. Transgenic organisms can make genetic products foreign to themselves using recombinant DNA.
- Bacteria, plants, and animals have been genetically engineered to be of use to humans.
- Gene cloning can be done by inserting a gene into bacterial cells, which copy the gene when they reproduce, or by a technique called polymerase chain reaction.
- Many species of animals have been cloned; the first cloned mammal was a sheep.

### Vocabulary

clone (p. 344)  
genetic engineering (p. 341)  
plasmid (p. 343)  
recombinant DNA (p. 341)  
restriction enzyme (p. 342)  
transgenic organism (p. 341)  
vector (p. 343)

### Section 13.3

## The Human Genome



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### Key Concepts

- The Human Genome Project, an international effort, has sequenced the chromosomal DNA of the human genome. Efforts are underway to determine the location for every gene.
- DNA fingerprinting can be used to identify individuals.
- Gene therapy technology can be used to treat genetic disorders.

### Vocabulary

gene therapy (p. 352)  
human genome (p. 349)  
linkage map (p. 349)

### FOLDABLES

#### Study Organizer

To help you review selective breeding, use the Organizational Study Fold on page 337.



# Chapter 13 Assessment

## Vocabulary Review

Review the Chapter 13 vocabulary words listed in the Study Guide on page 357. Match the words with the definitions below.

1. mating between closely related individuals
2. bacterial proteins that have the ability to cut both strands of a DNA molecule at specific nucleotide sequences
3. a small ring of DNA found in a bacterial cell
4. a vehicle for carrying DNA fragments into a host cell
5. the insertion of normal genes into human cells to correct genetic disorders

## Understanding Key Concepts

6. Polymerase chain reaction is used to \_\_\_\_\_.  
A. cleave DNA      C. copy DNA  
B. insert DNA      D. protect DNA
7. What is the purpose of a test cross?  
A. produce offspring that consistently exhibit a specific trait  
B. check for carriers of a trait  
C. explain recessiveness  
D. show polygenic inheritance
8. The goal of gene therapy is to insert a \_\_\_\_\_ into cells to correct a genetic disorder.  
A. recessive allele      C. dominant allele  
B. growth hormone      D. normal allele
9. Restriction enzyme *EcoRI* cuts DNA strands, leaving \_\_\_\_\_ ends.  
A. sticky      C. blunt  
B. smooth      D. linked
10. \_\_\_\_\_ usually increases the appearance of genetic disorders.  
A. Cloning      C. PCR  
B. Inbreeding      D. Gene therapy

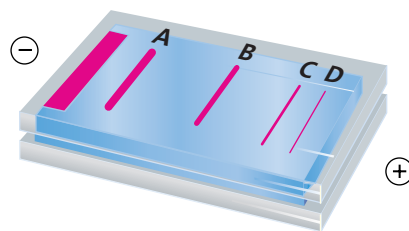
11. Cells in a cell culture all have the same genetic material because they are \_\_\_\_\_.  
A. vectors      C. hybrids  
B. plasmids      D. clones

## Constructed Response

12. **Open Ended** What is the potential use of a map showing the sequence of DNA bases in a human chromosome?
13. **Open Ended** Assume that transgenic organisms can be developed to speed nitrogen fixation. How might use of these organisms affect an ecosystem?
14. **Open Ended** How might transgenic organisms alter the course of evolution for a species?

## Thinking Critically

15. **Interpret Scientific Illustrations** A gel electrophoresis was run on DNA fragments 1 megabase (MB), 2 MB, 4 MB, and 7 MB in size. (MB=1 million nucleotide base pairs.) Identify the fragments and explain your answer.



16. **REAL WORLD BIOCHALLENGE** Through biotechnology, genetically modified food crops that are pesticide resistant, hardier, and higher yielding have been developed. However, the sale and use of genetically modified foods (GM foods) has become controversial. Research the pros and cons of genetically modified foods. Choose one side and make a class presentation that addresses the concerns of the opposite side.



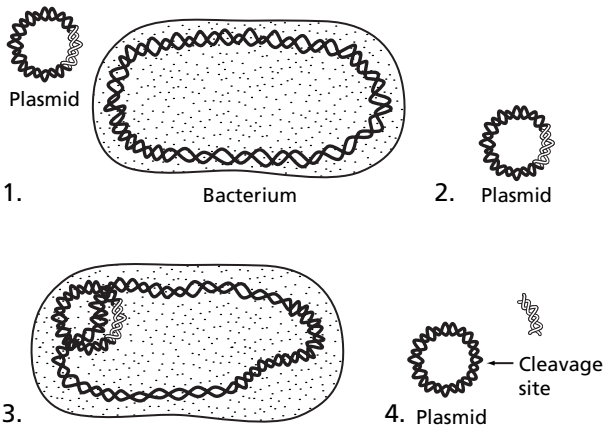
# Chapter 13 Assessment



## Part 1 Multiple Choice

17. A test cross was made between two Alaskan malamutes, a dominant phenotype for normal size and a homozygous recessive dwarf. Which of these results would indicate that the normal-sized dog is heterozygous?
- All puppies were phenotypically dominant.
  - All puppies were phenotypically recessive.
  - Some puppies were phenotypically dominant and some were recessive.
  - none of the above

Use the diagram below to answer question 18.



18. What is the proper sequence of steps for cloning recombinant DNA using a plasmid?
- 1-2-3-4
  - 2-3-4-1
  - 2-4-1-3
  - 4-2-1-3

Use the table below to answer question 19.

A. <i>Eco</i> RI	$\begin{array}{c} \text{GAATTC} \\   \quad   \quad   \quad   \\ \text{CTTAAG} \end{array}$
B. <i>Bam</i> HI	$\begin{array}{c} \text{GGATCC} \\   \quad   \quad   \quad   \\ \text{CCTAGG} \end{array}$
C. <i>Hind</i> III	$\begin{array}{c} \text{AAGCTT} \\   \quad   \quad   \quad   \\ \text{TTCGAA} \end{array}$

19. Which restriction enzyme could be used to cut the following DNA strand?
- 5d\*
- ```

-GGGGATCCCG-
| | | | | | | | |
-C CCTAGGGC-
    
```
- A
  - B
  - C
  - both A and B

## Part 2 Constructed Response/Grid In

Record your answers on your answer document.

20. **Open Ended** 5d\* Why was the discovery of restriction enzymes important to recombinant DNA technology?
21. **Open Ended** A wildlife officer found deer blood in the forest after hunting season ended. He took a sample to the lab for DNA fingerprinting. DNA fingerprinting also was done on deer meat from a suspect's freezer. As controls, DNA tests were done on the blood and meat of another deer. Was the suspect innocent or guilty? Explain.

| Control deer meat | Control deer blood | Freezer meat | Forest blood |
|-------------------|--------------------|--------------|--------------|
| —                 | —                  | —            | —            |
| —                 | —                  | —            | —            |
| —                 | —                  | —            | —            |
| —                 | —                  | —            | —            |





# BioDigest UNIT 4 REVIEW

## Genetics

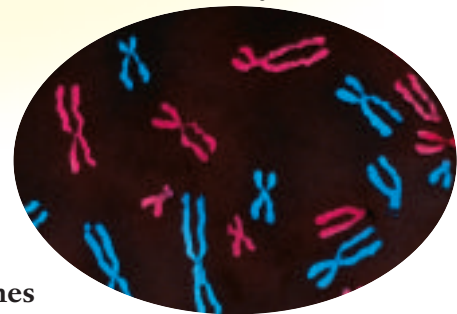
**G**enetics is the study of inheritance. The physical traits, or phenotype, of an individual are encoded in small segments of chromosomes called genes. Not all genes are expressed as a phenotype. Therefore, the genotype, the traits encoded in the genes, may be different from the expressed phenotype.

### Simple Mendelian Inheritance

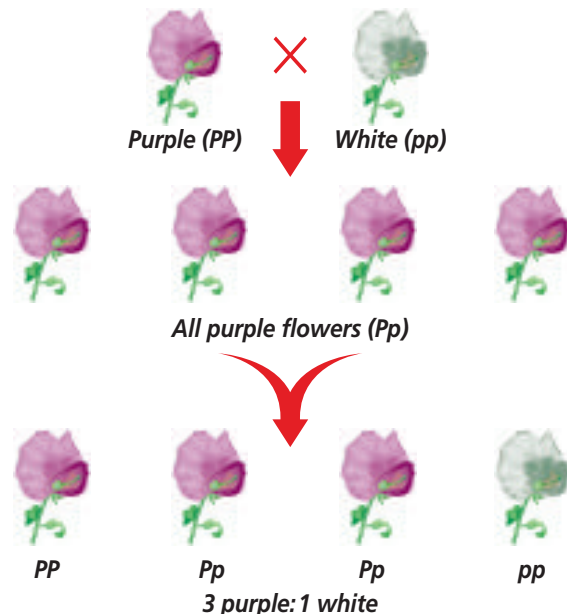
A trait is dominant if only one allele of a gene is needed for that trait to be expressed. If two alleles are needed for expression, the trait is said to be recessive. In pea plants, the allele for purple flowers is dominant, and the allele for white flowers is recessive. Any plant with  $PP$  or  $Pp$  alleles will have purple flowers. Any plant with  $pp$  alleles will have white flowers.

When a  $PP$  purple pea plant is crossed with a  $pp$  white plant, all the offspring are purple,  $Pp$ . When two  $Pp$  plants are crossed, three-fourths of the plants in the next generation will be purple and one-fourth will be white.

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Chromosomes



## FOCUS ON HISTORY

### Mendel



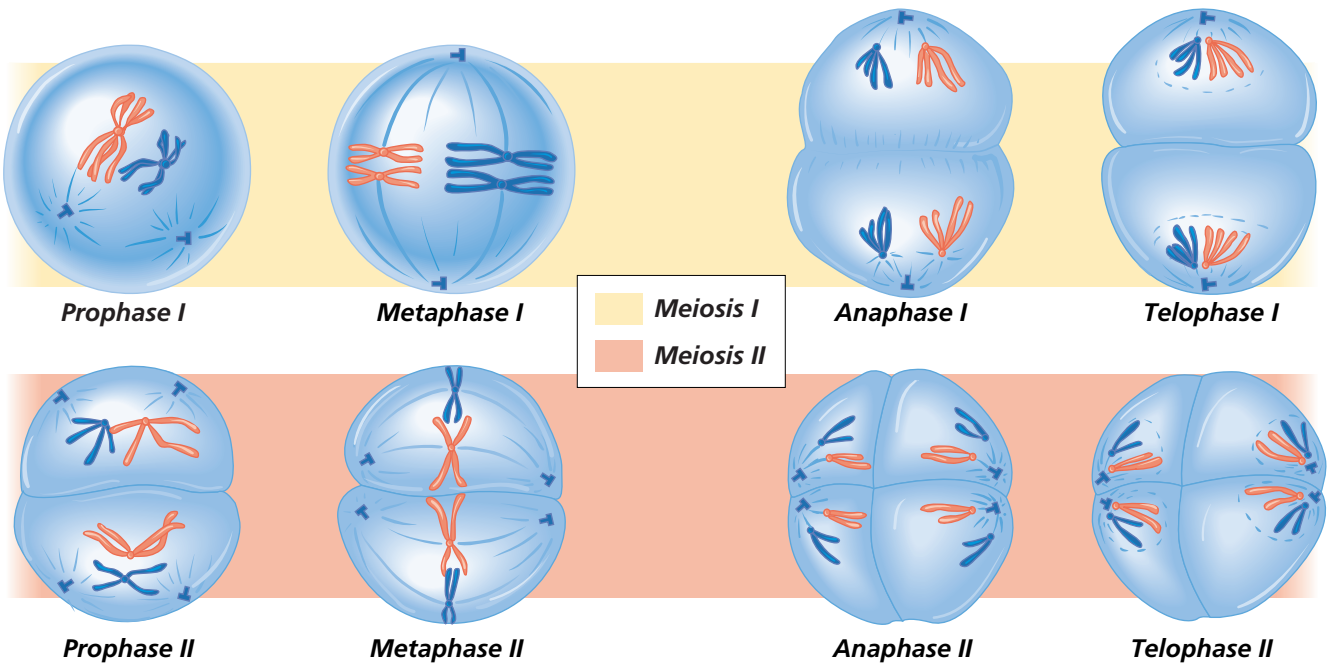
Gregor Mendel

**T**o investigate the genetic inheritance of pea plant traits, Austrian monk Gregor Mendel used critical thinking skills to design his experiments. When he collected data, he considered not only the qualitative characteristics, such as whether the plants were tall or short, but also the quantitative data by analyzing the ratios of tall to short plants in each generation. Mendel observed that there were two variations for each trait, such as tall and short plants. He formed the hypothesis that alleles transmitted these traits from one generation to the next. After studying several traits for many generations, Mendel formed two laws. The law of segregation states that the two alleles for each trait separate when gametes are formed. The law of independent assortment states that genes for different traits are inherited independently of each other.

## Meiosis

Meiosis produces gametes that contain only one copy of each chromosome instead of two. Some stages of meiosis are similar to those of mitosis, but in meiosis, homologous chromosomes come together as tetrads to exchange genes during a

process called crossing over. Meiosis also provides a mechanism for re-sorting the genetic information carried by cells. Both crossing over and the re-sorting of genes during meiosis produce genetic variability, which can give offspring a survival advantage if the environment changes.



Meiosis consists of two divisions, meiosis I and meiosis II. During meiosis I, the replicated homologous chromosomes separate from each other. In meiosis II, the sister chromatids of each replicated chromosome separate from each other.

## Producing Physical Traits

Deoxyribonucleic acid (DNA) is a double-stranded molecule made up of a sequence of paired nucleotides that encode each gene on a chromosome. There are four nitrogenous bases in DNA: A, T, C, and G. Because of their molecular shape, A can pair only with T, and C can pair only with G. This precise pairing allows the DNA molecule to copy itself in a process called DNA replication.

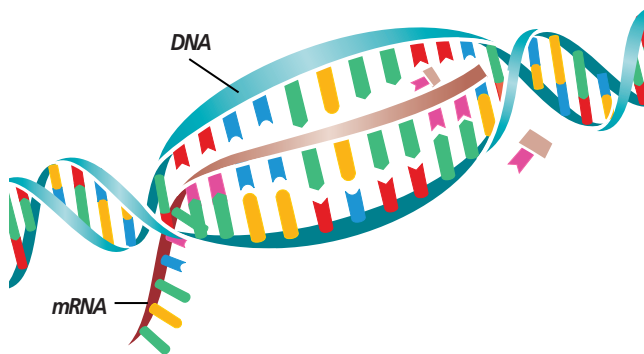


A DNA molecule is a double helix that resembles a zipper. The bases form the zipper's teeth.

DNA

**Transcription**

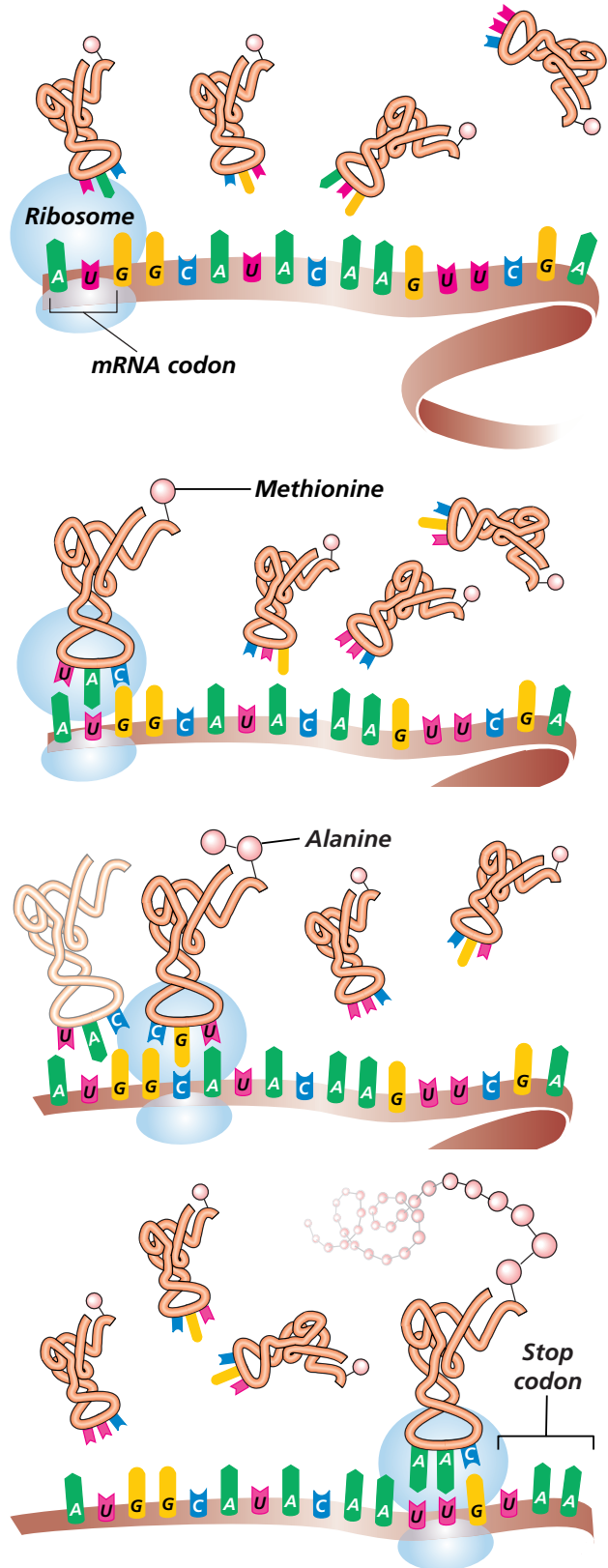
To make a protein, the segment of DNA containing the gene for that protein must be transcribed. First, the bases in the DNA segment separate and the sequence is copied into a molecule of messenger ribonucleic acid (mRNA), which moves through the nuclear envelope into the cytoplasm. RNA is similar to DNA except that RNA is a single strand and contains the base U in place of T.



In transcription, the two strands of DNA separate and a molecule of mRNA is made according to the sequence of bases in the DNA.

**Translation**

A codon is a sequence of three mRNA nitrogenous bases that codes for an amino acid. Translation occurs at a ribosome as it moves along the mRNA strand. The "start" codon—AUG—begins a protein. A transfer RNA (tRNA) molecule with a specific amino acid attached to it, comes to the mRNA and "reads" the codon. Another tRNA with an amino acid attached reads the next codon and the two amino acids bond. This process is repeated over and over as the ribosome moves along the mRNA until it comes to the "stop" codon—UAA.

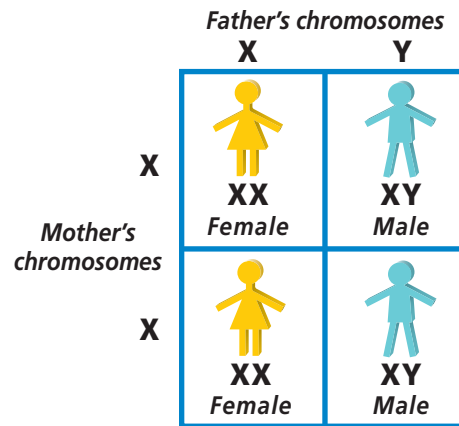


In translation, the sequence of nitrogenous bases in the mRNA is translated into a sequence of amino acids in a protein chain. Every three bases code for a specific amino acid.

## Complex Inheritance Patterns

An incomplete dominance pattern of inheritance produces an intermediate phenotype in the heterozygote. In codominant inheritance, the heterozygote expresses both alleles. Some traits, such as human blood types, are governed by multiple alleles, although any individual can carry only two of those alleles.

The X chromosome, one of two sex chromosomes, carries many genes, including the genes for hemophilia and color blindness. Most X-linked disorders appear in males because they inherit only one X chromosome. In females, a normal allele on one X chromosome can mask the expression of a recessive allele on the other X chromosome. Finally, some traits, such as skin color, are polygenic—governed by several genes.

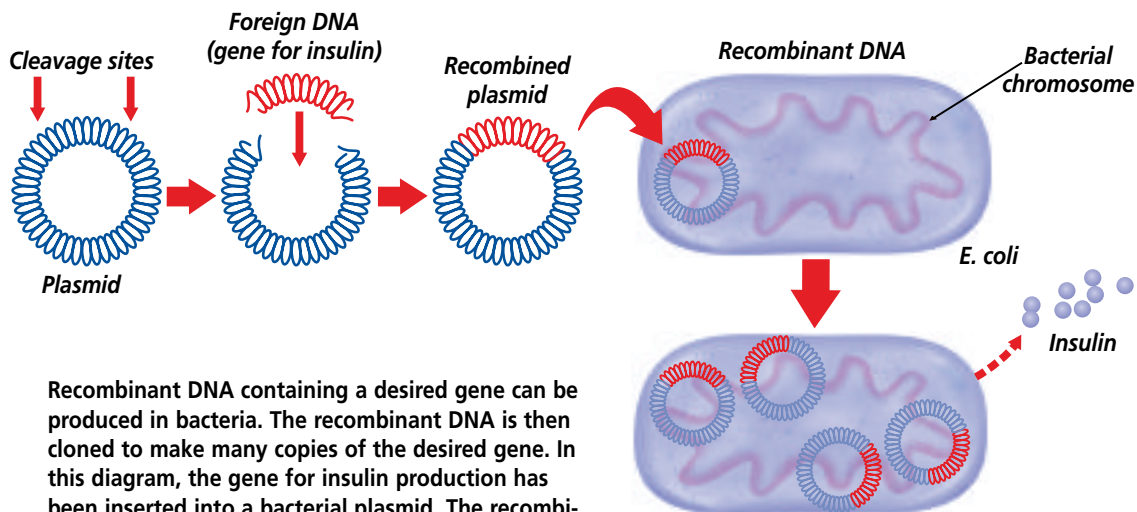


In any mating between humans, half the offspring will have the XX genotype, which are females, and half the offspring will have the genotype XY, which are males.

## Recombinant DNA Technology

To make recombinant DNA, a small segment of DNA containing a desired gene is inserted into a bacterial plasmid, a small ring of DNA. The plasmid acts as a vector to carry the DNA segment into

a host bacterial cell. Every time the bacterium reproduces, the plasmid containing the inserted DNA is duplicated, producing copies of the recombinant DNA along with the host chromosome. Because these new DNA segments are identical to the original, they are called clones. The host cell produces large quantities of the protein encoded by the recombinant DNA it contains.



Recombinant DNA containing a desired gene can be produced in bacteria. The recombinant DNA is then cloned to make many copies of the desired gene. In this diagram, the gene for insulin production has been inserted into a bacterial plasmid. The recombinant bacteria can then produce insulin.



## TEST-TAKING TIP

### Use the Buddy System

Study in a group. A small study group works well because it allows you to draw from a broader base of skills and content knowledge. Keep it small, question each other, and keep on target.

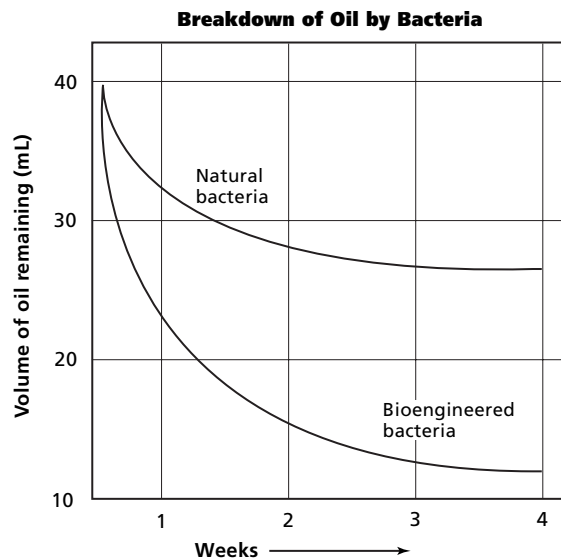
## Part 1 Multiple Choice

- Two parents have cleft chins. Their first child **3c\*** does not have a cleft chin. What type of inheritance does this display?
  - Cleft chins are dominant.
  - Cleft chins are recessive.
  - Cleft chins are codominant.
  - Cleft chins are incompletely dominant.
- What carries the information from the DNA **4a** to the cytoplasm?
  - tRNA
  - mRNA
  - enzymes
  - rRNA
- What type of inheritance shows a pattern **3c\*** where the only phenotype of the heterozygote is intermediate between those of the two homozygotes?
  - polygenic inheritance
  - sex-linked inheritance
  - incomplete dominance
  - codominance
- During what phase of meiosis do replicated **2a** homologous chromosomes line up next to each other at the cell's equator?
  - anaphase I
  - metaphase II
  - metaphase I
  - prophase I
- What is the source of most of the plasmids **5e\*** used in genetic engineering?
  - yeast cells
  - animal cells
  - bacterial cells
  - plant cells

For an investigation of the ability of a bioengineered species of bacteria to break down oil, the following procedure was followed:

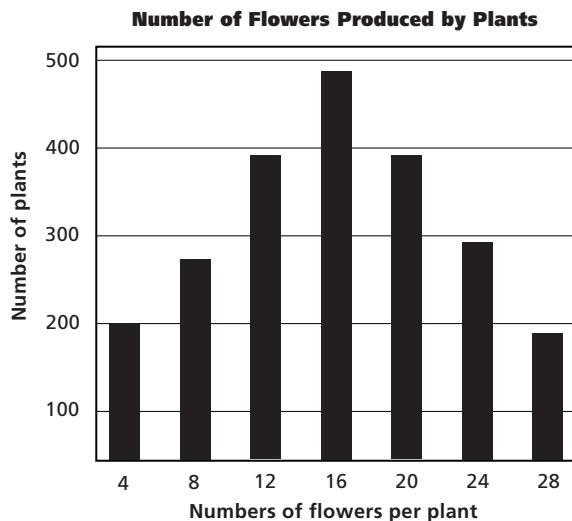
- Add 40 mL of oil to a culture of the bioengineered bacteria and to a culture of naturally occurring bacteria of the same species.
- Measure the volume of oil in each culture daily for four weeks.
- Graph the resulting data.

Use the graph below to answer questions 6–8.



- Approximately how much oil did the natural bacteria convert into harmless products after four weeks?
  - 4 mL
  - 14 mL
  - 24 mL
  - 40 mL
- About how much oil did the bioengineered bacteria convert after four weeks?
  - 4 mL
  - 14 mL
  - 28 mL
  - 40 mL
- About how much more efficient are the bioengineered bacteria than the natural bacteria?
  - 1×
  - 1.5×
  - 2×
  - 3×

Use the graph below to answer questions 9–11. The graph illustrates an inherited trait—the number of flowers produced per plant—in a certain plant population.



9. Which bars represent the homozygous condition for this trait?
- A. 8—16                      C. 16—24  
B. 12—20                     D. 4—28
10. Which of these groups of bars represent the heterozygous condition for this trait?
- A. 4—12—20                C. 12—20—28  
B. 8—16—24                D. 4—16—28
11. What pattern of inheritance is suggested by the graph?
- A. multiple alleles  
B. incomplete dominance  
C. polygenic inheritance  
D. sex-linkage
12. A couple has four children who are all boys. **2g** What are the chances that their next child also will be a boy?
- A. 100%                        C. 75%  
B. 50%                         D. 0%
13. A female, nonpregnant lab rat is exposed to X rays. Its future offspring will be affected only if a mutation occurs in one of the rat's \_\_\_\_\_ cells.
- A. body                         C. sex  
B. liver                        D. nerve
14. A frameshift mutation is more damaging than a point mutation because \_\_\_\_\_.
- A. the genetic code is changed in a frameshift mutation  
B. more codons are affected in a frameshift mutation  
C. more bases are deleted from the DNA in a frameshift mutation  
D. more bases are deleted from the DNA in a point mutation

### Part 2 Constructed Response/Grid In

Record your answers on your answer document.

15. **Open Ended** Explain the differences between the terms *monoploid*, *triploid*, and *tetraploid*. Would meiosis be affected by each of these conditions? Would mitosis be affected? Explain.
16. **Open Ended** Explain how RNA differs from DNA. Can RNA be replicated by the process that is **5a** described in Chapter 11? Explain.
17. **Open Ended** Draw a Punnett square for the following situation and summarize the results. A man **3a** who is color-blind is married to a woman who carries an allele for color blindness. What phenotypes of children can this couple have?
18. **Open Ended** Explain how a foreign gene can be inserted into a plasmid. Use the term *restriction* **5d**\*enzyme in your answer.

