Chapter

5

Modern Genetics

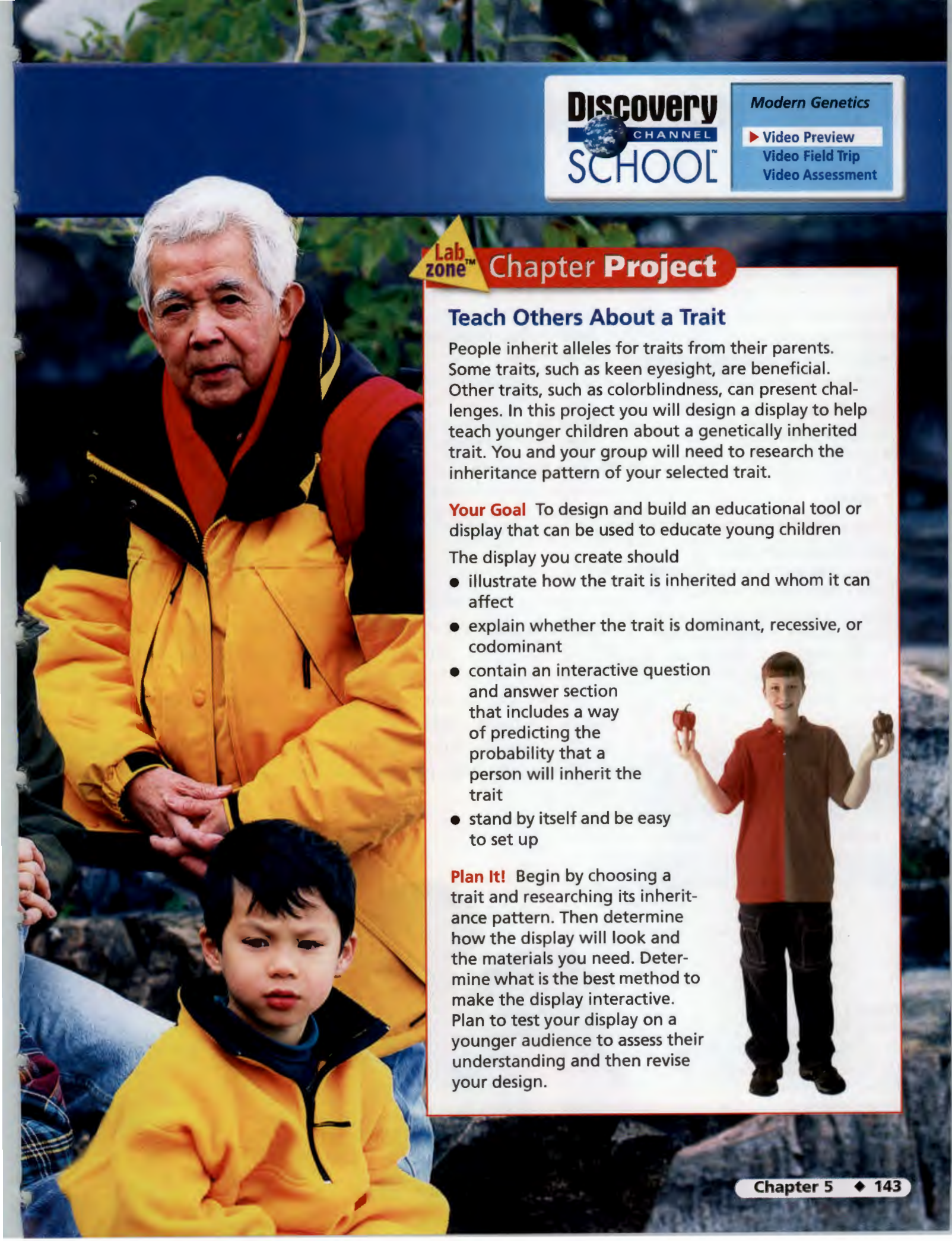
The BIG Idea

Science and Technology

What applications of science and technology have advanced the study of genetics?

Chapter Preview

The members of this family resemble one another because they share some alleles. ▶



Discovery CHANNEL SCHOOL

Modern Genetics

- ▶ Video Preview
- Video Field Trip
- Video Assessment

Lab zone™ Chapter **Project**

Teach Others About a Trait

People inherit alleles for traits from their parents. Some traits, such as keen eyesight, are beneficial. Other traits, such as colorblindness, can present challenges. In this project you will design a display to help teach younger children about a genetically inherited trait. You and your group will need to research the inheritance pattern of your selected trait.

Your Goal To design and build an educational tool or display that can be used to educate young children

The display you create should

- illustrate how the trait is inherited and whom it can affect
- explain whether the trait is dominant, recessive, or codominant
- contain an interactive question and answer section that includes a way of predicting the probability that a person will inherit the trait
- stand by itself and be easy to set up

Plan It! Begin by choosing a trait and researching its inheritance pattern. Then determine how the display will look and the materials you need. Determine what is the best method to make the display interactive. Plan to test your display on a younger audience to assess their understanding and then revise your design.

Section 1

Human Inheritance

Reading Preview

Key Concepts

- What are some patterns of inheritance in humans?
- What are the functions of the sex chromosomes?
- What is the relationship between genes and the environment?

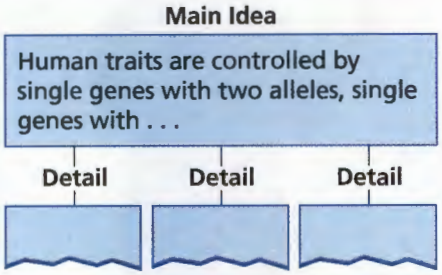
Key Terms

- multiple alleles
- sex chromosomes
- sex-linked gene
- carrier

Target Reading Skill

Identifying Main Ideas

As you read the Patterns of Human Inheritance section, write the main idea—the biggest or most important idea—in a graphic organizer like the one below. Then write three supporting details that further explain the main idea.



Lab zone **Discover Activity**

How Tall Is Tall?

1. Choose a partner. Measure each other's height to the nearest 5 centimeters. Record your measurements on the chalkboard.
2. Create a bar graph showing the number of students at each height. Plot the heights on the horizontal axis and the number of students on the vertical axis.

Think It Over

Inferring Do you think height in humans is controlled by a single gene, as it is in peas? Explain your answer.

The arrival of a baby is a happy event. Eagerly, the parents and grandparents gather around to admire the newborn baby. "Don't you think she looks like her father?" "Yes, but she has her mother's eyes."

When a baby is born, the parents, their families, and their friends try to determine whom the baby resembles. Chances are good that the baby will look a little bit like both parents. That is because both parents pass alleles for traits on to their offspring.

FIGURE 1
Family Resemblance
Because children inherit alleles for traits from their mother and father, children often look like their parents.

Patterns of Human Inheritance

Take a few seconds to look at the other students in your classroom. Some people have curly hair; others have straight hair. Some people are tall, some are short, and many others are in between. You'll probably see eyes of many different colors, ranging from pale blue to dark brown. The different traits you see are determined by a variety of inheritance patterns. **Some human traits are controlled by single genes with two alleles, and others by single genes with multiple alleles. Still other traits are controlled by many genes that act together.**

Single Genes With Two Alleles A number of human traits are controlled by a single gene with one dominant allele and one recessive allele. These human traits have two distinctly different phenotypes, or physical appearances.

For example, a widow's peak is a hairline that comes to a point in the middle of the forehead. The allele for a widow's peak is dominant over the allele for a straight hairline. The Punnett square in Figure 2 illustrates a cross between two parents who are heterozygous for a widow's peak. Trace the possible combinations of alleles that a child may inherit. Notice that each child has a 3 in 4, or 75 percent, probability of having a widow's peak. There is only a 1 in 4, or 25 percent, probability that a child will have a straight hairline. When Mendel crossed peas that were heterozygous for a trait, he obtained similar percentages in the offspring.

FIGURE 2
Widow's Peak Punnett Square
This Punnett square shows a cross between two parents with widow's peaks.
Interpreting Diagrams *What are the possible genotypes of the offspring? What percentage of the offspring will have each genotype?*

FIGURE 3
Inheritance of Blood Type
Blood type is determined by a single gene with three alleles. This chart shows which combinations of alleles result in each blood type.

Alleles of Blood Types	
Blood Type	**Combination of Alleles**
A	I^AI^A or I^Ai
B	I^BI^B or I^Bi
AB	I^AI^B
O	ii

Single Genes With Multiple Alleles

Some human traits are controlled by a single gene that has more than two alleles. Such a gene is said to have **multiple alleles**—three or more forms of a gene that code for a single trait. Even though a gene may have multiple alleles, a person can carry only two of those alleles. This is because chromosomes exist in pairs. Each chromosome in a pair carries only one allele for each gene.

Human blood type is controlled by a gene with multiple alleles. There are four main blood types—A, B, AB, and O. Three alleles control the inheritance of blood types. The allele for blood type A and the allele for blood type B are codominant. The allele for blood type A is written as I^A. The allele for blood type B is written I^B. The allele for blood type O—written i—is recessive. Recall that when two codominant alleles are inherited, neither allele is masked. A person who inherits an I^A allele from one parent and an I^B allele from the other parent will have type AB blood. Figure 3 shows the allele combinations that result in each blood type. Notice that only people who inherit two i alleles have type O blood.

Traits Controlled by Many Genes

If you completed the Discover activity, you saw that height in humans has more than two distinct phenotypes. In fact, there is an enormous variety of phenotypes for height. Some human traits show a large number of phenotypes because the traits are controlled by many genes. The genes act together as a group to produce a single trait. At least four genes control height in humans, so there are many possible combinations of genes and alleles. Skin color is another human trait that is controlled by many genes.

Reading Checkpoint **Why do some traits exhibit a large number of phenotypes?**

FIGURE 4
Many Phenotypes
Skin color in humans is determined by three or more genes. Different combinations of alleles for each of the genes result in a wide range of possible skin colors.

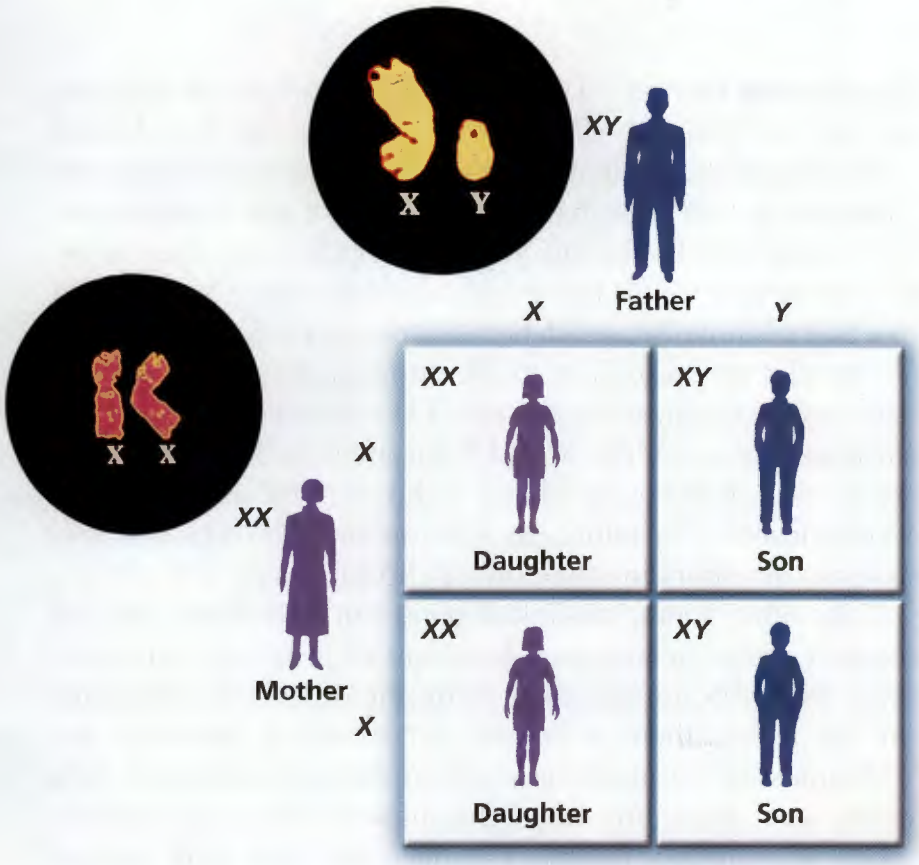


FIGURE 5
Male or Female?
As this Punnett square shows, there is a 50 percent probability that a child will be a girl and a 50 percent probability that a child will be a boy.
Interpreting Diagrams *What sex will the child be if a sperm with a Y chromosome fertilizes an egg?*

The Sex Chromosomes

The **sex chromosomes** are one of the 23 pairs of chromosomes in each body cell. **The sex chromosomes carry genes that determine whether a person is male or female. They also carry genes that determine other traits.**

Girl or Boy? The sex chromosomes are the only chromosome pair that do not always match. If you are a girl, your two sex chromosomes match. The two chromosomes are called X chromosomes. If you are a boy, your sex chromosomes do not match. One of them is an X chromosome, and the other is a Y chromosome. The Y chromosome is much smaller than the X chromosome.

Sex Chromosomes and Fertilization What happens to the sex chromosomes when egg and sperm cells form? Since both of a female's sex chromosomes are X chromosomes, all eggs carry one X chromosome. Males, however, have two different sex chromosomes. Therefore, half of a male's sperm cells carry an X chromosome, while half carry a Y chromosome.

When a sperm cell with an X chromosome fertilizes an egg, the egg has two X chromosomes. The fertilized egg will develop into a girl. When a sperm with a Y chromosome fertilizes an egg, the egg has one X chromosome and one Y chromosome. The fertilized egg will develop into a boy.

Lab zone Try This Activity

The Eyes Have It

One inherited trait is eye dominance—the tendency to use one eye more than the other. Here's how you can test yourself for this trait.

1. Hold your hand out in front of you at arm's length. Point your finger at an object across the room.
2. Close your right eye. With only your left eye open, observe how far your finger appears to move.
3. Repeat Step 2 with the right eye open. With which eye did your finger seem to remain closer to the object? That eye is dominant.

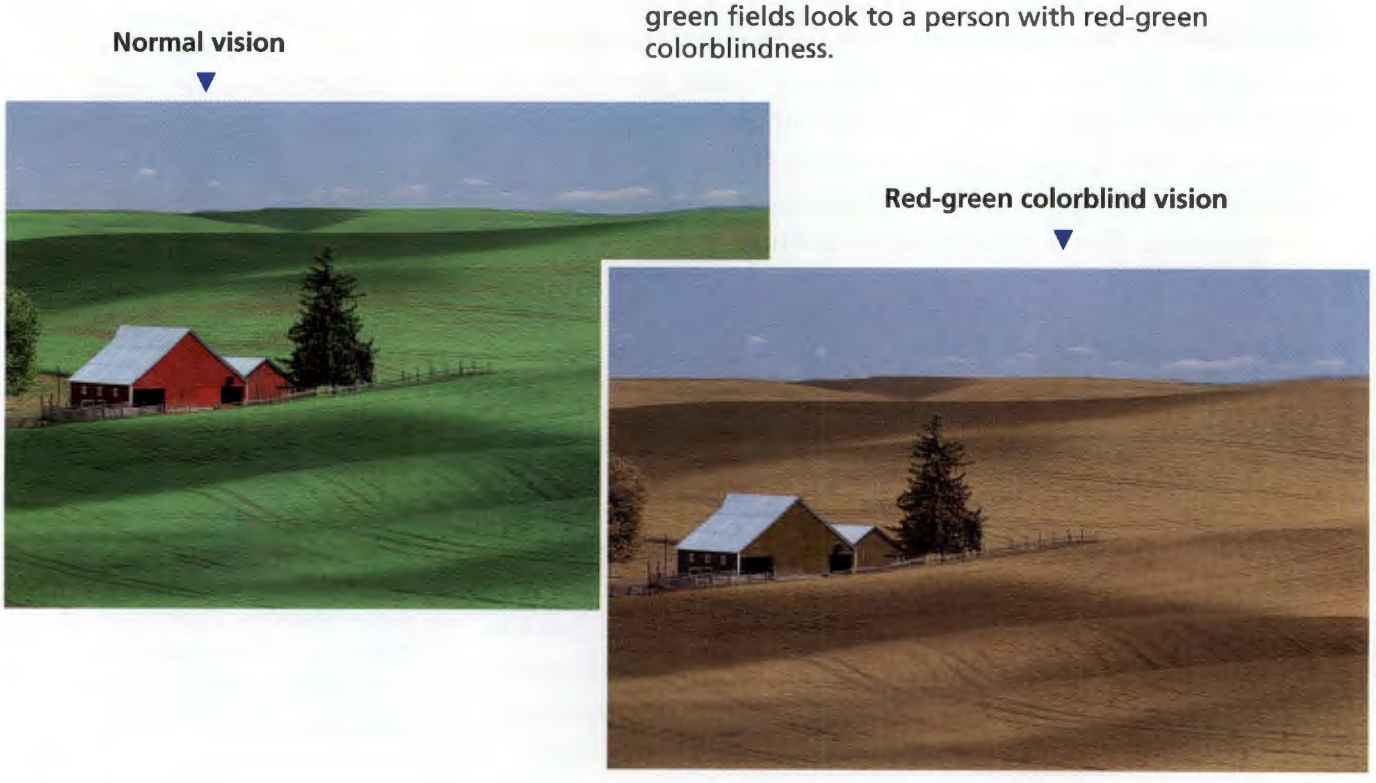
Designing Experiments
Is eye dominance related to hand dominance—whether a person is right-handed or left-handed? Design an experiment to find out. *Obtain your teacher's permission before carrying out your experiment.*

Sex-Linked Genes The genes for some human traits are carried on the sex chromosomes. Genes on the X and Y chromosomes are often called **sex-linked genes** because their alleles are passed from parent to child on a sex chromosome. Traits controlled by sex-linked genes are called sex-linked traits. One sex-linked trait is red-green colorblindness. A person with this trait cannot distinguish between red and green.

Recall that females have two X chromosomes, whereas males have one X chromosome and one Y chromosome. Unlike most chromosome pairs, the X and Y chromosomes have different genes. Most of the genes on the X chromosome are not on the Y chromosome. Therefore, an allele on an X chromosome may have no corresponding allele on a Y chromosome.

Like other genes, sex-linked genes can have dominant and recessive alleles. In females, a dominant allele on one X chromosome will mask a recessive allele on the other X chromosome. But in males, there is usually no matching allele on the Y chromosome to mask the allele on the X chromosome. As a result, any allele on the X chromosome—even a recessive allele—will produce the trait in a male who inherits it. Because males have only one X chromosome, males are more likely than females to have a sex-linked trait that is controlled by a recessive allele.

FIGURE 6
Colorblindness
The lower photo shows how a red barn and green fields look to a person with red-green colorblindness.



Inheritance of Colorblindness Colorblindness is a trait controlled by a recessive allele on the X chromosome. Many more males than females have red-green colorblindness. You can understand why this is the case by examining the Punnett square in Figure 7. Both parents in this example have normal color vision. Notice, however, that the mother is a carrier of colorblindness. A **carrier** is a person who has one recessive allele for a trait and one dominant allele. A carrier of a trait controlled by a recessive allele does not have the trait. However, the carrier can pass the recessive allele on to his or her offspring. In the case of sex-linked traits, only females can be carriers.

As you can see in Figure 7, there is a 25 percent probability that this couple will have a colorblind child. Notice that none of the couple's daughters will be colorblind. On the other hand, the sons have a 50 percent probability of being colorblind. For a female to be colorblind, she must inherit two recessive alleles for colorblindness, one from each parent. A male needs to inherit only one recessive allele. This is because there is no gene for color vision on the Y chromosome. Thus, there is no allele that could mask the recessive allele on the X chromosome.

Reading Checkpoint **What is the sex of a person who is a carrier for colorblindness?**

Go Online
NSTA SCILINKS™
For: Links on genetics
Visit: www.SciLinks.org
Web Code: scn-0341

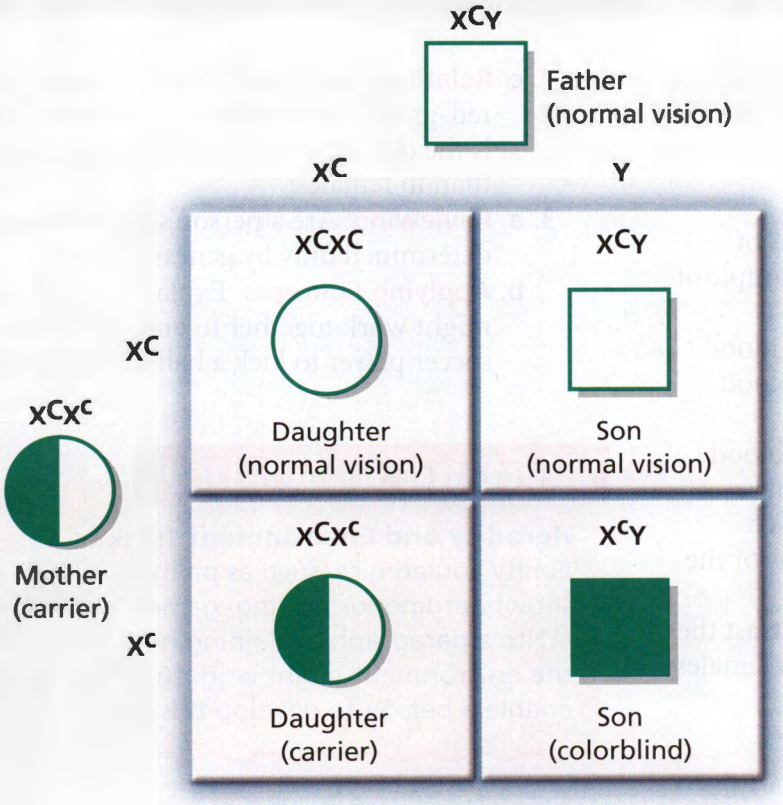


FIGURE 7
Colorblindness Punnett Square
Red-green colorblindness is a sex-linked trait. A girl who receives only one recessive allele (written X^C) for red-green colorblindness will not have the trait. However, a boy who receives one recessive allele will be colorblind.
Applying Concepts *What allele combination would a daughter need to inherit to be colorblind?*

FIGURE 8
Heredity and Environment
When a person plays a violin, genetically determined traits such as muscle coordination interact with environmental factors such as time spent in practice.

The Effect of Environment

In humans and other organisms, the effects of genes are often influenced by the environment—an organism's surroundings. **Many of a person's characteristics are determined by an interaction between genes and the environment.**

You have learned that several genes work together to help determine human height. However, people's heights are also influenced by their environments. People's diets can affect their height. A diet lacking in protein, certain minerals, or certain vitamins can prevent a person from growing as tall as might be possible.

Environmental factors can also affect human skills, such as playing a musical instrument. For example, physical traits such as muscle coordination and a good sense of hearing will help a musician play well. But the musician also needs instruction on how to play the instrument. Musical instruction is an environmental factor.

Reading Checkpoint **How can environmental factors affect a person's height?**

Section 1 Assessment

Target Reading Skill **Identifying Main Ideas** Use your graphic organizer to help you answer Question 1 below.

Reviewing Key Concepts

1. a. **Identifying** Identify three patterns of inheritance in humans. Give an example of a trait that follows each pattern.
   b. **Summarizing** How many human blood types are there? Summarize how blood type is inherited.
   c. **Drawing Conclusions** Aaron has blood type O. Can either of his parents have blood type AB? Explain your answer.
2. a. **Reviewing** What are the functions of the sex chromosomes?
   b. **Comparing and Contrasting** Contrast the sex chromosomes found in human females and human males.
   c. **Relating Cause and Effect** Explain how red-green colorblindness is inherited. Why is the condition more common in males than in females?
3. a. **Reviewing** Are a person's characteristics determined only by genes? Explain.
   b. **Applying Concepts** Explain what factors might work together to enable a great soccer player to kick a ball a long distance.

Writing in Science

Heredity and Environment Think of an ability you admire, such as painting, dancing, snowboarding, or playing games skillfully. Write a paragraph explaining how genes and the environment might work together to enable a person to develop this ability.

Section 2

Human Genetic Disorders

Reading Preview

Key Concepts

- What are two major causes of genetic disorders in humans?
- How do geneticists trace the inheritance of traits?
- How are genetic disorders diagnosed and treated?

Key Terms

- genetic disorder
- pedigree
- karyotype

Target Reading Skill

Comparing and Contrasting

As you read, compare and contrast the types of genetic disorders by completing a table like the one below.

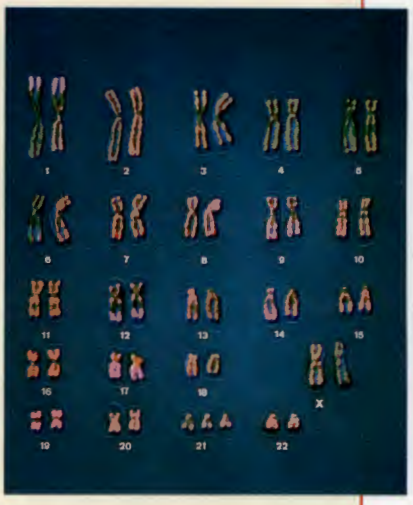
Disorder	Description	Cause
Cystic fibrosis	Abnormally thick mucus	Loss of three DNA bases

Lab zone **Discover Activity**

How Many Chromosomes?

The photo at right shows the chromosomes from a cell of a person with Down syndrome, a genetic disorder. The chromosomes have been sorted into pairs.

1. Count the number of chromosomes in the photo.
2. How does the number of chromosomes compare to the usual number of chromosomes in human cells?

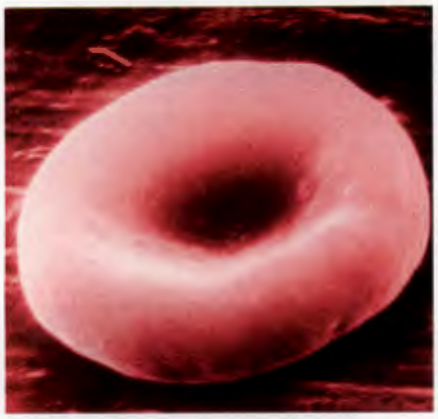


Think It Over

Inferring How do you think a cell could have ended up with this number of chromosomes? (*Hint:* Think about the events that occur during meiosis.)

The air inside the stadium was hot and still. The crowd cheered loudly as the runners approached the starting blocks. At the crack of the starter's gun, the runners leaped into motion and sprinted down the track. Seconds later, the race was over. The runners, bursting with pride, hugged each other and their coaches. These athletes were running in the Special Olympics, a competition for people with disabilities. Many of the athletes who compete in the Special Olympics have disabilities that result from genetic disorders.

◀ Runners in the Special Olympics



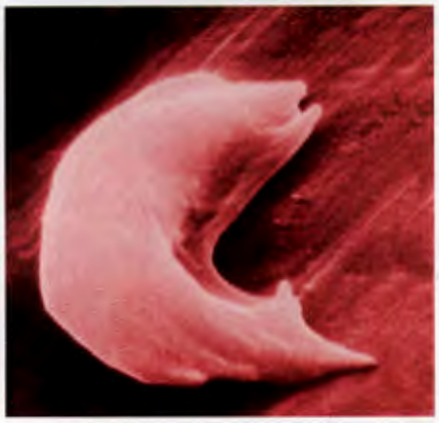


FIGURE 9
Sickle-Cell Disease
Normally, red blood cells are shaped like round disks (top). In a person with sickle-cell disease, red blood cells can become sickle-shaped (bottom).

Causes of Genetic Disorders

A **genetic disorder** is an abnormal condition that a person inherits through genes or chromosomes. **Some genetic disorders are caused by mutations in the DNA of genes. Other disorders are caused by changes in the overall structure or number of chromosomes.** In this section, you will learn about some common genetic disorders.

Cystic Fibrosis Cystic fibrosis is a genetic disorder in which the body produces abnormally thick mucus in the lungs and intestines. The thick mucus fills the lungs, making it hard for the affected person to breathe. Cystic fibrosis is caused by a recessive allele on one chromosome. The recessive allele is the result of a mutation in which three bases are removed from a DNA molecule.

Sickle-Cell Disease Sickle-cell disease affects hemoglobin, a protein in red blood cells that carries oxygen. When oxygen concentrations are low, the red blood cells of people with the disease have an unusual sickle shape. Sickle-shaped red blood cells clog blood vessels and cannot carry as much oxygen as normal cells. The allele for the sickle-cell trait is codominant with the normal allele. A person with two sickle-cell alleles will have the disease. A person with one sickle-cell allele will produce both normal hemoglobin and abnormal hemoglobin. This person usually will not have symptoms of the disease.

Hemophilia Hemophilia is a genetic disorder in which a person's blood clots very slowly or not at all. People with the disorder do not produce one of the proteins needed for normal blood clotting. The danger of internal bleeding from small bumps and bruises is very high. Hemophilia is caused by a recessive allele on the X chromosome. Because hemophilia is a sex-linked disorder, it occurs more frequently in males than in females.

Down Syndrome In Down syndrome, a person's cells have an extra copy of chromosome 21. In other words, instead of a pair of chromosomes, a person with Down syndrome has three of that chromosome. Down syndrome most often occurs when chromosomes fail to separate properly during meiosis. People with Down syndrome have some degree of mental retardation. Heart defects are also common, but can be treated.

Reading Checkpoint **How is the DNA in the sickle-cell allele different from the normal allele?**

Lab zone Skills Activity

Predicting

A man has sickle-cell disease. His wife does not have the disease, but is heterozygous for the sickle-cell trait. Predict the probability that their child will have sickle-cell disease. (*Hint:* Construct a Punnett square.)

Pedigrees

Imagine that you are a geneticist who is interested in tracing the occurrence of a genetic disorder through several generations of a family. What would you do? **One important tool that geneticists use to trace the inheritance of traits in humans is a pedigree.** A **pedigree** is a chart or "family tree" that tracks which members of a family have a particular trait.

The trait in a pedigree can be an ordinary trait, such as a widow's peak, or a genetic disorder, such as cystic fibrosis. Figure 10 shows a pedigree for albinism, a condition in which a person's skin, hair, and eyes lack normal coloring.

Go Online
active art

For: Pedigree activity
Visit: PHSchool.com
Web Code: cep-3042

FIGURE 10
A Pedigree

The father in the photograph has albinism. The pedigree shows the inheritance of the allele for albinism in three generations of a family. **Interpreting Diagrams** *Where is an albino male shown in the pedigree?*

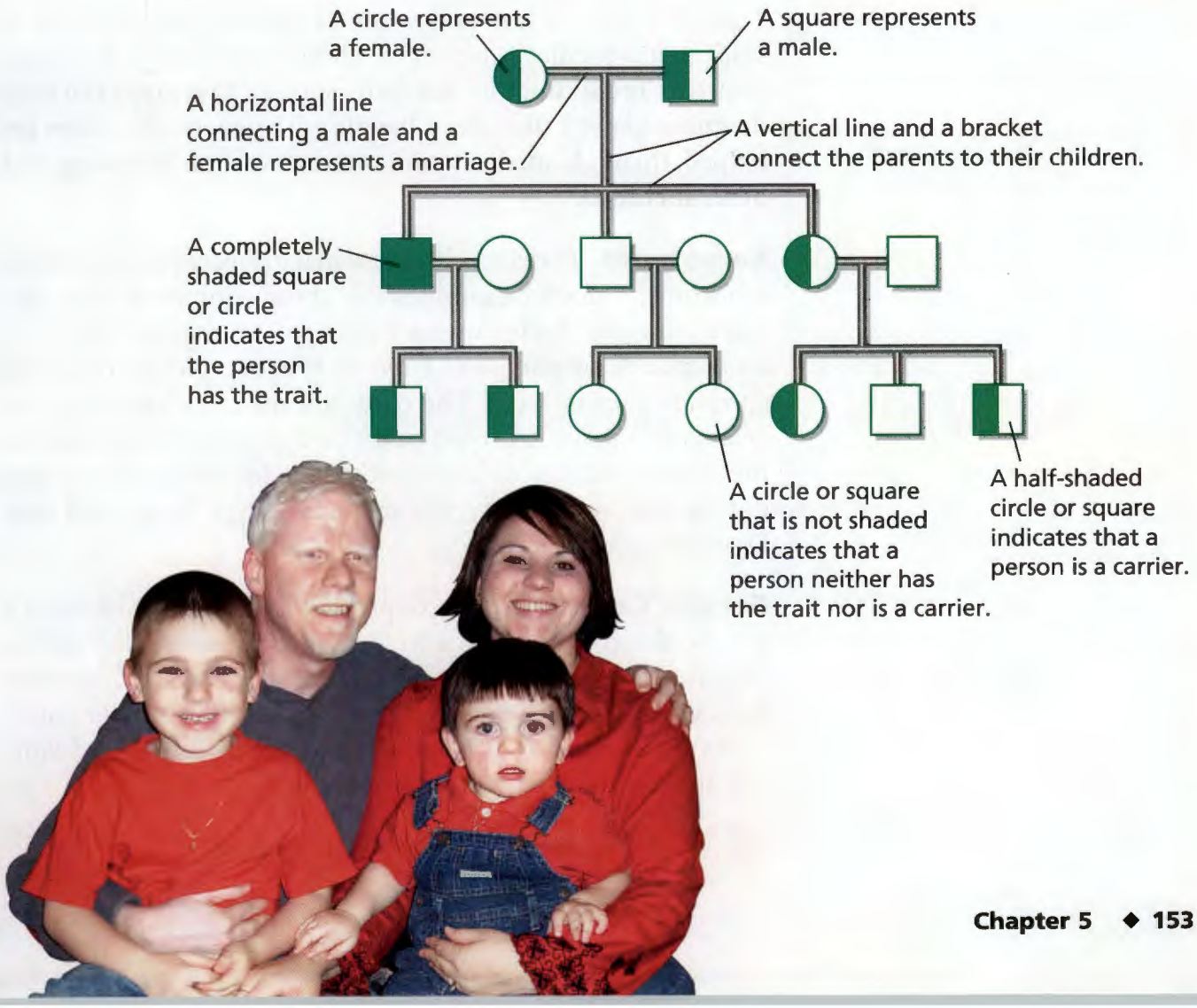
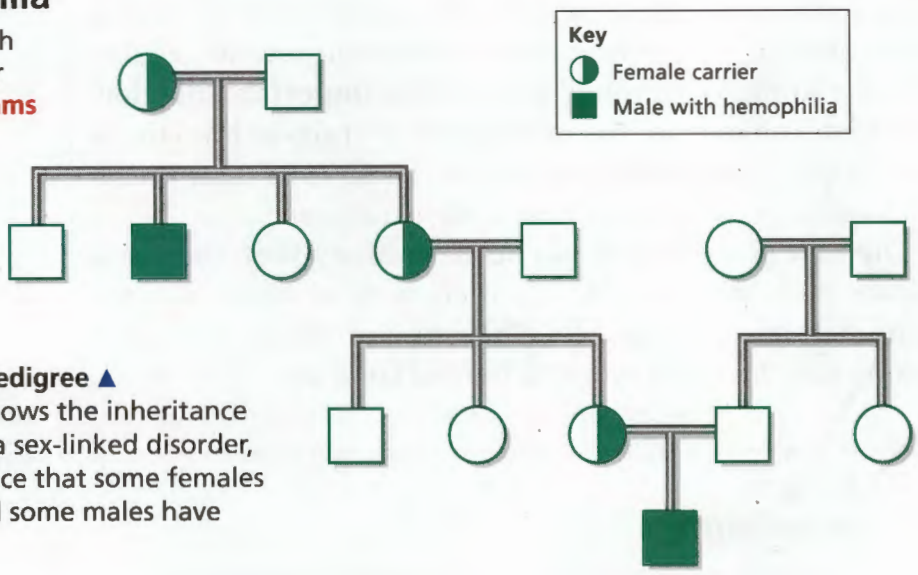


FIGURE 11

Living With Hemophilia

With proper care, people with hemophilia can manage their disorder. **Interpreting Diagrams** *In the pedigree, how many people have hemophilia?*



A Hemophilia Pedigree ▲
The pedigree shows the inheritance of hemophilia, a sex-linked disorder, in a family. Notice that some females are carriers, and some males have the disorder.

Managing Genetic Disorders

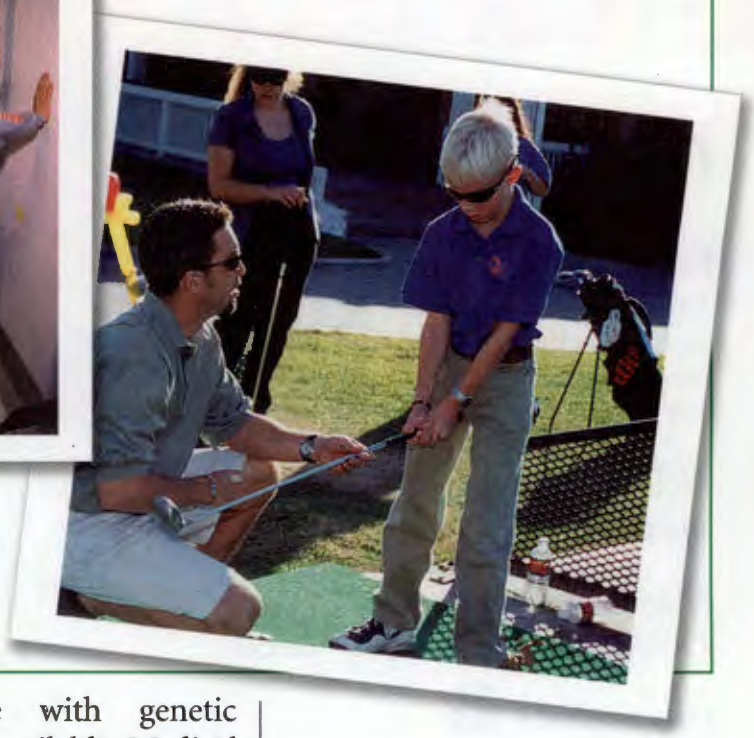
Years ago, doctors had only Punnett squares and pedigrees to help them predict whether a child might have a genetic disorder. **Today, doctors use tools such as karyotypes to help diagnose genetic disorders. People with genetic disorders are helped through medical care, education, job training, and other methods.**

Karyotypes To detect chromosomal disorders such as Down syndrome, a doctor examines the chromosomes from a person's cells. The doctor uses a karyotype to examine the chromosomes. A **karyotype** (KA ree uh typ) is a picture of all the chromosomes in a cell. The chromosomes in a karyotype are arranged in pairs. A karyotype can reveal whether a person has the correct number of chromosomes in his or her cells. If you did the Discover activity, you saw a karyotype from a girl with Down syndrome.

Genetic Counseling A couple that has a family history of a genetic disorder may turn to a genetic counselor for advice. Genetic counselors help couples understand their chances of having a child with a particular genetic disorder. Genetic counselors use tools such as karyotypes, pedigree charts, and Punnett squares to help them in their work.

Reading Checkpoint **What do genetic counselors do?**

Physical Therapy ▶ Trained medical workers help hemophilia patients cope with their disorder. Here, a boy receives physical therapy.



Sports ▶ A boy with hemophilia learns how to play golf. The disorder does not stop people from living active lives.

Dealing With Genetic Disorders People with genetic disorders face serious challenges, but help is available. Medical treatments help people with some disorders. For example, physical therapy helps remove mucus from the lungs of people with cystic fibrosis. People with sickle-cell disease take folic acid, a vitamin, to help their bodies manufacture red blood cells. Because of education and job training, adults with Down syndrome can find work in hotels, banks, restaurants, and other places of employment. Fortunately, most genetic disorders do not prevent people from living active, productive lives.

Section 2 Assessment

Target Reading Skill

Comparing and Contrasting Use the information in your table to help you answer Question 1 below.

Reviewing Key Concepts

1. a. **Identifying** Identify the two major causes of genetic disorders in humans.
   b. **Explaining** Which of those two major causes is responsible for Down syndrome?
   c. **Describing** How are the cells of a person with Down syndrome different from those of a person without the disorder?
2. a. **Defining** What is a pedigree?
   b. **Inferring** Why are pedigrees helpful in understanding genetic disorders?
   c. **Applying Concepts** Sam has hemophilia. Sam's brother, mother, and father do not have hemophilia. Draw a pedigree showing who has the disorder and who is a carrier.
3. a. **Reviewing** What is a karyotype?
   b. **Inferring** Would a karyotype reveal the presence of sickle-cell disease? Why or why not?

Writing in Science

Creating a Web Site Create an imaginary Web site to inform the public about genetic disorders. Write a description of one disorder for the Web site.

Lab zone Skills Lab

Family Puzzle

Problem

A husband and wife want to understand the probability that their children might inherit cystic fibrosis. How can you use the information in the box labeled Case Study to predict the probability?

Skills Focus

interpreting data, predicting

Materials

• 12 index cards • scissors • marker

Procedure

1. Read the Case Study. In your notebook, draw a pedigree that shows all the family members. Use circles to represent the females, and squares to represent the males. Shade in the circles or squares representing the individuals who have cystic fibrosis.
2. You know that cystic fibrosis is controlled by a recessive allele. To help you figure out Joshua and Bella's family pattern, create a set of cards to represent the alleles. Cut each of six index cards into four smaller cards. On 12 of the small cards, write *N* to represent the dominant normal allele. On the other 12 small cards, write *n* for the recessive allele.

Case Study: Joshua and Bella

- Joshua and Bella have a son named Ian. Ian has been diagnosed with cystic fibrosis.
- Joshua and Bella are both healthy.
- Bella's parents are both healthy.
- Joshua's parents are both healthy.
- Joshua's sister, Sara, has cystic fibrosis.

3. Begin by using the cards to represent Ian's alleles. Since he has cystic fibrosis, what alleles must he have? Write in this genotype next to the pedigree symbol for Ian.
4. Joshua's sister, Sara, also has cystic fibrosis. What alleles does she have? Write in this genotype next to the pedigree symbol that represents Sara.
5. Now use the cards to figure out what genotypes Joshua and Bella must have. Write their genotypes next to their symbols in the pedigree.
6. Work with the cards to figure out the genotypes of all other family members. Fill in each person's genotype next to his or her symbol in the pedigree. If more than one genotype is possible, write in both genotypes.

Analyze and Conclude

1. **Interpreting Data** What were the possible genotypes of Joshua's parents? What were the genotypes of Bella's parents?
2. **Predicting** Joshua also has a brother. What is the probability that he has cystic fibrosis? Explain.
3. **Communicating** Imagine that you are a genetic counselor. A couple asks why you need information about many generations of their families to draw conclusions about a hereditary condition. Write an explanation you can give to them.

More to Explore

Review the pedigree that you just studied. What data suggest that the traits are not sex-linked? Explain.

Section 3

Tech & Design

Advances in Genetics

Reading Preview

Key Concepts

- What are three ways of producing organisms with desired traits?
- What is the goal of the Human Genome Project?

Key Terms

- selective breeding
- inbreeding • hybridization
- clone • genetic engineering
- gene therapy • genome

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a question for each heading. As you read, write answers to your questions.

Advances in Genetics

Question	Answer
What is selective breeding?	Selective breeding is . . .

Lab zone Discover Activity

What Do Fingerprints Reveal?

1. Label a sheet of paper with your name. Then roll one of your fingers from side to side on an ink pad. Make a fingerprint by carefully rolling your inked finger on the paper.
2. Divide into groups. Each group should choose one member to use the same finger to make a second fingerprint on a sheet of paper. Leave the paper unlabeled.
3. Exchange your group's fingerprints with those from another group. Compare each labeled fingerprint with the fingerprint on the unlabeled paper. Decide whose fingerprint it is.
4. Wash your hands after completing this activity.

Think It Over

Observing Why are fingerprints used to identify people?

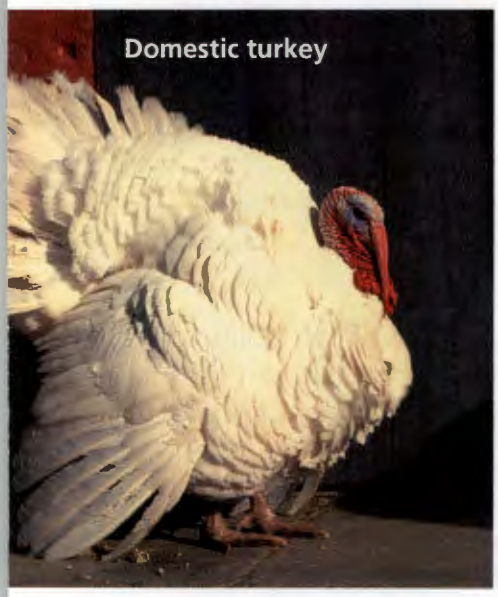
Would you like to have your picture taken with a 9,000-year-old family member? Adrian Targett, a history teacher in the village of Cheddar in England, has actually done that. All that's left of his ancient relative, known as "Cheddar Man," is a skeleton. The skeleton was discovered in a cave near the village. DNA analysis indicates that Targett and Cheddar Man are relatives.

Like your fingerprints, your DNA is different from everyone else's. Because of advances in genetics, DNA evidence can show many things, such as family relationships.

FIGURE 12
Distant Relatives
Adrian Targett visits his distant relative, Cheddar Man. Unfortunately, Cheddar Man cannot respond to questions about life 9,000 years ago.

FIGURE 13
Inbreeding
Turkeys such as the one with white feathers were developed by inbreeding. Breeders started with wild turkeys.

Wild turkey



Domestic turkey

Selective Breeding

Genetic techniques have enabled people to produce organisms with desirable traits. **Selective breeding, cloning, and genetic engineering are three methods for developing organisms with desirable traits.**

The process of selecting organisms with desired traits to be parents of the next generation is called **selective breeding**. Thousands of years ago, in what is now Mexico, the food that we call corn was developed in this way. Every year, farmers saved seeds from the healthiest plants that produced the best food. In the spring, they planted those seeds. By repeating this process over and over, farmers developed plants that produced better corn. People have used selective breeding with many different plants and animals. Two selective breeding techniques are inbreeding and hybridization.

Inbreeding The technique of **inbreeding** involves crossing two individuals that have similar characteristics. For example, suppose a male and a female turkey are both plump and grow quickly. Their offspring will probably also have those desirable qualities. Inbred organisms have alleles that are very similar to those of their parents.

Inbred organisms are genetically very similar. Therefore, inbreeding increases the probability that organisms may inherit alleles that lead to genetic disorders. For example, inherited hip problems are common in many breeds of dogs.

Hybridization In **hybridization** (hy brid ih ZAY shun), breeders cross two genetically different individuals. The hybrid organism that results is bred to have the best traits from both parents. For example, a farmer might cross corn that produces many kernels with corn that is resistant to disease. The result might be a hybrid corn plant with both of the desired traits.

Reading Checkpoint **What is the goal of hybridization?**

FIGURE 14
Hybridization
McIntosh and Red Delicious apples were crossed to produce Empire apples.
Applying Concepts *What desirable traits might breeders have been trying to produce?*

Math Analyzing Data

Changing Rice Production

The graph shows how worldwide rice production changed between 1965 and 2000. New, hybrid varieties of rice plants are one factor that has affected the amount of rice produced.

1. **Reading Graphs** According to the graph, how did rice production change between 1965 and 2000?
2. **Reading Graphs** How many metric tons of rice per hectare were produced in 1965? How many were produced in 2000?
3. **Calculating** Calculate the approximate difference between rice production in 1965 and 2000.

4. **Developing Hypotheses** What factors besides new varieties of plants might help account for the difference in rice production between 1965 and 2000?

Cloning

For some organisms, a technique called cloning can be used to produce offspring with desired traits. A **clone** is an organism that has exactly the same genes as the organism from which it was produced. It isn't hard to clone some kinds of plants, such as an African violet. Just cut a stem from one plant, and put the stem in soil. Water it, and soon you will have a whole new plant. The new plant is genetically identical to the plant from which the stem was cut.

Researchers have also cloned animals such as sheep and pigs. The methods for cloning these animals are complex. They involve taking the nucleus of an animal's body cell and using that nucleus to produce a new animal.

Reading Checkpoint **How can a clone of a plant be produced?**

FIGURE 15
Cloned Goats
These goats were produced by cloning.

Genetic Engineering

Geneticists have developed another powerful technique for producing organisms with desired traits. In this process, called **genetic engineering**, genes from one organism are transferred into the DNA of another organism. Genetic engineering can produce medicines and improve food crops.

Genetic Engineering in Bacteria One type of genetically engineered bacteria produces a protein called insulin. Injections of insulin are needed by many people with diabetes. Recall that bacteria have a single DNA molecule in the cytoplasm. Some bacterial cells also contain small circular pieces of DNA called plasmids. In Figure 16, you can see how scientists insert the DNA for a human gene into the plasmid of a bacterium.

FIGURE 16

Genetic Engineering

Scientists use genetic engineering to create bacterial cells that produce important human proteins such as insulin.

Interpreting Diagrams *How does a human insulin gene become part of a plasmid?*

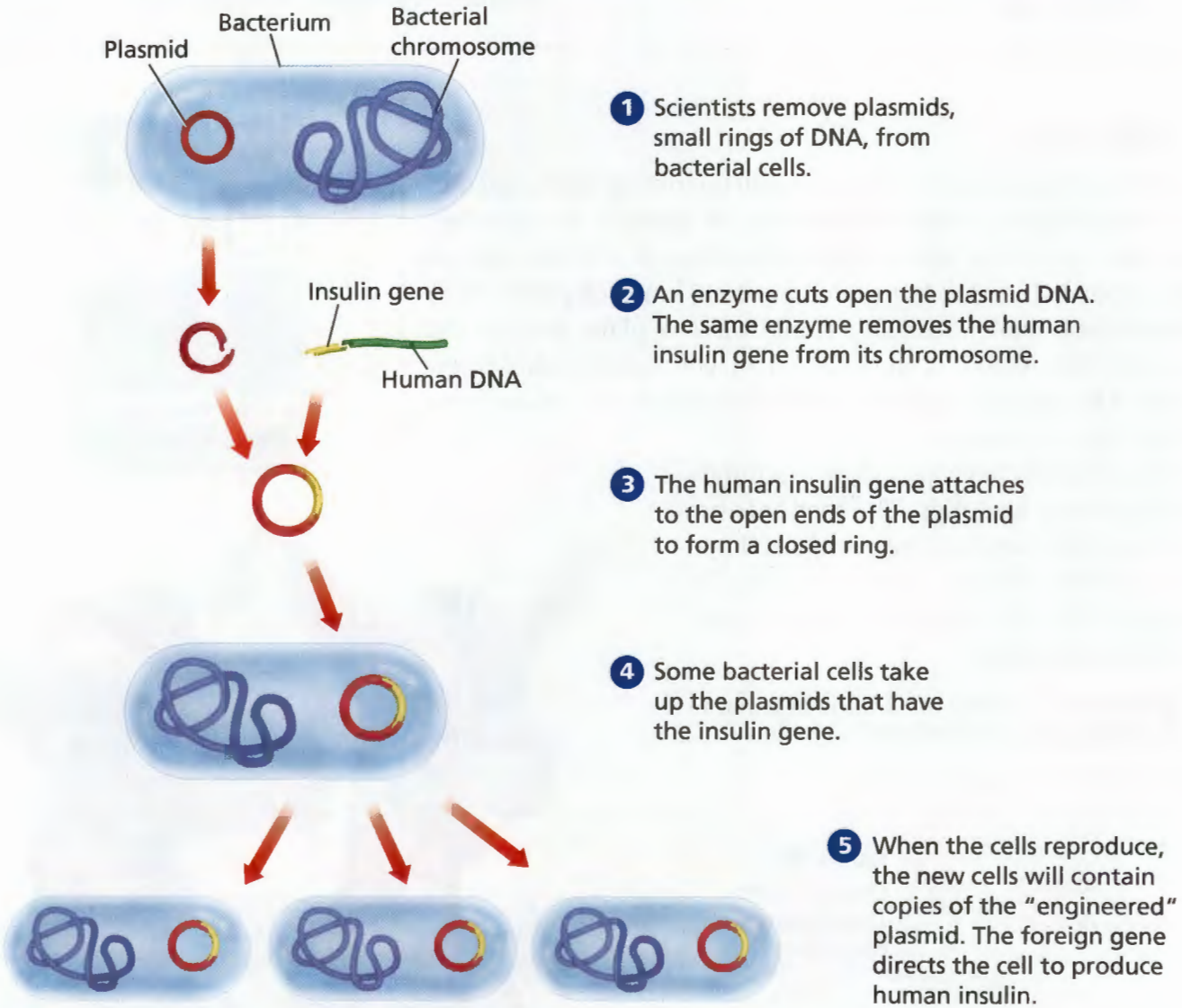


FIGURE 17
Genetically Engineered Fish
The bright red zebra danios are the result of genetic engineering.

Once the gene is inserted into the plasmid, the bacterial cell and all its offspring will contain this human gene. As a result, the bacteria produce the protein that the human gene codes for—in this case, insulin. Because bacteria reproduce quickly, large amounts of insulin can be produced in a short time.

Genetic Engineering in Other Organisms Scientists can also use genetic engineering techniques to insert genes into animals. For example, human genes can be inserted into the cells of cows. The cows then produce the human protein for which the gene codes in their milk. Scientists have used this technique to produce the blood clotting protein needed by people with hemophilia.

Genes have also been inserted into the cells of plants, such as tomatoes and rice. Some of the genes enable the plants to survive in cold temperatures or in poor soil. Other genetically engineered crops can resist insect pests.

Gene Therapy Someday it may be possible to use genetic engineering to correct some genetic disorders in humans. This process, called **gene therapy**, will involve inserting copies of a gene directly into a person's cells. For example, doctors may be able to treat hemophilia by replacing the defective allele on the X chromosome. The person's blood would then clot normally.

Concerns About Genetic Engineering Some people are concerned about the long-term effects of genetic engineering. For example, some people think that genetically engineered crops may not be entirely safe. People fear that these crops may harm the environment or cause health problems in humans. To address such concerns, scientists are trying to learn more about the effects of genetic engineering.

Reading Checkpoint **How do genetic engineering techniques enable scientists to produce clotting proteins?**

Go Online
SCILINKS NSTA
For: Links on genetic engineering
Visit: www.SciLinks.org
Web Code: scn-0343

Lab zone Skills Activity

Communicating

Suppose you work for a drug company that uses genetically engineered bacteria to produce insulin. Write an advertisement for the drug that includes a simplified explanation of how the drug is produced.

Learning About Human Genetics

Recent advances have enabled scientists to learn a great deal about human genetics. The Human Genome Project and DNA fingerprinting are two applications of this new knowledge.

FIGURE 18
The Human Genome Project
Scientists on the Human Genome Project continue to study human DNA.

The Human Genome Project Imagine trying to crack a code that is 6 billion letters long. That's exactly what the scientists working on the Human Genome Project did. A **genome** is all the DNA in one cell of an organism. **The main goal of the Human Genome Project was to identify the DNA sequence of every gene in the human genome.** In May 2006, the last chromosome in the human genome, chromosome 1, was sequenced. Scientists estimate that human DNA has between 20,000 and 25,000 genes. Analysis of the human genome, such as determining the exact location and function of each gene, could take several decades to complete.

DNA Fingerprinting DNA technology used in the Human Genome Project can also identify people and show whether people are related. DNA from a person's cells is broken down into small pieces, or fragments. Selected fragments are used to produce a pattern called a DNA fingerprint. Except for identical twins, no two people have exactly the same DNA fingerprint. You will learn more about DNA fingerprinting in Technology and Society.

Reading Checkpoint **About how many genes are in the human genome?**

Section 3 Assessment

Target Reading Skill **Asking Questions** Work with a partner to check your answers in your graphic organizer.

Reviewing Key Concepts

1. a. **Listing** List three methods that scientists can use to develop organisms with desirable traits.
   b. **Describing** Briefly describe each method.
   c. **Applying Concepts** Lupita has a houseplant. Which method would be the best way of producing a similar plant for a friend? Explain your answer.
2. a. **Defining** What is a genome?
   b. **Explaining** What is the Human Genome Project?
   c. **Relating Cause and Effect** How might knowledge gained from the Human Genome Project be used in gene therapy?

Lab zone **At-Home Activity**

Food and Selective Breeding Go to a grocery store with a parent or other family member. Discuss how fruits and vegetables have been produced by selective breeding. Choose a fruit or vegetable, and identify the traits that make it valuable.

Lab zone Skills Lab

Guilty or Innocent?

Problem

A crime scene may contain hair, skin, or blood from a criminal. These materials all contain DNA that can be used to make a DNA fingerprint. A DNA fingerprint, which consists of a series of bands, is something like a bar code. How can a DNA fingerprint identify individuals?

Skills Focus

drawing conclusions, inferring

Materials

- 4–6 bar codes
- hand lens

Procedure

1. Look at the photograph of DNA band patterns shown at right. Each person's DNA produces a unique pattern of these bands.
2. Now look at the Universal Product Code, also called a bar code, shown below the DNA bands. A bar code can be used as a model of a DNA band pattern. Compare the bar code with the DNA bands to see what they have in common. Record your observations.
3. Suppose that a burglary has taken place, and you're the detective leading the investigation. Your teacher will give you a bar code that represents DNA from blood found at the crime scene. You arrange to have DNA samples taken from several suspects. Write a sentence describing what you will look for as you try to match each suspect's DNA to the DNA sample from the crime scene.
4. You will now be given bar codes representing DNA samples taken from the suspects. Compare those bar codes with the bar code that represents DNA from the crime scene.
5. Use your comparisons to determine whether any of the suspects was present at the crime scene.

Analyze and Conclude

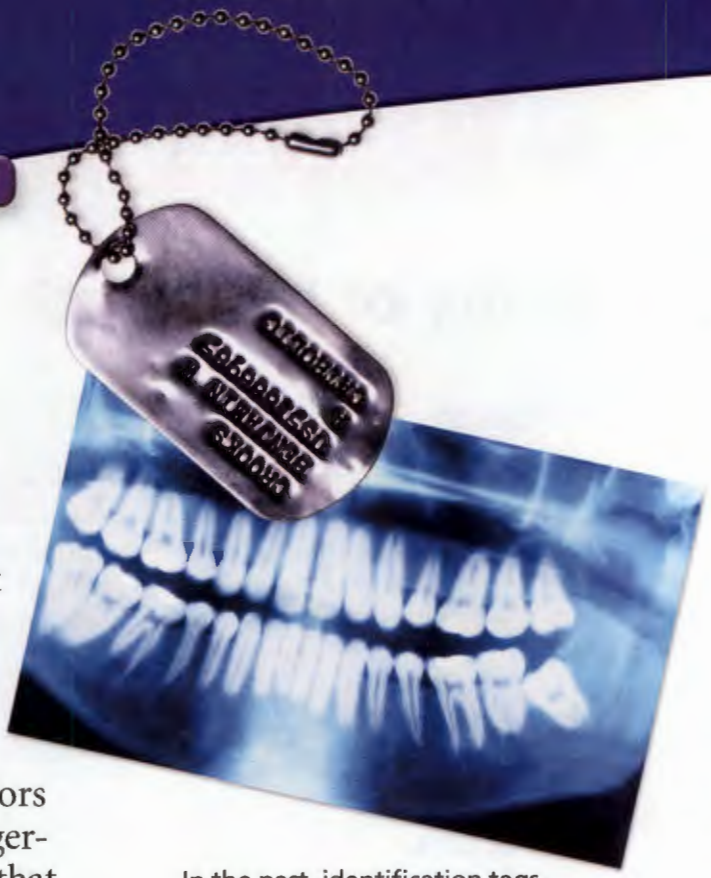
1. **Drawing Conclusions** Based on your findings, were any of the suspects present at the crime scene? Support your conclusion with specific evidence.
2. **Inferring** Why do people's DNA patterns differ so greatly?
3. **Drawing Conclusions** How would your conclusions be affected if you learned that the suspect whose DNA matched the evidence had an identical twin?
4. **Communicating** Suppose you are a defense lawyer. DNA evidence indicates that the bloodstain at the scene of a crime belongs to your client. Do you think this DNA evidence should be enough to convict your client? Write a speech you might give to the jury in defense of your client.

More to Explore

Do you think the DNA fingerprints of a parent and a child would show any similarities? Explain your thinking.

DNA Fingerprinting

What do you have that no one else has? Unless you are an identical twin, your DNA is unique. Because one person's DNA is like no one else's, it can be used to produce genetic "fingerprints." These fingerprints can tie a person to the scene of a crime. They can prevent the wrong person from going to jail. They can also be used to identify skeletal remains. Today, soldiers and sailors give blood and saliva samples so their DNA fingerprints can be saved. Like the identification tags that soldiers wear, DNA records can be used to identify the bodies of unknown soldiers or civilians.



In the past, identification tags and dental records were the main methods for identifying skeletal remains.

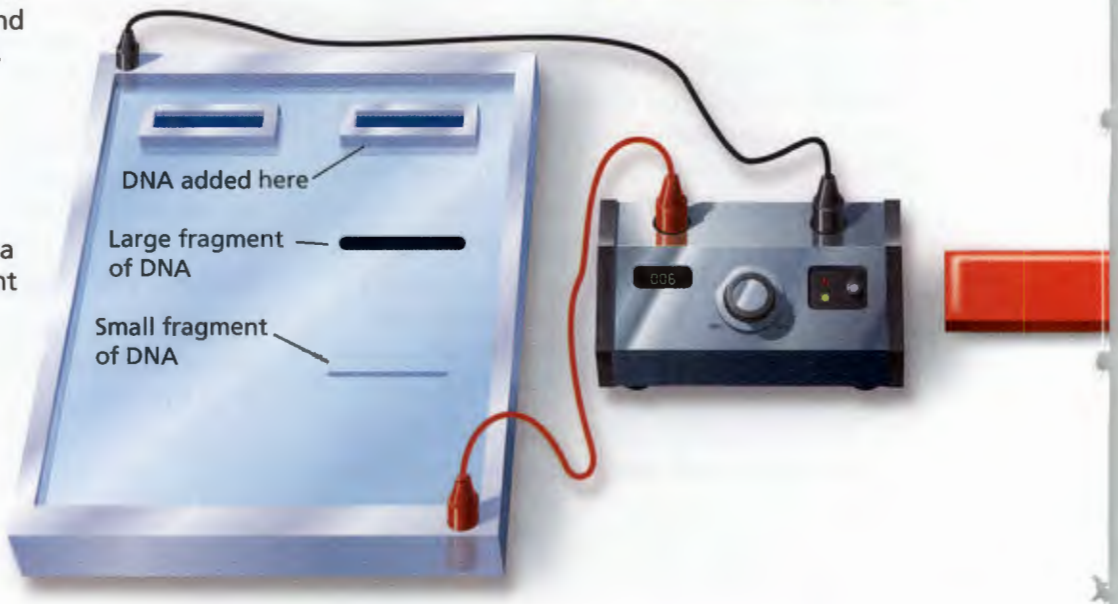
TTCGAATTCGAATTCTGAATTCTAGAATTCGAA

TTCG | AATTCG | AATTCTG | AATTCTAG | AATTCGAA

4 bases | 6 bases | 7 bases | 8 bases | 8 bases

This enzyme cuts the DNA every time it encounters the DNA sequence GAATTC.

1 After a sample of DNA is extracted from the body, an enzyme cuts the DNA strand into several smaller pieces.



2 The cut-up DNA fragments are loaded into a gel that uses electric current to separate fragments. Larger fragments of DNA move through the gel more slowly than the smaller fragments.

Analyzing DNA

In one method of DNA analysis, DNA from saliva, blood, bones, teeth, or other fluids or tissues is taken from cells. Special enzymes are added to cut the DNA into small pieces. Selected pieces are put into a machine that runs an electric current through the DNA and sorts the pieces by size. The DNA then gets stained and photographed. When developed, a unique banded pattern, similar to a product bar code, is revealed. The pattern can be compared to other samples of DNA to determine a match.

Limitations of DNA Fingerprinting

Like all technology, DNA fingerprinting has its limitations. DNA is very fragile and the films produced can be difficult to read if the DNA samples are old. In rare instances, DNA from the people testing the samples can become mixed in with the test samples and produce inaccurate results. DNA testing is also time consuming and expensive.

▲ Scientist reading a DNA fingerprint

3 Once the DNA fragments have separated, the gel is stained. The unique banded pattern is a DNA fingerprint.

Weigh the Impact

1. Identify the Need
Make a list of at least five situations in which DNA fingerprinting could be useful.

2. Research
Research the situations you listed in Question 1 to find out if DNA analysis is or can be used in each.

3. Write
Choose one application of DNA analysis and write one or two paragraphs to explain when the application can be used.

Go Online
PHSchool.com

For: More on DNA fingerprinting
Visit: PHSchool.com
Web Code: ceh-3040

Chapter 5

Study Guide

The BIG Idea **Science and Technology** Karyotyping, hybridization, cloning, genetic engineering, the Human Genome Project, and DNA fingerprinting are all science and technology applications that have advanced the study of genetics.

1 Human Inheritance

Key Concepts

- Some human traits are controlled by single genes with two alleles, and others by single genes with multiple alleles. Still other traits are controlled by many genes that act together.
- The sex chromosomes carry genes that determine whether a person is male or female. They also carry genes that determine other traits.
- Many of a person's characteristics are determined by an interaction between genes and the environment.

Key Terms

multiple alleles
sex chromosomes
sex-linked gene
carrier

2 Human Genetic Disorders

Key Concepts

- Some genetic disorders are caused by mutations in the DNA of genes. Other disorders are caused by changes in the overall structure or number of chromosomes.
- One important tool that geneticists use to trace the inheritance of traits in humans is a pedigree.
- Today doctors use tools such as karyotypes to help detect genetic disorders. People with genetic disorders are helped through medical care, education, job training, and other methods.

Key Terms

genetic disorder
pedigree
karyotype

3 Advances in Genetics

Key Concepts

- Selective breeding, cloning, and genetic engineering are three methods for developing organisms with desirable traits.
- The main goal of the Human Genome Project has been to identify the DNA sequence of every gene in the human genome.

Key Terms

• selective breeding • inbreeding
• hybridization • clone • genetic engineering
• gene therapy • genome

Review and Assessment

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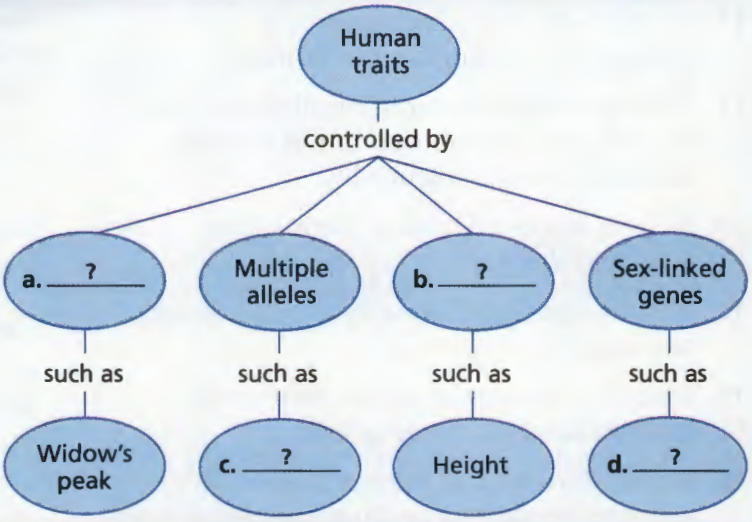
Organizing Information

Concept Mapping Copy the concept map about human traits onto a separate sheet of paper. Then complete it and add a title. (For more on Concept Mapping, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

1. A human trait that is controlled by a single gene with multiple alleles is
   a. dimples. **b.** blood type.
   c. height. **d.** skin color.
2. A sex-linked disorder is
   a. cystic fibrosis.
   b. sickle-cell disease.
   c. hemophilia.
   d. Down syndrome.
3. Which of the following would most likely be used to diagnose Down syndrome?
   a. a karyotype
   b. a pedigree
   c. a blood-clotting test
   d. a Punnett square
4. Inserting a human gene into a bacterial plasmid is an example of
   a. inbreeding.
   b. selective breeding.
   c. DNA fingerprinting.
   d. genetic engineering.
5. An organism that has the same genes as the organism from which it was produced is called a
   a. clone. **b.** hybrid.
   c. genome. **d.** pedigree.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. A widow's peak is a human trait that is controlled by a single gene.
7. A male inherits two X chromosomes.
8. A karyotype tracks which members of a family have a trait.
9. Hybridization is the crossing of two genetically similar organisms.
10. A genome is all the DNA in one cell of an organism.

Writing in Science

Fact Sheet You are a scientist in a cloning lab. Write a fact sheet that explains what the process of cloning involves. Describe at least one example.

Discovery CHANNEL SCHOOL

Modern Genetics
Video Preview
Video Field Trip
Video Assessment

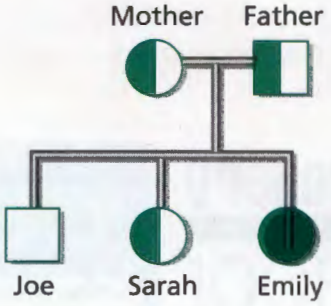
Review and Assessment

Checking Concepts

11. Explain why there are a wide variety of phenotypes for skin color in humans.
12. Traits controlled by recessive alleles on the X chromosome are more common in males than in females. Explain why.
13. What is sickle-cell disease? How is this disorder inherited?
14. What is a pedigree? How do geneticists use pedigrees?
15. Describe two ways in which people with genetic disorders can be helped.
16. Explain how a horse breeder might use selective breeding to produce horses that have golden coats.
17. Describe how gene therapy might be used in the future to treat a person with hemophilia.
18. What is the Human Genome Project?

Thinking Critically

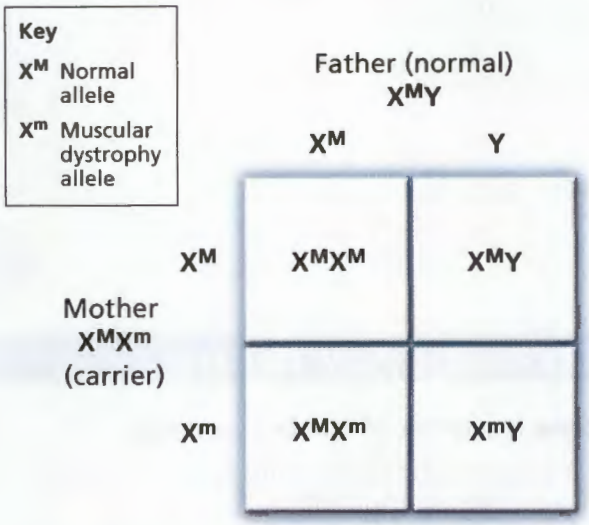
19. **Problem Solving** A woman with normal color vision has a colorblind daughter. What are the genotypes and phenotypes of both parents?
20. **Calculating** If a mother is a carrier of hemophilia and the father does not have hemophilia, what is the probability that their son will have the trait? Explain your answer.
21. **Interpreting Diagrams** The allele for cystic fibrosis is recessive. Identify which members of the family in the pedigree have cystic fibrosis and which are carriers.



Applying Skills

Use the Punnett square to answer Questions 22–24.

The Punnett square below shows how muscular dystrophy, a sex-linked recessive disorder, is inherited.



22. **Interpreting Data** What is the probability that a daughter of these parents will have muscular dystrophy? Explain your answer.
23. **Interpreting Data** What is the probability that a son of these parents will have muscular dystrophy? Explain your answer.
24. **Inferring** Is it possible for a woman to have muscular dystrophy? Why or why not?

Lab zone Chapter Project

Performance Assessment Present your display board to your class. Highlight important facts about the genetic trait you selected. Discuss the innovative designs you incorporated into the display board. In your presentation, highlight the interactive part of your project.

Standardized Test Prep

Test-Taking Tip

Interpreting Diagrams

If you are asked to interpret a pedigree diagram, first determine the trait that the pedigree shows. For example, the pedigree for Questions 3–4 shows the inheritance of sickle-cell disease. Remember that a circle represents a female and a square represents a male. Also look for a key that explains what the symbols in this particular pedigree show.

Use the pedigree for Questions 3–4 to answer the sample question below.

Sample Question

Which of the following is true for the first generation shown in the pedigree?

A Both the man and the woman have sickle-cell disease.
B Both the man and the woman are carriers of sickle-cell disease.
C Only the woman is a carrier of sickle-cell disease.
D Only the man is a carrier of sickle-cell disease.

Answer

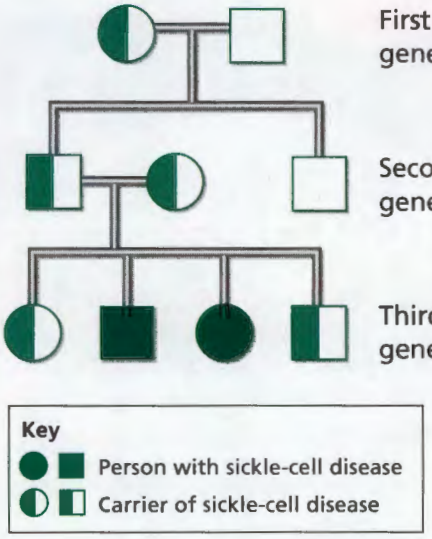
The correct answer is **C**. Since the circle is half shaded, the woman is a carrier.

Choose the letter of the best answer.

1. A woman is heterozygous for the trait of hemophilia. Her husband does not have hemophilia. What is the probability that their son will have hemophilia?
A 0%
B 25%
C 50%
D 100%

2. Down syndrome is an example of a genetic disorder in which
F one DNA base has been added.
G one DNA base has been deleted.
H one chromosome is substituted for another.
J an extra chromosome is added to a pair.

Use the pedigree to answer Questions 3–4.



3. How many people in the second generation have sickle-cell disease?
A none
B one person
C two people
D three people

4. Which statement is true about the third generation in the pedigree?
F No one has sickle-cell disease.
G Everyone has sickle-cell disease.
H Everyone has at least one allele for sickle-cell disease.
J No one has any alleles for sickle-cell disease.

5. To produce a human protein through genetic engineering, scientists use
A a bacterial gene inserted into a human chromosome.
B a human gene inserted into a plasmid.
C a bacterial gene inserted into a plasmid.
D a human gene inserted into a human chromosome.

Constructed Response

6. Explain why, for each pregnancy, human parents have a 50 percent probability of having a boy and a 50 percent probability of having a girl. Your answer should include the terms *X chromosome* and *Y chromosome*.