Chapter 6

Modern Genetics

CALIFORNIA Standards Preview

S 7.2 A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences. As a basis for understanding this concept:

b. Students know sexual reproduction produces offspring that inherit half their genes from each parent.

Framework Mitochondria DNA is derived solely from the mother, making possible the tracing of heritage from grandmothers to grandchildren with great certainty.

c. Students know an inherited trait can be determined by one or more genes.

d. Students know plant and animal cells contain many thousands of different genes and typically have two copies of every gene. The two copies (or alleles) of the gene may or may not be identical, and one may be dominant in determining the phenotype while the other is recessive.

e. Students know DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.

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

Video Preview
Discovery Channel School
Modern Genetics

S 7.2

Focus on the
BIG Idea

How are traits inherited in people?

Check What You Know

Suppose you have a friend who doesn't have freckles. Both of her biological parents have freckles. The allele for freckles is dominant. What can you infer about the genotype of your friend's parents? Explain your answer.

Build Science Vocabulary

The images shown here represent some of the Key Terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some Key Terms in this chapter.

Vocabulary Skill

High-Use Academic Words

High-use academic words are words that are used frequently in classrooms. You and your teachers use these words when you discuss the subjects you study. Look for the words in the table below as you read this chapter.

Word	Definition	Example Sentence
normal (NAWR muhl) p. 200	*adj.* Usual, typical, expected	Its normal to feel nervous a bout going to a new school.
structure (STRUK chur) p. 200	*n.* The way in which parts of something are connected	You have learned the basic structure of plant and animal cells.
affect (uh FEKT) p. 198	*v.* To influence; to produce a change in	Scientists are looking for ways to treat diseases that affect people.
technique (tek NEEK) p. 206	*n.* A special way of doing something, a method, a procedure	There are special techniques for balancing on a skateboard.

Apply It!

Choose the word that best completes each sentence.

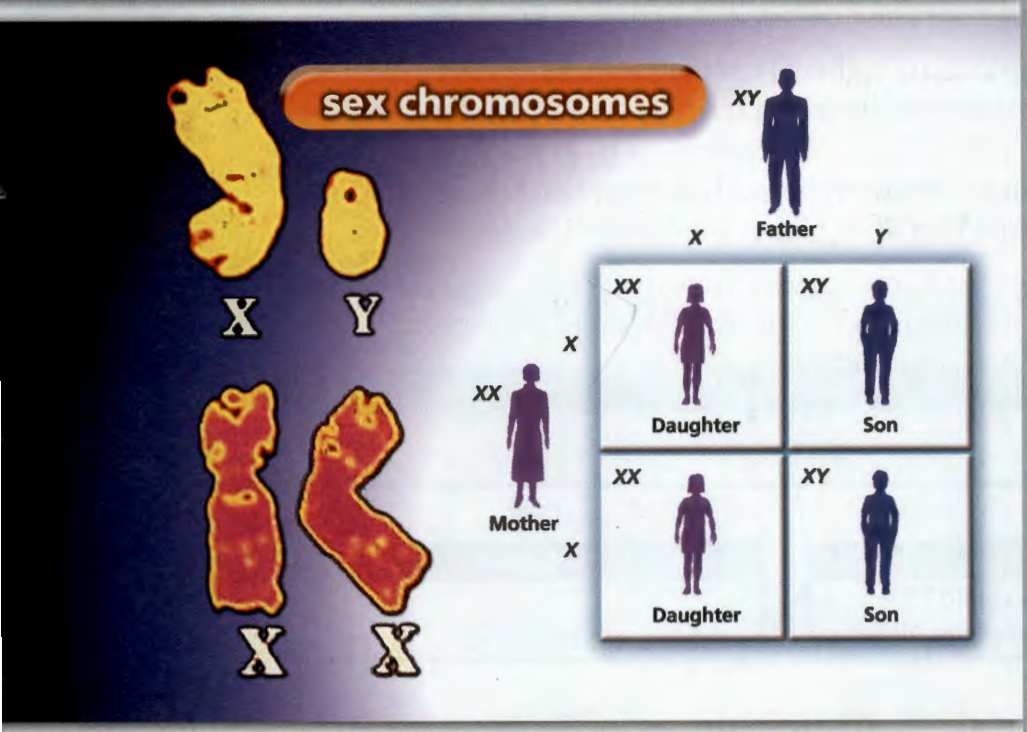
1. People's diets can _____ their health.
2. Doctors have developed a new _____ for doing heart surgery.
3. A(n) _____ body temperature in a human is about 37°C.

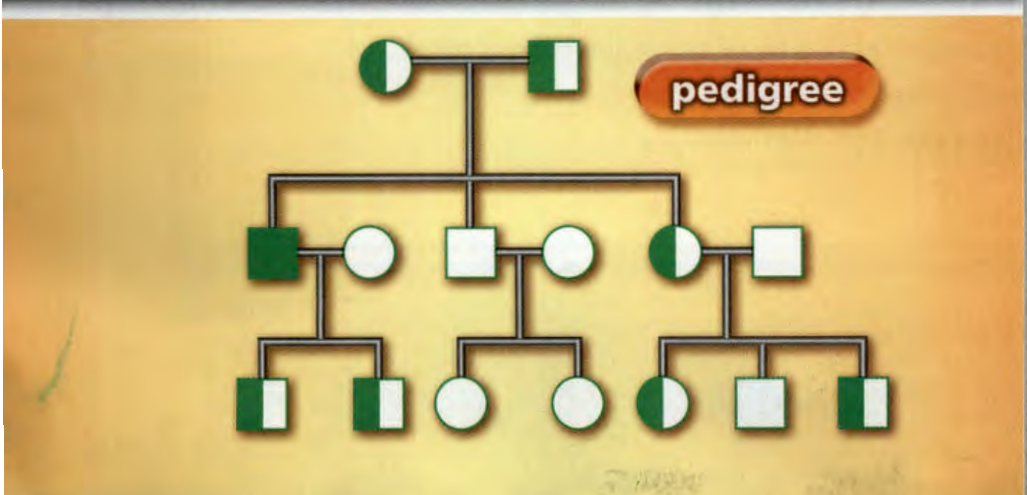
Chapter 6 Vocabulary

Section 1 (page 192)
multiple alleles
sex chromosomes
sex-linked gene
carrier

Section 2 (page 199)
genetic disorder
pedigree
karyotype

Section 3 (page 205)
selective breeding
inbreeding
hybridization
clone
genetic engineering
gene therapy
genome





Interactive Textbook

Build Science Vocabulary Online
Visit: PHSchool.com
Web Code: cvj-2060

How to Read Science

Reading Skill

Identify Main Ideas

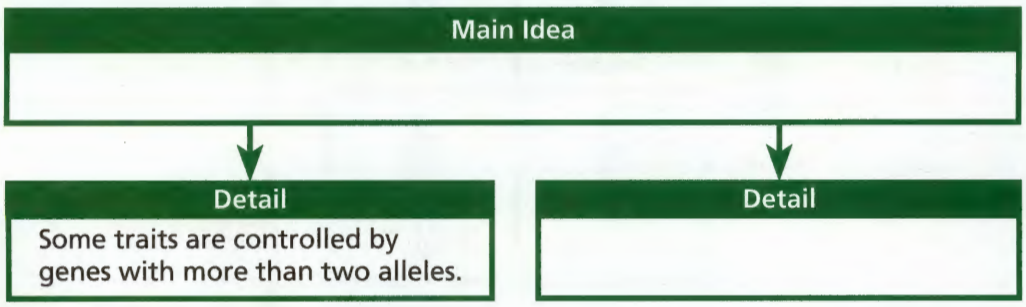
The main idea in a paragraph or section is the most important—or biggest—idea. Sometimes the main idea is stated directly in a sentence. Other times you have to figure it out on your own. The boldfaced Key Concept statements can help you identify main ideas.

The details in a paragraph or section support the main idea. Details are usually specific facts and examples that help readers understand the main idea.

Look for the main idea and details in the paragraph below.

> In human inheritance, there is not always a one-to-one relationship between gene and trait. For example, some traits, such as blood type, are controlled by genes with more than two alleles. Other traits, such as height, are controlled by many genes that act together to produce the trait.

After you have read the paragraph, copy the graphic organizer below. Complete it by filling in the main idea and missing detail.



Apply It!

Use your graphic organizer to answer the following questions.

1. What is the main idea of the paragraph?
2. What details support the main idea?

Lab zone

Standards Investigation

S 7.2.d

Teach Others About a Trait

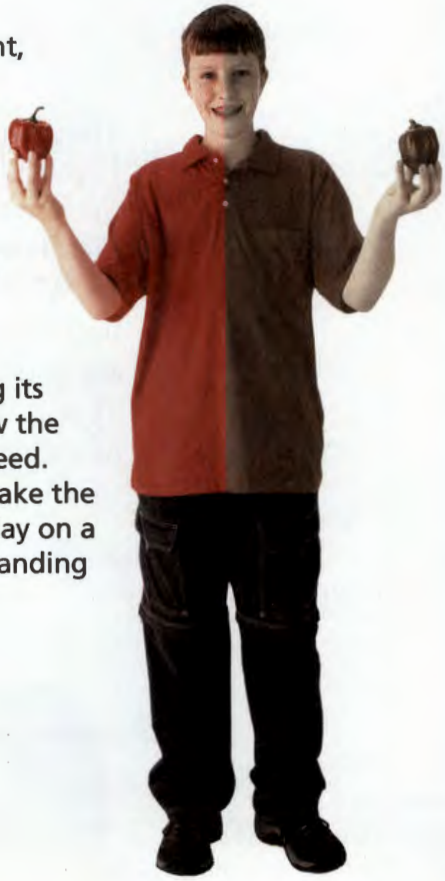
People inherit alleles for traits from their parents. Some traits, such as keen eyesight, are beneficial. Other traits, such as colorblindness, can present challenges. In this investigation, you will design a display to help teach younger children about a genetically inherited trait. You and your group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

Your Goal

To design and build an educational tool or display about genetically inherited traits 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

CALIFORNIA Standards Focus

S 7.2 A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences.

7.2.c. Students know an inherited trait can be determined by one or more genes.

- 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

Lab zone Standards Warm-Up

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

When Mendel experimented with peas, he studied traits that were controlled by genes with one dominant allele and one recessive allele. The inheritance of traits is rarely this simple. A single gene can have more than two alleles, or more than one gene can be involved. Sometimes, a single gene can affect more than one trait. Or, all of a gene's effects may not be visible or even known. Because patterns of inheritance can be complicated, there is not always a one-to-one correspondence between trait and gene.

In this section, you will learn about some patterns of human inheritance. **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 Several 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.

Whether your earlobes are free or attached is a trait controlled by a single gene with two alleles. A widow's peak is another. 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. 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.

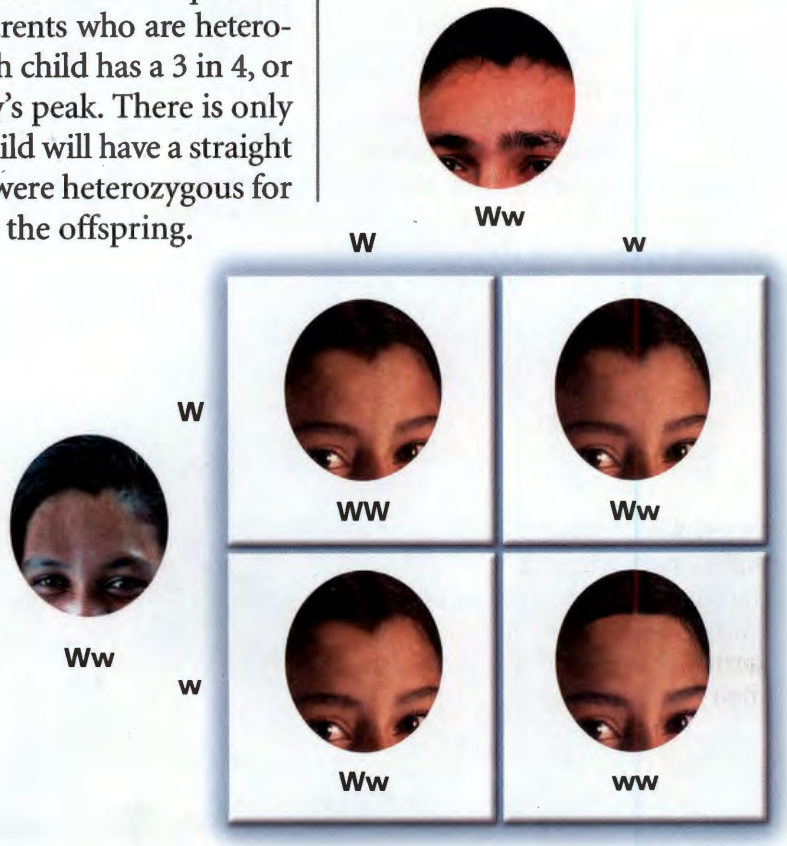


FIGURE 2
Widow's Peak Punnett Square
This Punnett square shows a cross between two parents with widow's peaks.
Interpreting Diagrams *What are the possible genotypes of the offspring? What percentage of the offspring will have each genotype?*

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.

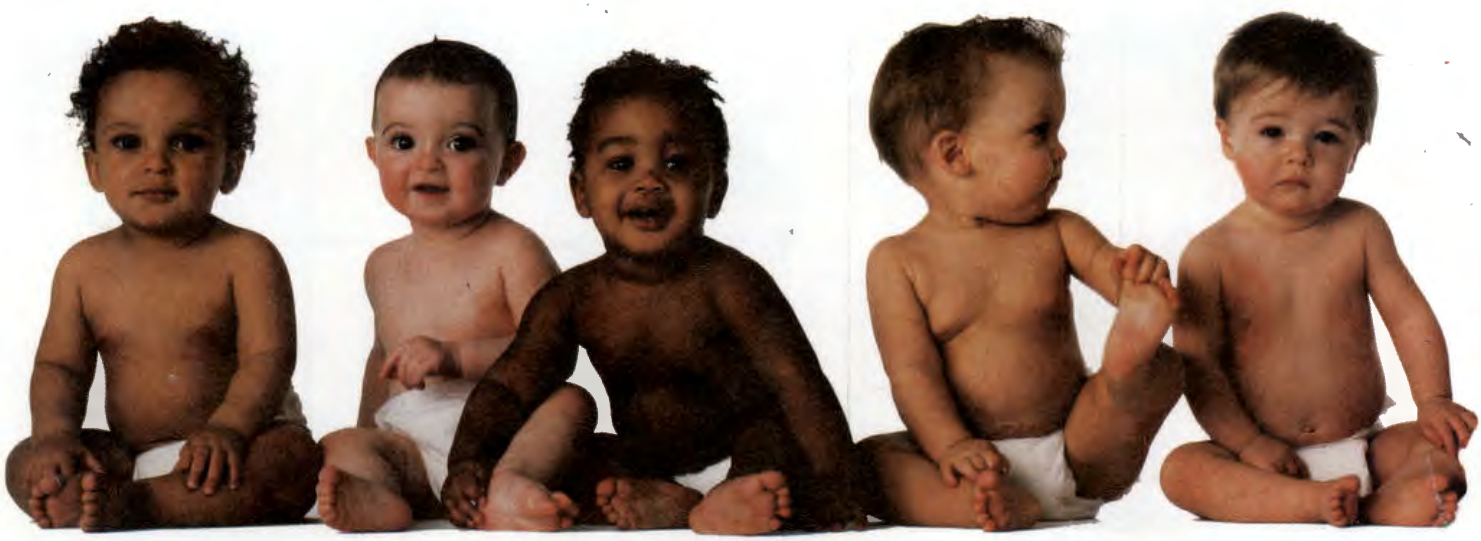
Human blood type is controlled by a gene with multiple alleles, as shown in Figure 3. There are four main blood types—A, B, AB, and O. Three alleles control the inheritance of blood types. The alleles for blood types A and B are codominant. The allele for blood type A is written as I^A. The allele for 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. Only people who inherit two i alleles have type O blood.

Traits Controlled by Many Genes

If you completed the Standards Warm-Up 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, eye, and hair color are other human traits that are controlled by multiple 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.



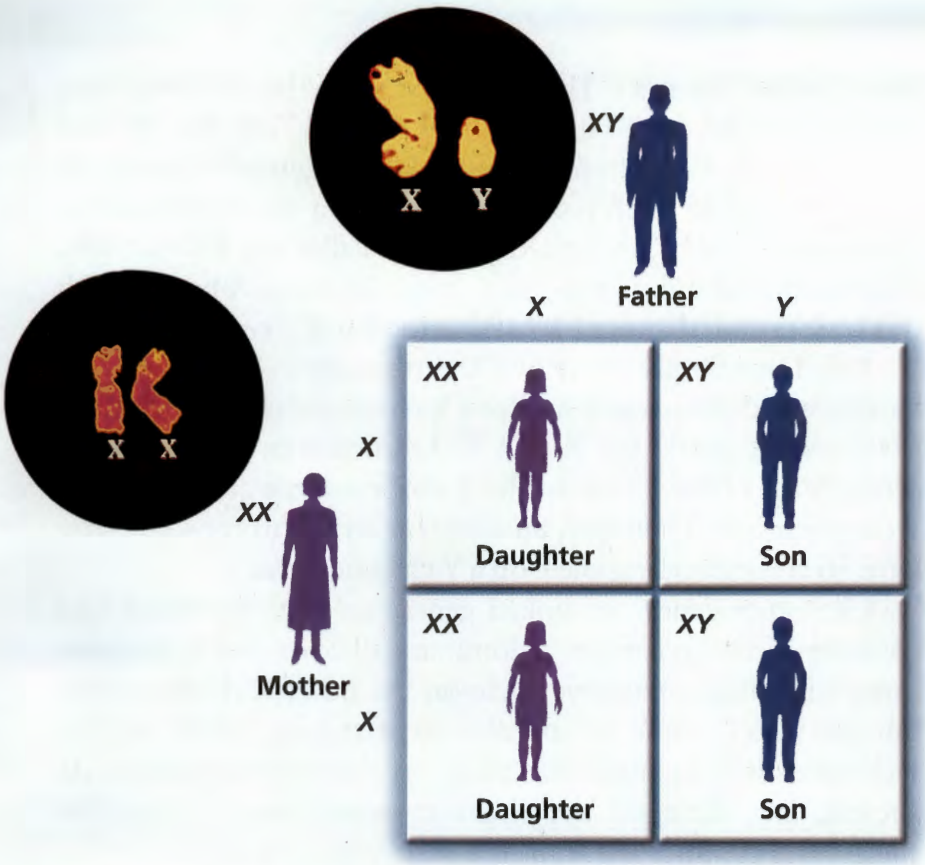


FIGURE 5
Male or Female?
As this Punnett square shows, there is a 50 percent probability that a child will be a girl and a 50 percent probability that a child will be a boy.
Interpreting Diagrams *What sex will the child be if a sperm with a Y chromosome fertilizes an egg?*

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, as you can see in Figure 5.

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.

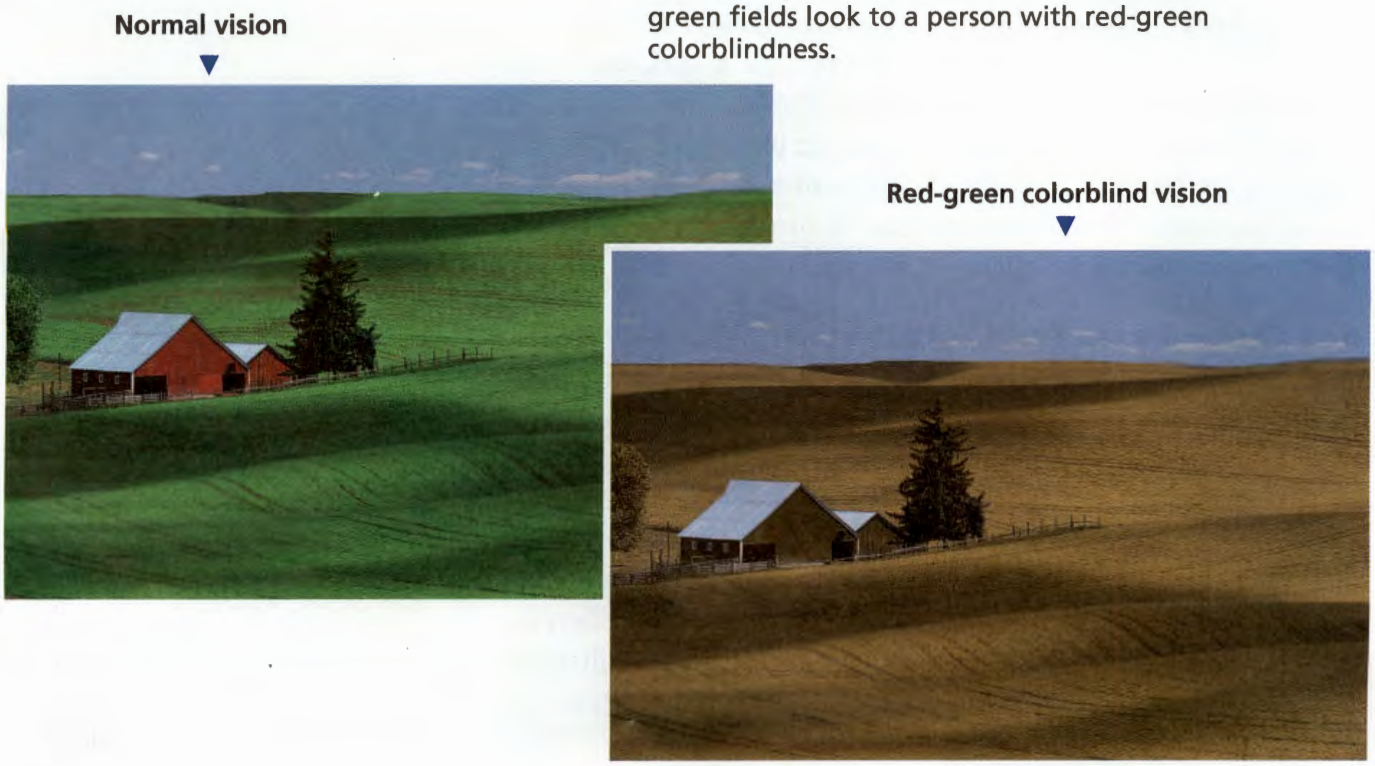
When a sperm cell with an X chromosome fertilizes an egg, the egg has two X chromosomes. The fertilized egg will develop into a girl. When a sperm with a Y chromosome fertilizes an egg, the egg has one X chromosome and one Y chromosome. The fertilized egg will develop into a boy.

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 much 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.

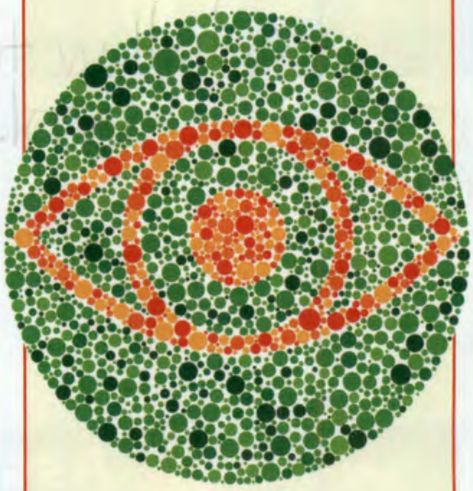
As you can see in Figure 7, there is a 25 percent probability that this couple will have a colorblind child. Notice that none of the couple's daughters will be colorblind. On the other hand, the sons have a 50 percent probability of being colorblind. For a female to be colorblind, she must inherit two 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?**

Lab zone Try This Activity

Seeing Red

In this activity, you will take a simple test to see if you have red-green colorblindness. Take a look at the diagram below. What do you see? Can you see an eye among the dots? If you do not see the eye, you cannot distinguish between red and green.



Inferring Based on the results of the test, what is your genotype for this trait?

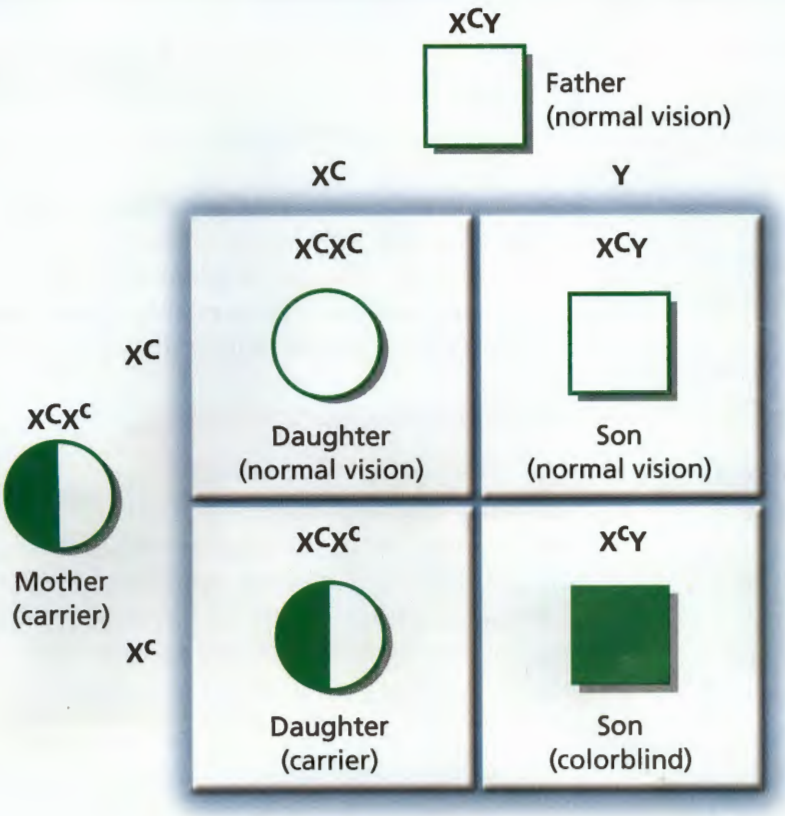


FIGURE 7
Colorblindness Punnett Square
Red-green colorblindness is a sex-linked trait. A girl who receives only one recessive allele (written X^c) for red-green colorblindness will not have the trait. However, a boy who receives one recessive allele will be colorblind.
Applying Concepts *What allele 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 an organism's surroundings—the environment. **Many of an organism'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. For example, 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

S 7.2, 7.2.c, E-LA: Reading 7.2.0, Writing 7.2.0

Target Reading Skill **Identify Main Ideas** Read the text following the heading Girl or Boy (page 195). Identify the main idea and two supporting details.

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

CALIFORNIA Standards Focus

S 7.2.d Students know plant and animal cells contain many thousands of different genes and typically have two copies of every gene. The two copies (or alleles) of the gene may or may not be identical, and one may be dominant in determining the phenotype while the other is recessive.

- 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

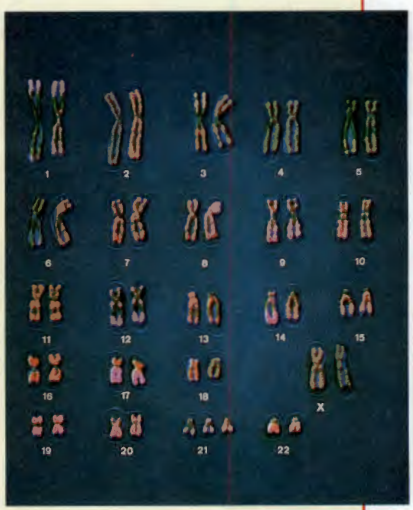
- genetic disorder
- pedigree
- karyotype

Lab zone Standards Warm-Up

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?

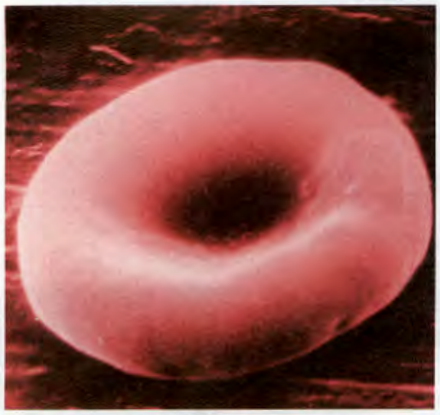


Think It Over

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 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. A **genetic disorder** is an abnormal condition that a person inherits through genes or chromosomes.

◀ Runners in the Special Olympics



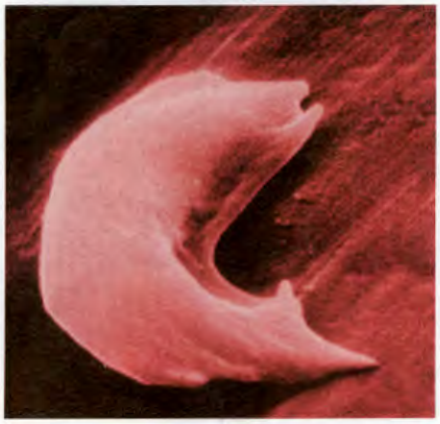


FIGURE 9
Sickle-Cell Disease
Normally, red blood cells are shaped like round disks (top). In a person with sickle-cell disease, red blood cells can become sickle-shaped (bottom).

Causes of Genetic Disorders

Recall that a person normally inherits two copies of a gene, one from each parent. But sometimes a person inherits an abnormal version of a gene that can lead to a disorder. (It is not accurate to say that someone has a *gene* for a disorder. Instead, a person has an *allele* for the trait.)

Some genetic disorders are caused by changes in the DNA of genes. Other disorders are caused by changes in the overall structure or number of chromosomes. Common genetic disorders include cystic fibrosis, sickle-cell disease, hemophilia, and Down syndrome.

Cystic Fibrosis Cystic fibrosis is a 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 sex-linked 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.

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.

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.

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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?*

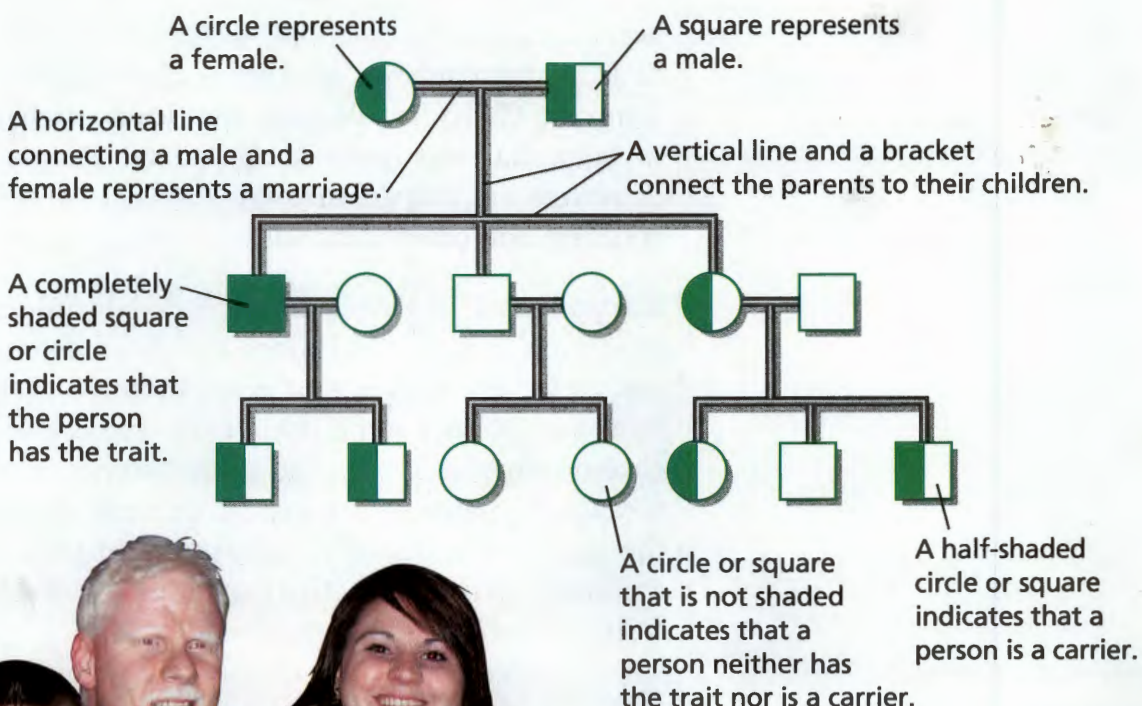
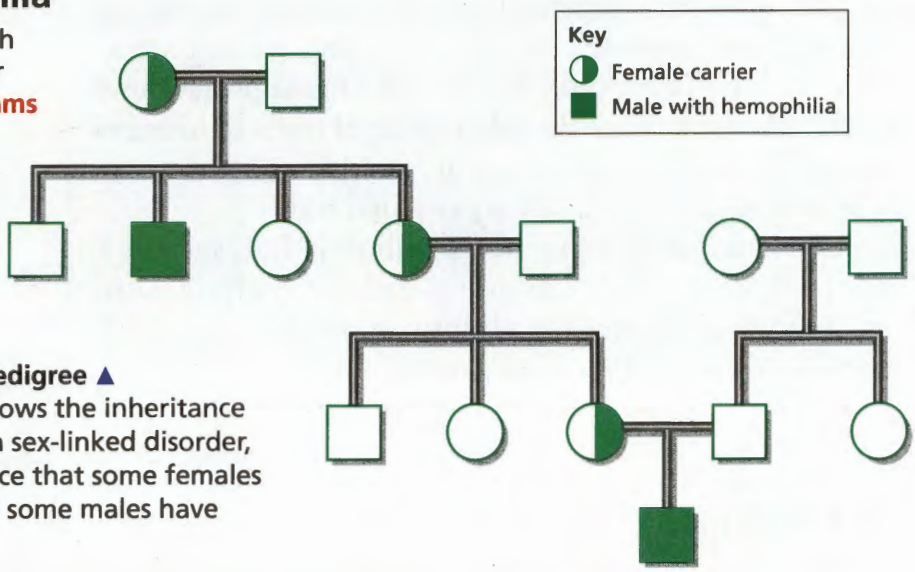


FIGURE 11

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

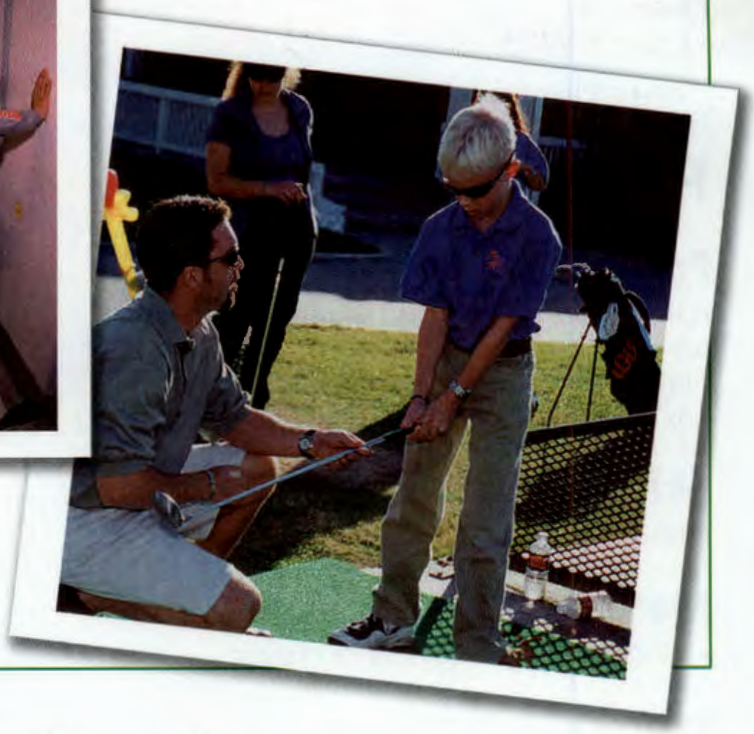
Years ago, doctors had only Punnett squares and pedigrees to help them predict whether a child might have a genetic disorder. **Today, doctors use tools such as karyotypes to help diagnose genetic disorders. People with genetic disorders are helped through medical care, education, job training, and other 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. The Standards Warm-Up activity on page 199 shows 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. Modifying an affected person's environment—for example, through medicine, diet, or education—can help manage some disorders. People with sickle-cell disease take folic acid, a vitamin, to help their bodies make red blood cells. Through education and job training, adults with Down syndrome can find work in many places. Fortunately, most genetic disorders do not prevent people from living active, productive lives.

Section 2 Assessment

S 7.2.d, E-LA: Reading 7.1.0, Writing 7.2.0

Vocabulary Skill **High-Use Academic Words** Use the words *effect* and *normal* to explain the relationship between hemophilia and blood-clotting.

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.

Family Puzzle

S 7.2.d

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.

Advances in Genetics

California Standards Focus

S 7.2.b Framework Mitochondria DNA is derived solely from the mother, making possible the tracing of heritage from grandmothers to grandchildren with great certainty.

S 7.2.e Students know DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.

- What are three ways of producing organisms with desired traits?
- What are two applications of DNA technology in human genetics?

Key Terms

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

Lab zone Standards Warm-Up

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

Inferring Why are fingerprints used to identify people? Would it be useful if DNA could be used to identify organisms?

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.

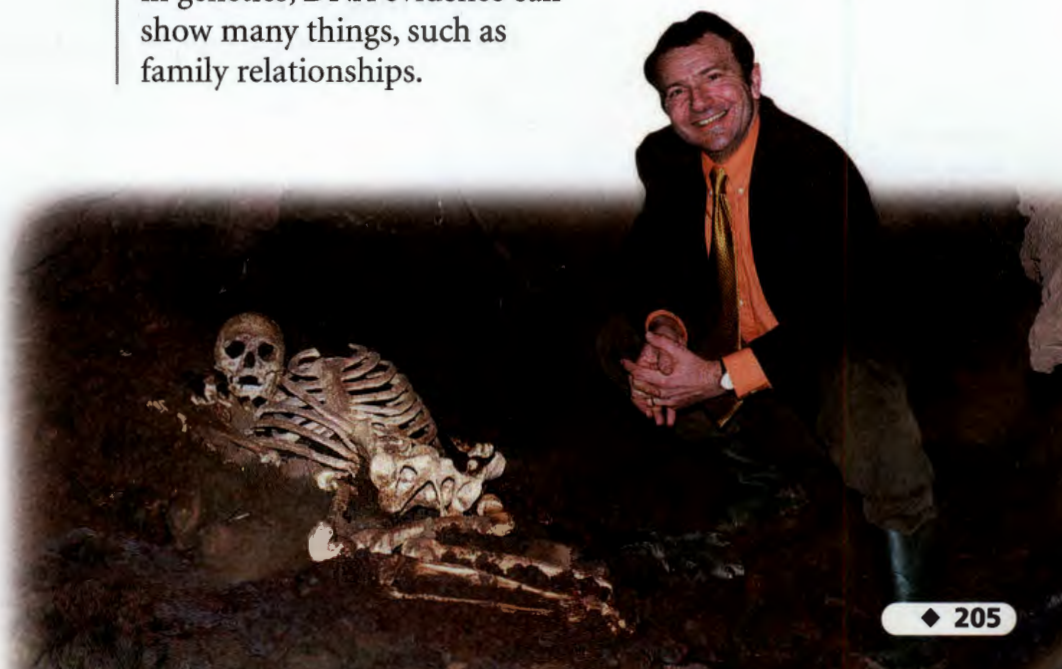


FIGURE 12
Distant Relatives
Adrian Targett visits his distant relative, Cheddar Man. Unfortunately, Cheddar Man cannot respond to questions about life 9,000 years ago.

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: Statistics, Data Analysis, and Probability 7.1.0

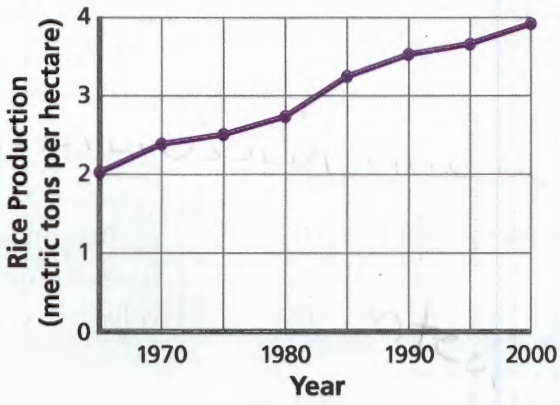
Math Analyzing Data

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 difference between rice production in 1965 and 2000.

Worldwide Rice Production



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.

Video Field Trip
Discovery Channel School
Modern Genetics

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. 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?*

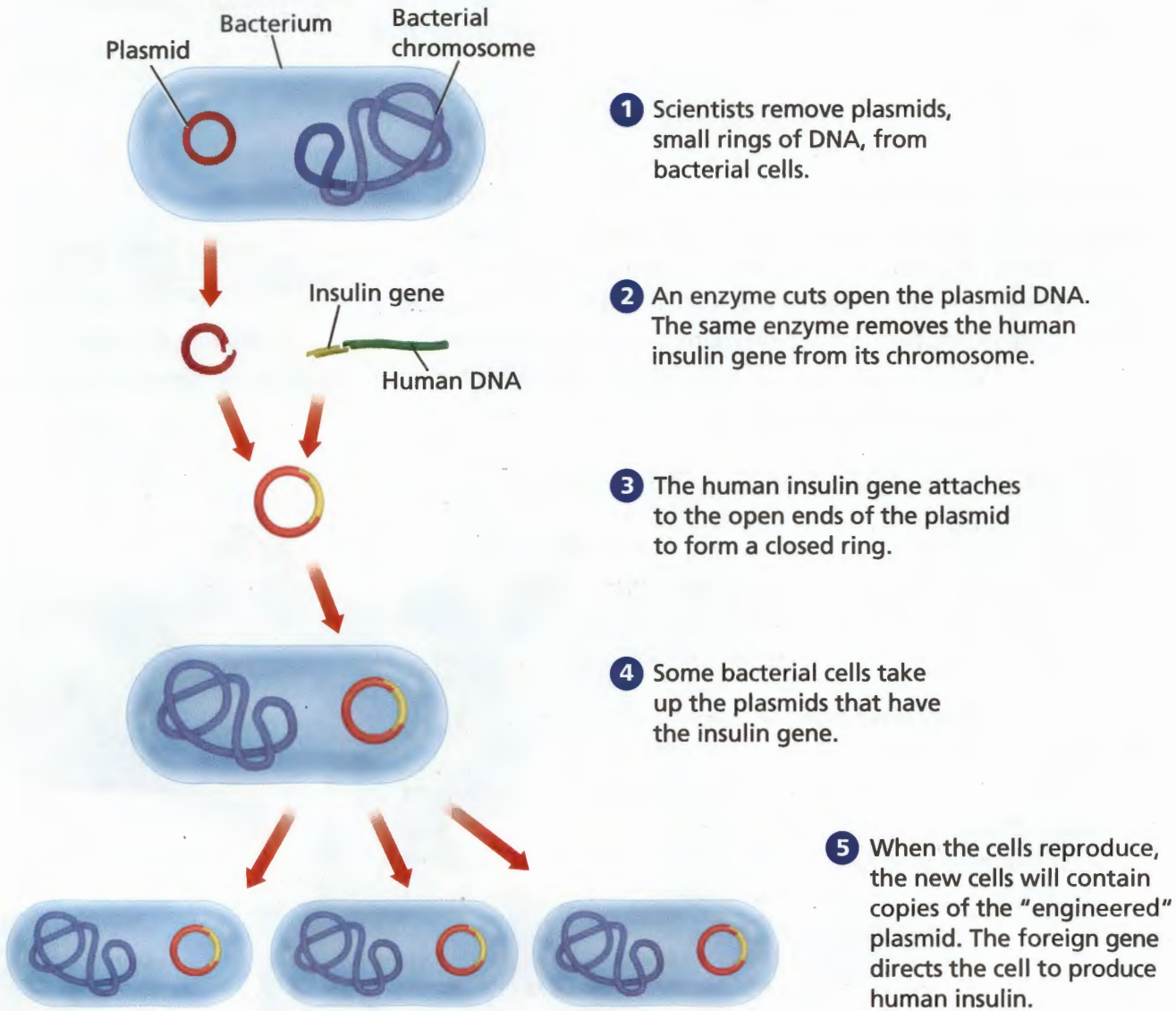


FIGURE 17
Genetically Engineered Fish
The bright red zebra danios are the result of genetic engineering.

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

Learning About Human Genetics

Applications of DNA technology include studying the human genome in detail and identifying people.

The Human Genome Project A **genome** is all the DNA in one cell of an organism. The main goal of a project called the Human Genome Project has been to identify the DNA sequence of every gene in the human genome. Scientists have learned that the DNA of humans has at least 30,000 genes. The average gene has about 3,000 bases. Scientists now know the DNA sequence of nearly every human gene.

DNA Fingerprinting DNA technology can also identify people and show whether people are related. Nuclear 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.

Scientists can also use mitochondrial DNA to determine a person's identity. Mitochondria contain their own DNA, which is inherited from the mother through the egg cell. This means that a child has virtually the same mitochondrial DNA as his or her mother. By analyzing mitochondrial DNA, it is possible to trace inheritance from grandmothers to grandchildren with great certainty. For example, mitochondrial DNA was used to establish the relationship between Cheddar Man and his descendant.

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

Section 3 Assessment

S 7.2.b Framework, 7.2.e
E-LA: Reading 7.1.0

Vocabulary Skill **High-Use Academic Words**
What is hybridization? Use the word *technique* in your answer.

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** Which method would be the best way of producing a plant similar to the one you already have? Explain.
2. **a.** **Reviewing** What are two applications of DNA technology?
   b. **Making Judgments** Do you think DNA fingerprinting would be useful in solving crimes? Explain your reasoning.

Lab zone At-Home Activity

Food and Selective Breeding Go to a grocery store with a 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?

S 7.2.e

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.

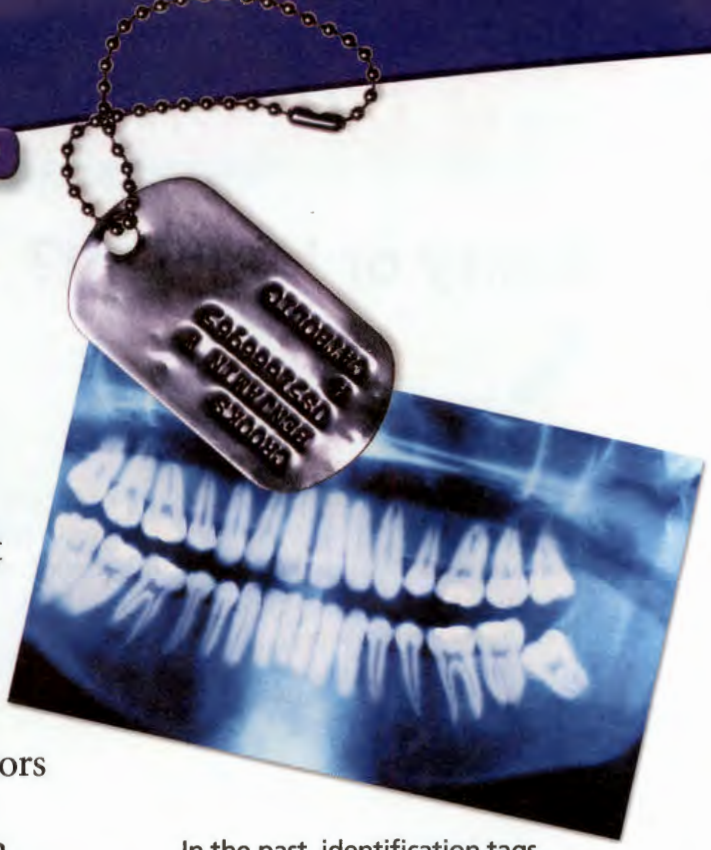
More to Explore

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

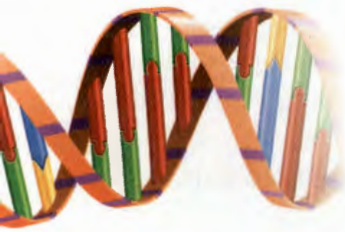
S 7.2.e

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

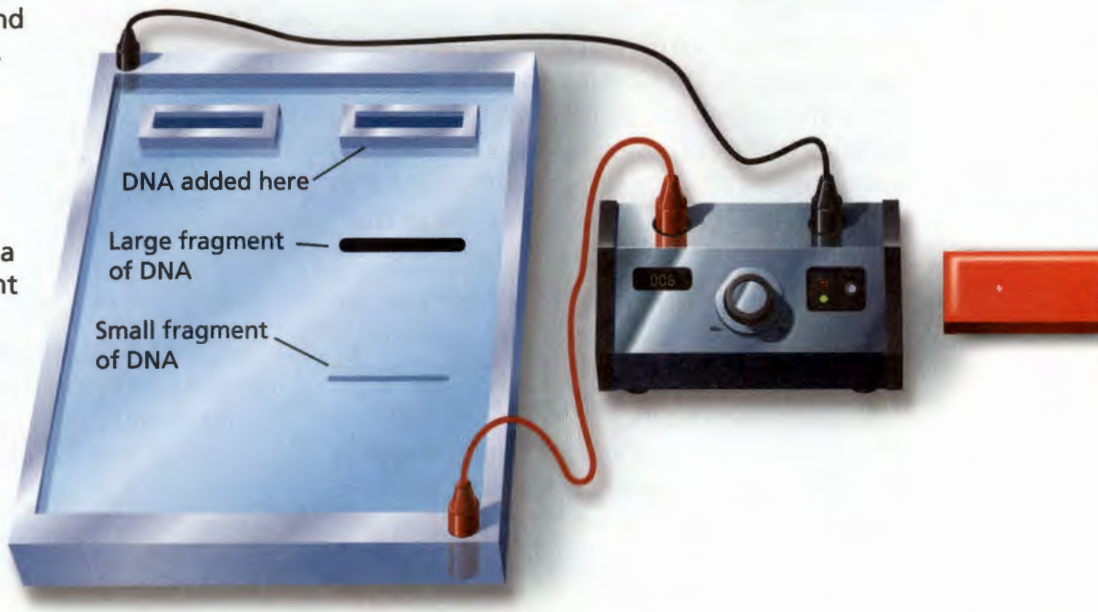
TTCG | AATTCG | AATTCTG | AATTCTAG | AATTCGAA

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.



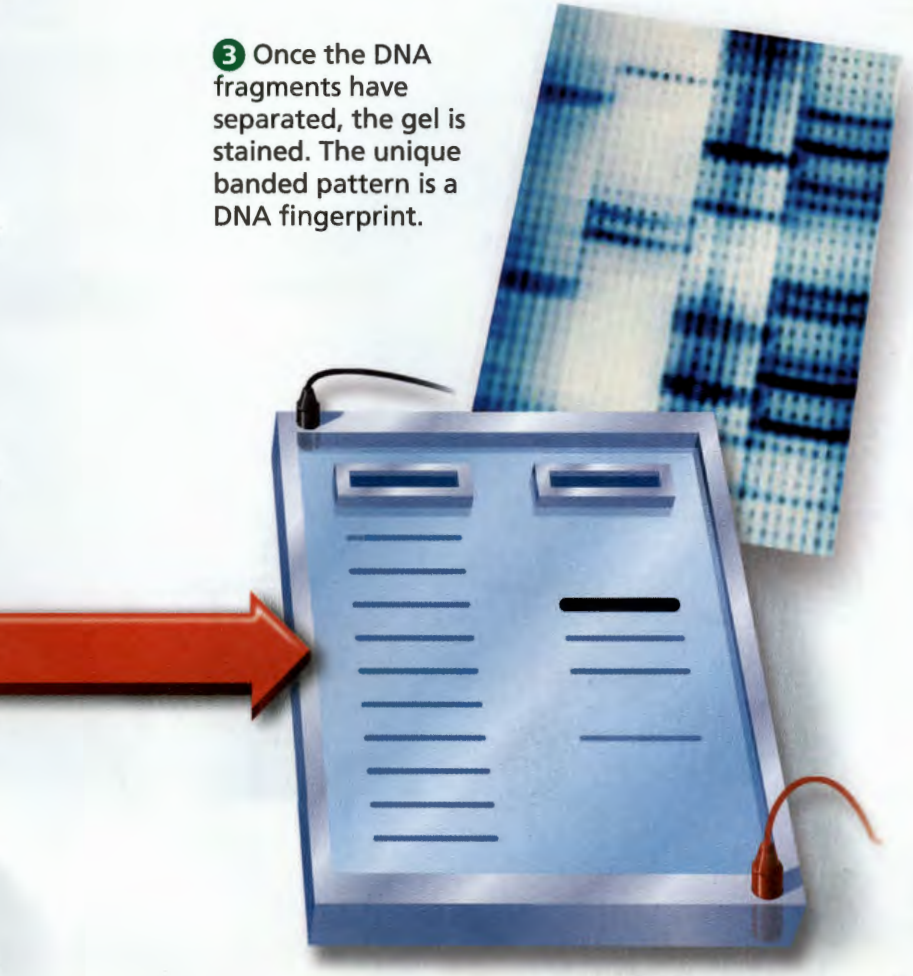
Analyzing DNA

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 6 Study Guide

The BIG Idea A person's traits depend on which alleles are inherited from each parent, how those alleles work together, and environmental factors.

1 Human Inheritance

Key Concepts S 7.2, 7.2.c

- 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 an organism's characteristics are determined by an interaction between genes and the environment.

Key Terms

multiple alleles
sex chromosomes
sex-linked gene
carrier

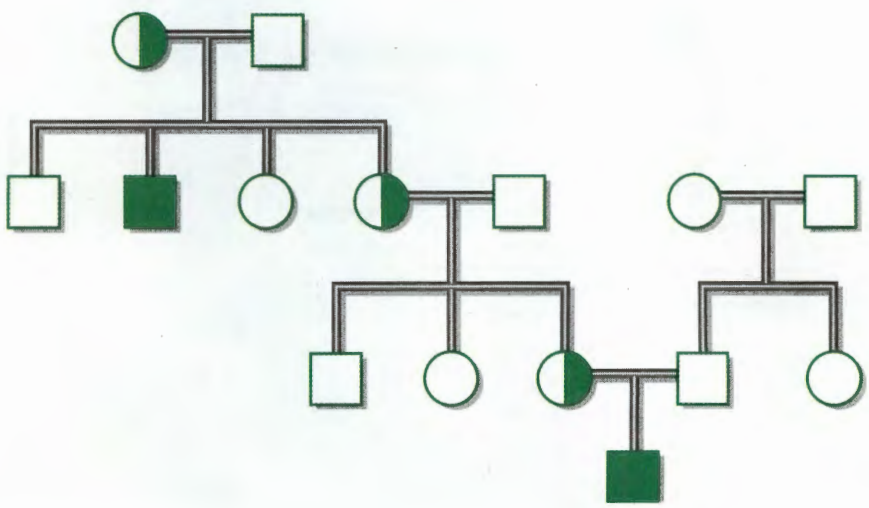
2 Human Genetic Disorders

Key Concepts S 7.2.d

- 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 S 7.b Framework, 7.2.e

- Selective breeding, cloning, and genetic engineering are three methods for developing organisms with desirable traits.
- Applications of DNA technology include studying the human genome in detail and identifying people.

Key Terms

selective breeding
inbreeding
hybridization
clone
genetic engineering
gene therapy
genome

Review and Assessment

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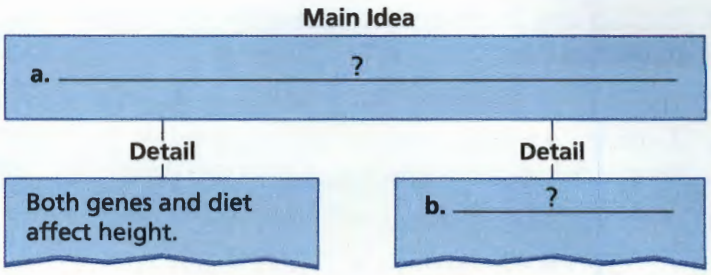
Target Reading Skill

Identifying Main Ideas Reread the three paragraphs following the heading The Effect of Environment, page 198. In a graphic organizer like the one at right, identify the main idea and supply the second detail.



Reviewing Key Terms

Choose the letter of the best answer.

1. A gene that is carried on the X or Y chromosome is called a
   a. carrier.
   b. sex-linked gene.
   c. sex chromosome.
   d. clone.
2. An abnormal condition that a person inherits through genes or chromosomes is called a
   a. karyotype.
   b. pedigree.
   c. multiple allele.
   d. genetic disorder.
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.

Complete the following sentences so that your answers clearly explain the Key Terms.

6. In humans, the X and Y chromosomes are **sex chromosomes,** which determine the _____ .
7. A person that has an extra copy of chromosome 21 is an example of someone with a **genetic disorder** because _____ .
8. Selecting and growing only the healthiest corn plants every season is an example of **selective breeding,** a process in which _____ .
9. **Inbreeding** produces organisms that are genetically very similar because _____ .
10. Modifying bacteria to produce human insulin is an example of **genetic engineering,** a process in which _____ .

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.

Video Assessment
Discovery Channel School
Modern Genetics

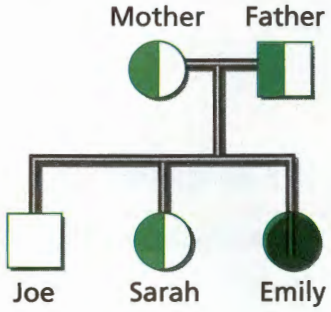
Review and Assessment

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

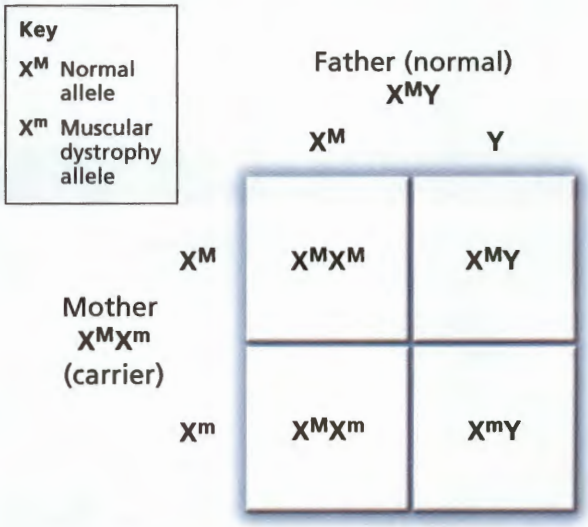
19. **Problem Solving** A woman with normal color vision has a colorblind daughter. What are the genotypes and phenotypes of both parents?
20. **Calculating** If a mother is a carrier of hemophilia and the father does not have hemophilia, what is the probability that their son will have the trait? Explain 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 Standards Investigation

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 investigation.

Choose the letter of the best answer.

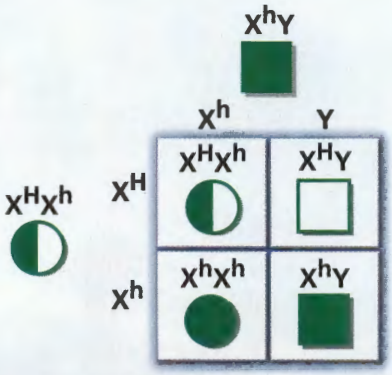
1. To produce a human protein through genetic engineering, scientists use
   - **A** a bacterial gene inserted into a human chromosome.
   - **B** a human gene inserted into a plasmid.
   - **C** a bacterial gene inserted into a plasmid.
   - **D** a human gene inserted into a human chromosome.

   S 7.2.e

2. Down syndrome is an example of a genetic disorder in which
   - **A** one DNA base has been added.
   - **B** one DNA base has been deleted.
   - **C** one chromosome is substituted for another.
   - **D** an extra chromosome is added to a pair.

   S 7.2.d

3. The Punnett square shows the probability that the children of this couple will inherit hemophilia.



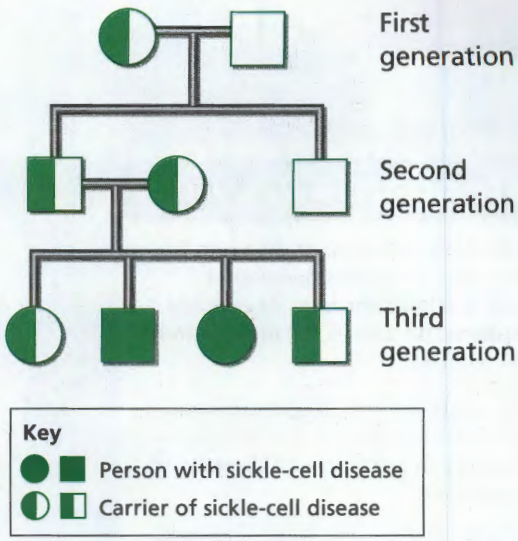
   Which of the following statements best describes the pattern of inheritance in this family?
   - **A** All the sons will have hemophilia.
   - **B** All the daughters will have hemophilia.
   - **C** 50% of daughters and 50% of sons will have hemophilia.
   - **D** 25% of all children will have hemophilia.

   S 7.2.b

4. Height in humans is an example of a trait that is controlled by
   - **A** a single gene with two alleles.
   - **B** a single gene with multiple alleles.
   - **C** many genes.
   - **D** environmental factors only.

   S 7.2.c

Use the pedigree to answer Questions 5–6.



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

   S 7.2.d

6. Which statement is true about the third generation in the pedigree?
   - **A** No one has sickle-cell disease.
   - **B** Everyone has sickle-cell disease.
   - **C** Everyone has at least one allele for sickle-cell disease.
   - **D** No one has any alleles for sickle-cell disease.

   S 7.2.d

Apply the BIG Idea

7. Identical twin boys were separated at birth and raised by different families. One boy is tall and is an outstanding soccer player. The other boy is shorter and not very athletic, but he is a good musician. Which of the boys' characteristics were influenced by genetics? Which were influenced by environment? S 7.2.c