CHAPTER 13

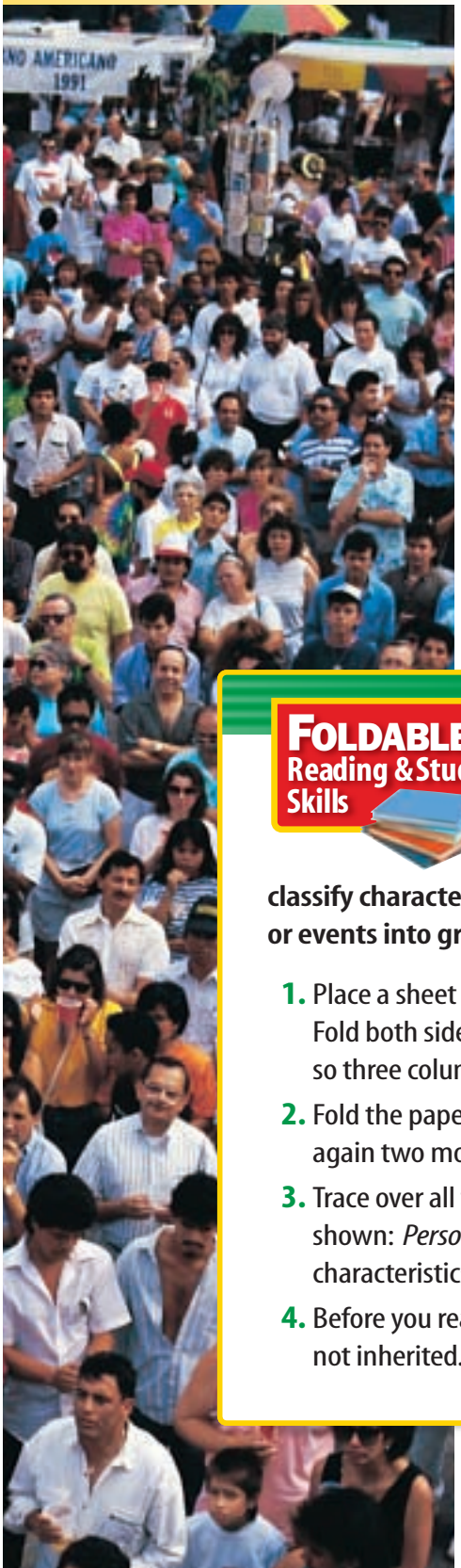
Science TEKS 7.10 A, B, C; 7.11 C

Heredity

Wherever you go, look around you. You don't have the same skin color, the same kind of hair, or the same height as everyone else. Why do you resemble some people but do not look like others at all? In this chapter, you'll find out how differences are determined, and you will learn how to predict when certain traits might appear. You also will learn what causes some hereditary disorders.

What do you think?

Science Journal Look at the picture below with a classmate. Discuss what you think this might be or what is happening. Here's a hint: *The secret to why you look the way you do is found in this picture.* Write your answer or best guess in your Science Journal.



EXPLORE ACTIVITY

You and your best friend enjoy the same sports, like the same food, and even have similar haircuts. But, there are noticeable differences between your appearances. Most of these differences are controlled by the genes you inherited from your parents. In the following activity, you will observe one of these differences.

Observe dimples on faces

1. Notice the two students in the photographs. One student has dimples when she smiles, and the other student doesn't have dimples.
2. Ask your classmates to smile naturally. In your Science Journal, record the name of each classmate and whether each one has dimples.

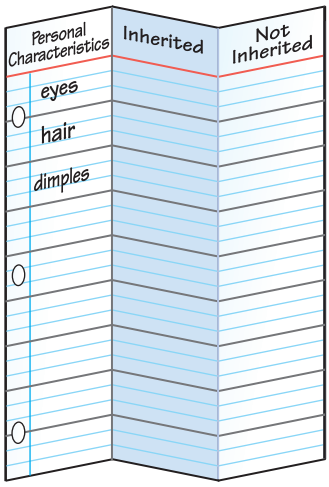
Observe

In your Science Journal, calculate the percentage of students who have dimples. Are facial dimples a common feature among your classmates?

Before You Read

FOLDABLES Reading & Study Skills

Making a Classify Study Fold **As you read this chapter about heredity, you can use the following Foldable to help you classify characteristics. When you classify, you organize objects or events into groups based on their common features.**



1. Place a sheet of paper in front of you so the short side is at the top. Fold both sides in to divide the paper into thirds. Unfold the paper so three columns show.
2. Fold the paper in half from top to bottom. Then fold it in half again two more times. Unfold all the folds.
3. Trace over all the fold lines and label the columns you created as shown: *Personal Characteristics*, *Inherited*, and *Not Inherited*. List personal characteristics down the left-hand column, as shown.
4. Before you read the chapter, predict which characteristics are inherited or not inherited. As you read the chapter, check and change the table.

SECTION 1

Genetics

As You Read

What You'll Learn

- **Explain** how traits are inherited.
- **Identify** Mendel's role in the history of genetics.
- **Use** a Punnett square to predict the results of crosses.
- **Compare and contrast** the difference between an individual's genotype and phenotype.

Vocabulary

heredity
allele
genetics
hybrid
dominant
recessive
Punnett square
genotype
phenotype
homozygous
heterozygous

Why It's Important

Heredity and genetics help explain why people are different.

Review Grade 6 TEKS

For a review of the grade 6 TEKS *Species Change Through Generations,* see page 788.

Inheriting Traits

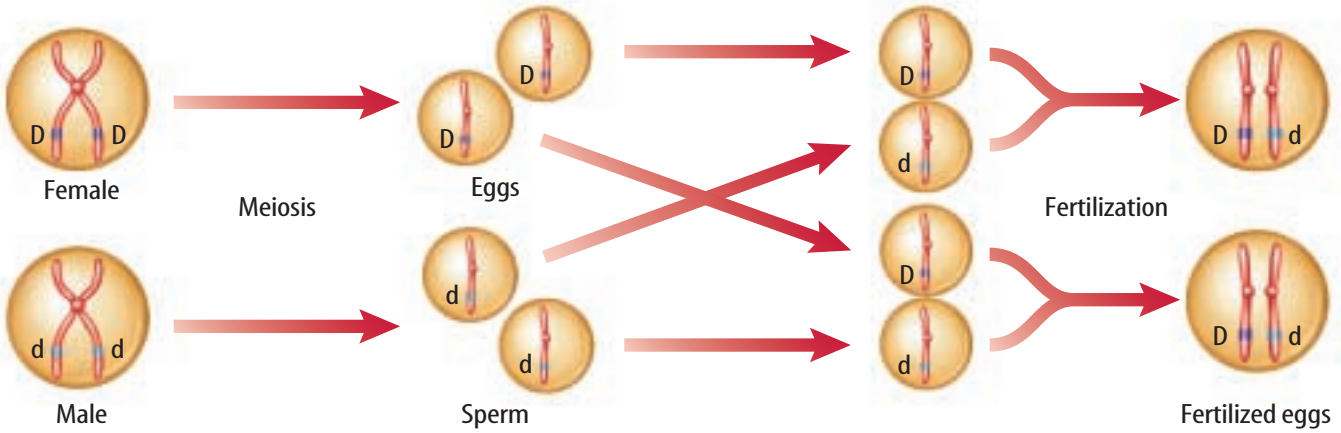
Do you look more like one parent or grandparent? Do you have your father's eyes? What about Aunt Isabella's cheekbones? Eye color, nose shape, and many other physical features are some of the traits that are inherited from parents, as **Figure 1** shows. An organism is a collection of traits, all inherited from its parents. **Heredity** (huh REH duh tee) is the passing of traits from parent to offspring. What controls these traits?

What is genetics? Generally, genes on chromosomes control an organism's form and function. The different forms of a trait that a gene may have are called **alleles** (uh LEELZ). When a pair of chromosomes separates during meiosis (mi OH sus), alleles for each trait also separate into different sex cells. As a result, every sex cell has one allele for each trait, as shown in **Figure 2.** The allele in one sex cell may control one form of the trait, such as having facial dimples. The allele in the other sex cell may control a different form of the trait—not having dimples. The study of how traits are inherited through the interactions of alleles is the science of **genetics** (juh NET ihks).

Figure 1
Note the strong family resemblance among these four generations.

Figure 2

An allele is one form of a gene. Alleles separate into separate sex cells during meiosis. In this example, the alleles that control the trait for dimples include *D*, the presence of dimples, and *d*, the absence of dimples.



A **The alleles that control a trait are located on each duplicated chromosome.**

B **During meiosis, duplicated chromosomes separate.**

C **During fertilization, each parent donates one chromosome. This results in two alleles for the trait of dimples in the new individual formed.**

Mendel—The Father of Genetics

Did you know that an experiment with pea plants helped scientists understand why your eyes are the color that they are? Gregor Mendel was an Austrian monk who studied mathematics and science but became a gardener in a monastery. His interest in plants began as a boy in his father's orchard where he could predict the possible types of flowers and fruits that would result from crossbreeding two plants. Curiosity about the connection between the color of a pea flower and the type of seed that same plant produced inspired him to begin experimenting with garden peas in 1856. Mendel made careful use of scientific methods, which resulted in the first recorded study of how traits pass from one generation to the next. After eight years, Mendel presented his results with pea plants to scientists.

Before Mendel, scientists mostly relied on observation and description, and often studied many traits at one time. Mendel was the first to trace one trait through several generations. He was also the first to use the mathematics of probability to explain heredity. The use of math in plant science was a new concept and not widely accepted then. Mendel's work was forgotten for a long time. In 1900, three plant scientists, working separately, reached the same conclusions as Mendel. Each plant scientist had discovered Mendel's writings while doing his own research. Since then, Mendel has been known as the father of genetics.

CLICK HERE

SCIENCE *Online*

Research Visit the Glencoe Science Web site at **tx.science.glencoe.com** for more information about early genetics experiments. Write a paragraph in your Science Journal about a scientist, other than Gregor Mendel, who studied genetics.

Table 1 Traits Compared by Mendel

Traits	Shape of Seeds	Color of Seeds	Color of Pods	Shape of Pods	Plant Height	Position of Flowers	Flower Color
Dominant Trait	 Round	 Yellow	 Green	 Full	 Tall	 At leaf junctions	 Purple
Recessive Trait	 Wrinkled	 Green	 Yellow	 Flat, constricted	 Short	 At tips of branches	 White

Genetics in a Garden

Each time Mendel studied a trait, he crossed two plants with different expressions of the trait and found that the new plants all looked like one of the two parents. He called these new plants **hybrids** (HI brudz) because they received different genetic information, or different alleles, for a trait from each parent. The results of these studies made Mendel even more curious about how traits are inherited.

Garden peas are easy to breed for pure traits. An organism that always produces the same traits generation after generation is called a purebred. For example, tall plants that always produce seeds that produce tall plants are purebred for the trait of tall height. **Table 1** shows other pea plant traits that Mendel studied.

Reading Check *Why might farmers plant purebred crop seeds?*

Dominant and Recessive Factors In nature, insects randomly pollinate plants as they move from flower to flower. In his experiments, Mendel used pollen from the flowers of purebred tall plants to pollinate by hand the flowers of purebred short plants. This process is called cross-pollination. He found that tall plants crossed with short plants produced seeds that produced all tall plants. Whatever caused the plants to be short had disappeared. Mendel called the tall form the **dominant** (DAHM uh nunt) factor because it dominated, or covered up, the short form. He called the form that seemed to disappear the **recessive** (rih SES ihv) factor. Today, these are called dominant alleles and recessive alleles. What happened to the recessive form? **Figure 3** answers this question.

TRY AT HOME

Mini LAB

Comparing Common Traits

Procedure

1. Safely survey as many **dogs** in your neighborhood as you can for the presence of a solid color or spotted coat, short or long hair, and floppy ears or ears that stand up straight.
2. Make a data table that lists each of the traits. Record your data in the data table.

Analysis

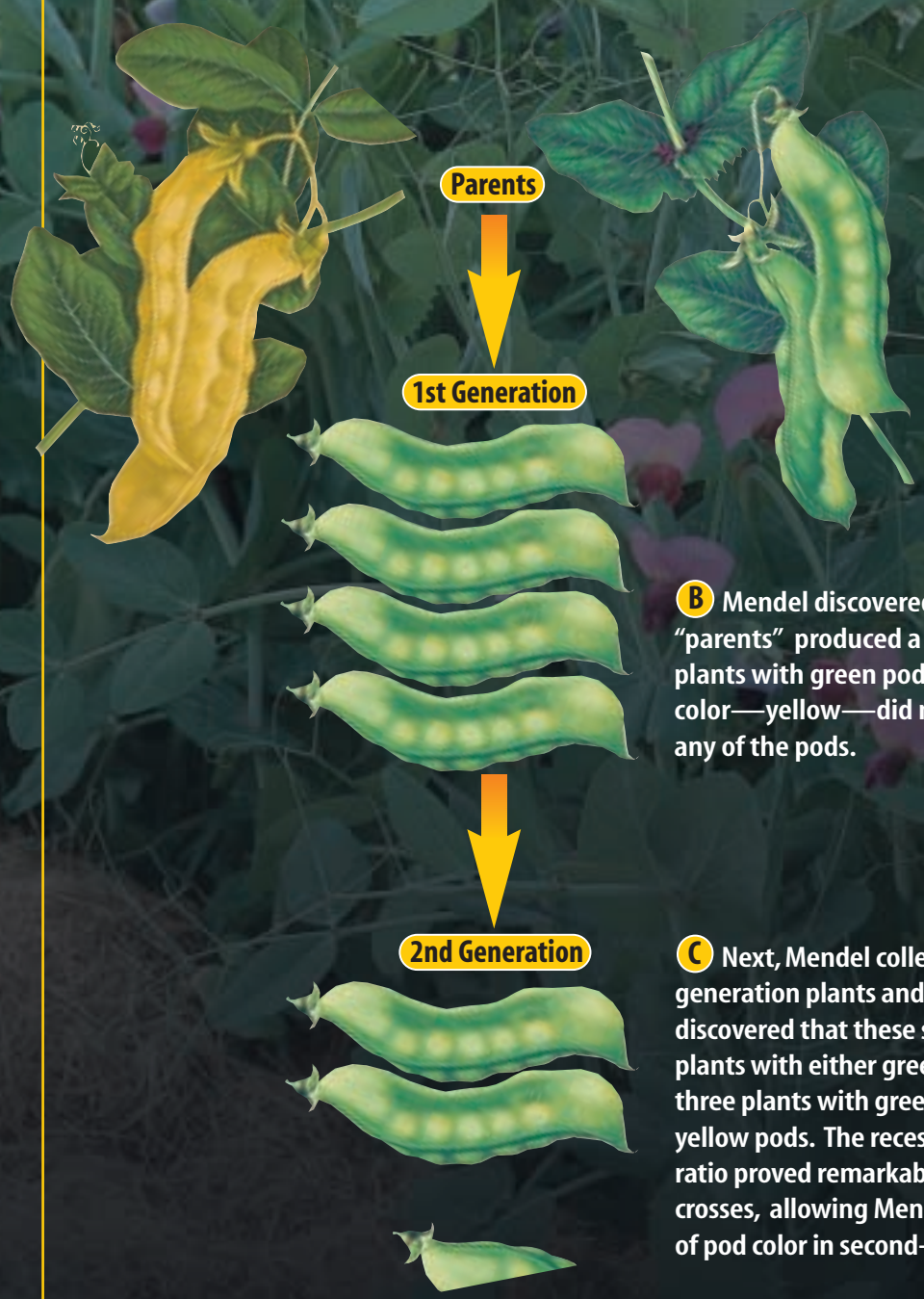
1. Compare the number of dogs that have one form of a trait with those that have the other form. How do those two groups compare?
2. What can you conclude about the variations you noticed in the dogs?

NATIONAL GEOGRAPHIC

VISUALIZING MENDEL'S EXPERIMENTS

Figure 3

Gregor Mendel discovered that the experiments he carried out on garden plants provided an understanding of heredity. For eight years he crossed plants that had different characteristics and recorded how those characteristics were passed from generation to generation. One such characteristic, or trait, was the color of pea pods. The results of Mendel's experiment on pea pod color are shown below.



A One of the so-called "parent plants" in Mendel's experiment had pods that were green, a dominant trait. The other parent plant had pods that were yellow, a recessive trait.

B Mendel discovered that the two "parents" produced a generation of plants with green pods. The recessive color—yellow—did not appear in any of the pods.

C Next, Mendel collected seeds from the first-generation plants and raised a second generation. He discovered that these second-generation plants produced plants with either green or yellow pods in a ratio of about three plants with green pods for every one plant with yellow pods. The recessive trait had reappeared. This 3:1 ratio proved remarkably consistent in hundreds of similar crosses, allowing Mendel to accurately predict the ratio of pod color in second-generation plants.

Using Probability to Make Predictions If you and your sister can't agree on what movie to see, you could solve the problem by tossing a coin. When you toss a coin, you're dealing with probabilities. Probability is a branch of mathematics that helps you predict the chance that something will happen. If your sister chooses tails while the coin is in the air, what is the probability that the coin will land tail-side up? Because a coin has two sides, there are two possible outcomes, heads or tails. One outcome is tails. Therefore, the probability of one side of a coin showing is one out of two, or 50 percent.

Mendel also dealt with probabilities. One of the things that made his predictions accurate was that he worked with large numbers of plants. He studied almost 30,000 pea plants over a period of eight years. By doing so, Mendel increased his chances of seeing a repeatable pattern. Valid scientific conclusions need to be based on results that can be duplicated.

Figure 4
This snapdragon's phenotype is red. *Can you tell what the flower's genotype for color is? Explain your answer.*

Punnett Squares Suppose you wanted to know what colors of pea plant flowers you would get if you pollinated white flowers on one pea plant with pollen from purple flowers on a different plant. How could you predict what the offspring would look like without making the cross? A handy tool used to predict results in Mendelian genetics is the **Punnett** (PUN ut) **square.** In a Punnett square, letters represent dominant and recessive alleles. An uppercase letter stands for a dominant allele. A lowercase letter stands for a recessive allele. The letters are a form of code. They show the **genotype** (JEE nuh tipe), or genetic makeup, of an organism. Once you understand what the letters mean, you can tell a lot about the inheritance of a trait in an organism.

The way an organism looks and behaves as a result of its genotype is its **phenotype** (FEE nuh tipe), as shown in **Figure 4.** If you have brown hair, then the phenotype for your hair color is brown.

Alleles Determine Traits Most cells in your body have two alleles for every trait. These alleles are located on chromosomes within the nucleus of cells. An organism with two alleles that are the same is called **homozygous** (hoh muh ZI gus). For Mendel's peas, this would be written as *TT* (homozygous for the tall-dominant trait) or *tt* (homozygous for the short-recessive trait). An organism that has two different alleles for a trait is called **heterozygous** (het uh roh ZI gus). The hybrid plants Mendel produced were all heterozygous for height, *Tt*.

Reading Check ***What is the difference between homozygous and heterozygous organisms?***

Making a Punnett Square In a Punnett square for predicting one trait, the letters representing the two alleles from one parent are written along the top of the grid, one letter per section. Those of the second parent are placed down the side of the grid, one letter per section. Each square of the grid is filled in with one allele donated by each parent. The letters that you use to fill in each of the squares represent the genotypes of possible offspring that the parents could produce.

Math Skills Activity

Math TEKS 7.10 A, B; 7.15 A, B

Calculating Probability Using a Punnett Square

You can determine the probability of certain traits by using a Punnett square. Letters are used to represent the two alleles from each parent and are combined to determine the possible genotypes of the offspring.

Example Problem

One dog carries heterozygous, black-fur traits (Bb), and its mate carries homogeneous, blond-fur traits (bb). Calculate the probability of the puppy having black fur.

Solution

1. *This is what you know:*
   dominant allele is represented by *B*
   recessive allele is represented by *b*
2. *This is what you need to find:*
   the probability of a puppy's fur color being black using a Punnett square
3. *This is the diagram you need to use:*

		Black dog	
		B	b
Blond dog	b		
	b		

4. *Complete the Punnett square by taking each letter in each column and combining it with each letter from each row in the corresponding square.*

		Black dog	
		B	b
Blond dog	b	Bb	bb
	b	Bb	bb

Genotypes of offspring:
2Bb, 2bb
Phenotypes of offspring:
2 black, 2 blond

5. *Find the needed probability. There are two Bb genotypes and four possible outcomes.*

$$P(\text{black fur}) = \frac{\text{number of ways to get black fur}}{\text{number of possible outcomes}}$$

$$= \frac{2}{4} = \frac{1}{2} = 50\%$$

Practice Problem

Use a Punnett square to determine the probability of each of the offspring's genotype and phenotype when two heterozygous, tall-dominant traits (Tt) are crossed with each other.

For more help, refer to the Math Skill Handbook.

Principles of Heredity Even though Gregor Mendel didn't know anything about DNA, genes, or chromosomes, he succeeded in beginning to describe and mathematically represent how inherited traits are passed from parents to offspring. He realized that some factor in the pea plant produced certain traits. Mendel also concluded that these factors separated when the pea plant reproduced. Mendel arrived at his conclusions after years of detailed observation, careful analysis, and repeated experimentation. **Table 2** summarizes Mendel's principles of heredity.

Table 2 Principles of Heredity

1	Traits are controlled by alleles on chromosomes.
2	An allele's effect is dominant or recessive.
3	When a pair of chromosomes separates during meiosis, the different alleles for a trait move into separate sex cells.

Section 1 Assessment

1. Alleles are described as being dominant or recessive. What is the difference between a dominant and a recessive allele?
2. How are dominant and recessive alleles represented in a Punnett square?
3. Explain the difference between genotype and phenotype. Give examples.
4. Gregor Mendel, an Austrian monk who lived in the 1800s, is known as the father of genetics. Explain why Mendel has been given this title.
5. **Think Critically** If an organism expresses a recessive phenotype, can you tell the genotype? Explain your answer by giving an example.

Skill Builder Activities

6. **Predicting** Hairline shape is an inherited trait in humans. The widow's peak allele is dominant, and the straight hairline allele is recessive. Predict how both parents with widow's peaks could have a child without a widow's peak hairline. **For more help, refer to the Science Skill Handbook.**
7. **Using Percentages** One fruit fly is heterozygous for long wings, and another fruit fly is homozygous for short wings. Long wings are dominant to short wings. Using a Punnett square, find out what percent of the offspring are expected to have short wings. **For more help, refer to the Math Skill Handbook.**

Activity

Predicting Results

Could you predict how many brown rabbits would result from crossing two heterozygous black rabbits? Try this investigation to find out. Brown color is a recessive trait for hair color in rabbits.

What You'll Investigate

How does chance affect combinations of genes?

Materials

paper bags (2)
red beans (100)
white beans (100)

Goals

- **Model** chance events in heredity.
- **Compare and contrast** predicted and actual results.

Safety Precautions

WARNING: *Do not taste, eat, or drink any materials used in the lab.*

Procedure

1. Use a Punnett square to predict how many red/red, red/white, and white/white bean combinations are possible. The combinations represent the coat colors in rabbit offspring.
2. Place 50 red beans and 50 white beans in a paper bag. Place 50 red beans and 50 white beans in a second bag. Red beans represent black alleles and white beans represent brown alleles.
3. Label one of the bags *female* for the female parent. Label the other bag *male* for the male parent.
4. Use a data table to record the combination each time you remove two beans. Your table will need to accommodate 100 picks.
5. Without looking, remove one bean from each bag. The two beans represent the alleles that combine when sperm and egg join. After recording, return the beans to their bags.
6. **Count** and record the total numbers for each of the three combinations in your data table.
7. **Compile** and record the class totals.

Conclude and Apply

1. Which combination occurred most often?
2. **Calculate** the ratio of red/red to red/white to white/white. What hair color in rabbits do these combinations represent?
3. **Compare** your predicted (expected) results with your observed (actual) results.
4. **Hypothesize** how you could get predicted results to be closer to actual results.

Gene Combinations

Rabbits	Red/ Red	Red/ White	White/ White
Your Total			
Class Total			

Communicating Your Data

Write a paragraph that clearly describes your results. Have another student read your paragraph. Ask if he or she could understand what happened. If not, rewrite your paragraph and have the other student read it again. **For more help, refer to the Science Skill Handbook.**

SECTION 2

Genetics Since Mendel

As You Read

What You'll Learn

- **Explain** how traits are inherited by incomplete dominance.
- **Compare** multiple alleles and polygenic inheritance, and give examples of each.
- **Describe** two human genetic disorders and how they are inherited.
- **Explain** how sex-linked traits are passed to offspring.

Vocabulary

incomplete dominance
polygenic inheritance
sex-linked gene

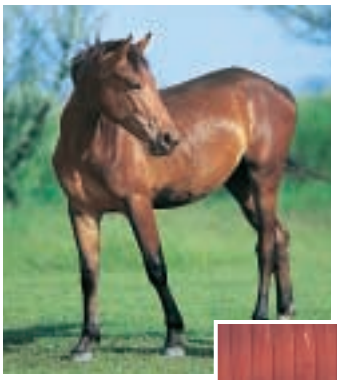
Why It's Important

Most of your inherited traits involve more complex patterns of inheritance than Mendel discovered.

Incomplete Dominance

Not even in science do things remain the same. After Mendel's work was rediscovered in 1900, scientists repeated his experiments. For some plants, such as peas, Mendel's results proved true. However, when different plants were crossed, the results were sometimes different. One scientist crossed purebred red four-o'clock plants with purebred white four-o'clock plants. He expected to get all red flowers, but they were pink. Neither allele for flower color seemed dominant. Had the colors become blended like paint colors? He crossed the pink-flowered plants with each other, and red, pink, and white flowers were produced. The red and white alleles had not become blended. Instead, when the allele for white flowers and the allele for red flowers combined, the result was an intermediate phenotype—a pink flower. Similar results for horses are shown in **Figure 5. Incomplete dominance** produces a phenotype that is intermediate between the two homozygous parents. Feather color in some types of chickens also is inherited by incomplete dominance.

A



B

C

		Chestnut horse (CC)	
		C	C
White horse (C'C')	C'	CC'	CC'
	C'	CC'	CC'

Genotypes: All CC'
Phenotypes: All Appaloosa horses

Figure 5
These Punnett squares show how the color of horses can be inherited by incomplete dominance. A When a chestnut horse is bred with B a white horse, all the offspring will be Appaloosa, as shown in C, the first Punnett square. D When two Appaloosa horses from the offspring are bred, many phenotypes are produced as illustrated in E, the second Punnett square. *What is the ratio of the different phenotypes produced in this second generation?*

Multiple Alleles Mendel studied traits in peas that were controlled by just two alleles. However, many traits are controlled by more than two alleles. A trait that is controlled by more than two alleles is said to be controlled by multiple alleles. Traits controlled by multiple alleles produce more than three phenotypes of that trait.

Imagine that only three types of coins are made—nickels, dimes, and quarters. If every person can have only two coins, six different combinations are possible. In this problem, the coins represent alleles of a trait. The sum of each two-coin combination represents the phenotype. Can you name the six different phenotypes possible with two coins?

Blood type in humans is an example of multiple alleles that produce only four phenotypes. The alleles for blood types are called A, B, and O. The O allele is recessive to both the A and B alleles. When a person inherits one A allele and one B allele for blood type, both are expressed—phenotype AB. A person with phenotype A blood has the genetic makeup, or genotype—AA or AO. Someone with phenotype B blood has the genotype BB or BO. Finally, a person with phenotype O blood has the genotype OO.

Reading Check *What are the six different blood type genotypes?*

SCIENCE Online

Research Visit the Glencoe Science Web site at **tx.science.glencoe.com** for information on the importance of blood types in blood transfusions. In your Science Journal, draw a chart showing which blood types can be used safely during transfusions.

CLICK HERE

D

E

		Appaloosa horse (CC')	
		C	C'
Appaloosa horse (CC')	C	CC	C'C
	C'	CC'	C'C'

Genotypes: CC, CC', C'C'
Phenotypes: One chestnut, two Appaloosas, and one white horse

Mini LAB

Interpreting Polygenic Inheritance

Procedure

1. Measure the hand spans of your classmates.
2. Using a **ruler,** measure from the tip of the thumb to the tip of the little finger when the hand is stretched out. Read the measurement to the nearest centimeter.
3. Record the name and hand-span measurement of each person in a data table.

Analysis

1. What range of hand spans did you find?
2. Are hand spans inherited as a simple Mendelian pattern or as a polygenic or incomplete dominance pattern? Explain.

Polygenic Inheritance

Eye color is an example of a trait that is produced by a combination of many genes. **Polygenic** (pahl ih JEHN ihk) **inheritance** occurs when a group of gene pairs acts together to produce a trait. The effects of many alleles produces a wide variety of phenotypes. For this reason, it may be hard to classify all the different shades of eye color.

Your height and the color of your eyes and skin are just some of the many human traits controlled by polygenic inheritance. It is estimated that three to six gene pairs control your skin color. Even more gene pairs might control the color of your hair and eyes. The environment also plays an important role in the expression of traits controlled by polygenic inheritance. Polygenic inheritance is common and includes such traits as grain color in wheat and milk production in cows. Egg production in chickens is also a polygenic trait.

Impact of the Environment Your environment plays a role in how some of your genes are expressed or whether they are expressed at all, as shown in **Figure 6.** Environmental influences can be internal or external. For example, most male birds are more brightly colored than females. Chemicals in their bodies determine whether the gene for brightly colored feathers is expressed.

Although genes determine many of your traits, you might be able to influence their expression by the decisions you make. Some people have genes that make them at risk for developing certain cancers. Whether they get cancer might depend on external environmental factors. For instance, if some people at risk for skin cancer limit their exposure to the Sun and take care of their skin, they might never develop cancer.

Reading Check *What environmental factors might affect the size of leaves on a tree?*

Figure 6
Himalayan rabbits have alleles for dark-colored fur. However, this allele is able to express itself only at lower temperatures. Only the areas located farthest from the rabbit's main body heat (ears, nose, feet, tail) have dark-colored fur.

Human Genes and Mutations

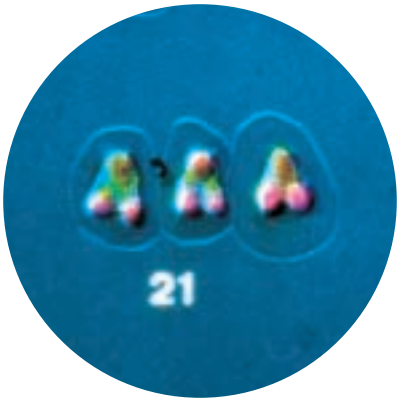
Sometimes a gene undergoes a change that results in a trait that is expressed differently. Occasionally errors occur in the DNA when it is copied inside of a cell. Such changes and errors are called mutations. Not all mutations are harmful. They might be helpful or have no effect on an organism.

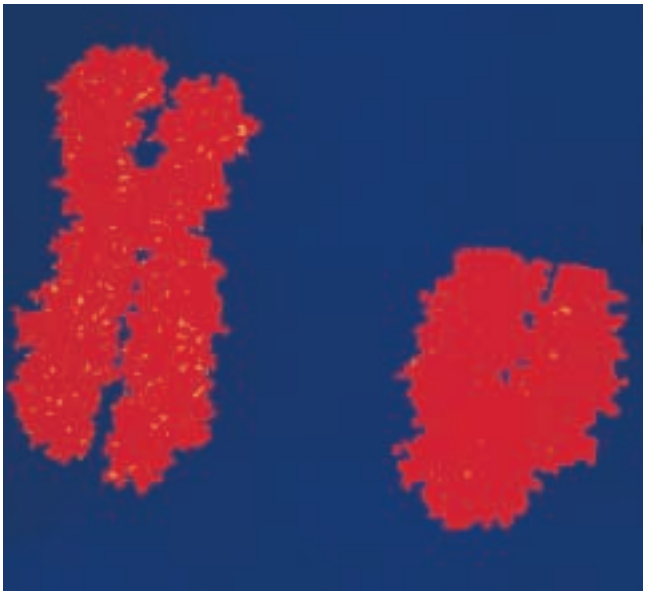
Certain chemicals are known to produce mutations in plants or animals, including humans. X rays and radioactive substances are other causes of some mutations. Mutations are changes in genes.

Chromosome Disorders In addition to individual mutations, problems can occur if the incorrect number of chromosomes is inherited. Every organism has a specific number of chromosomes. However, mistakes in the process of meiosis can result in a new organism with more or fewer chromosomes than normal. A change in the total number of human chromosomes is usually fatal to the unborn embryo or fetus, or the baby may die soon after birth.

Look at the human chromosomes in **Figure 7.** If three copies of chromosome 21 are produced in the fertilized human egg, Down's syndrome results. Individuals with Down's syndrome can be short, exhibit learning disabilities, and have heart problems. Such individuals can lead normal lives if they have no severe health complications.

Figure 7
Humans usually have 23 pairs of chromosomes. Notice that three copies of chromosome 21 are present in this photo, rather than the usual two chromosomes. This change in chromosome number results in Down's syndrome. Chris Burke, a well-known actor, has this syndrome.





Magnification: 10,000×

Figure 8
Sex in many organisms is determined by X and Y chromosomes. *How do the X (left) and Y (right) chromosomes differ from one another in shape and size?*

Recessive Genetic Disorders

Many human genetic disorders, such as cystic fibrosis, are caused by recessive genes. Some recessive genes are the result of a mutation within the gene. Many of these alleles are rare. Such genetic disorders occur when both parents have a recessive allele responsible for this disorder. Because the parents are heterozygous, they don't show any symptoms. However, if each parent passes the recessive allele to the child, the child inherits both recessive alleles and will have a recessive genetic disorder.

Reading Check *How is cystic fibrosis inherited?*

Cystic fibrosis is a homozygous recessive disorder. It is the most common genetic disorder that can lead to death among Caucasian Americans. In most people, a thin fluid is produced that lubricates the lungs and intestinal tract. People with cystic fibrosis produce thick mucus instead of this thin fluid. The thick mucus builds up in the lungs and makes it hard to breathe. This buildup often results in repeated bacterial respiratory infections. The thick mucus also reduces or prevents the flow of substances necessary for digesting food. Physical therapy, special diets, and new drug therapies have increased the life spans of patients with cystic fibrosis.

Chemistry INTEGRATION

People with PKU, a recessive disorder, cannot produce the enzyme needed for the breakdown of a substance found in some artificially sweetened drinks. Soft-drink cans must be labeled to ensure that individuals with this disorder do not unknowingly consume the substance. Explain in your Science Journal how a person can be born with PKU if neither parent has this recessive disorder.

Sex Determination

What determines the sex of an individual? Much information on sex inheritance came from studies of fruit flies. Fruit flies have only four pairs of chromosomes. Because the chromosomes are large and few in number, they are easy to study. Scientists identified one pair that contains genes that determine the sex of the organism. They labeled the pair XX in females and XY in males. Geneticists use these labels when studying organisms, including humans. You can see human X and Y chromosomes in **Figure 8.**

Each egg produced by a female normally contains one X chromosome. Males produce sperm that normally have either an X or a Y chromosome. When a sperm with an X chromosome fertilizes an egg, the offspring is a female, XX. A male offspring, XY, is the result of a Y-containing sperm fertilizing an egg. What pair of sex chromosomes is in each of your cells? Sometimes chromosomes do not separate during meiosis. When this occurs, an individual can inherit an abnormal number of sex chromosomes.

Sex-Linked Disorders

Some inherited conditions are linked with the X and Y chromosomes. An allele inherited on a sex chromosome is called a **sex-linked gene.** Color blindness is a sex-linked disorder in which people cannot distinguish between certain colors, particularly red and green. This trait is a recessive allele on the X chromosome. Because males have only one X chromosome, a male with this allele on his X chromosome is color-blind. However, a color-blind female occurs only when both of her X chromosomes have the allele for this trait.

The allele for the distinct patches of three different colors found in calico cats is recessive and carried on the X chromosome. As shown in **Figure 9,** calico cats have inherited two X chromosomes with this recessive allele—one from both parents.

		Female carrier of calico gene (X^cX)	
		X^c	X
Male carrier of calico gene (X^cY)	X^c	X^cX^c	XX^c
	Y	X^cY	XY

Genotypes: X^cX^c, X^cX, X^cY, XY
Phenotypes: One calico female, one carrier female, one carrier male, one normal male

Figure 9
Calico cat fur is a homozygous recessive sex-linked trait. Female cats that are heterozygous are not calico but are only carriers. Two recessive alleles must be present for this allele to be expressed. *Why aren't all the females calico?*

Pedigrees Trace Traits

How can you trace a trait through a family? A pedigree is a visual tool for following a trait through generations of a family. Males are represented by squares and females by circles. A completely filled circle or square shows that the trait is seen in that person. Half-colored circles or squares indicate carriers. A carrier is heterozygous for the trait and it is not seen. People represented by empty circles or squares do not have the trait and are not carriers. The pedigree in **Figure 10** shows how the trait for color blindness is carried through a family.

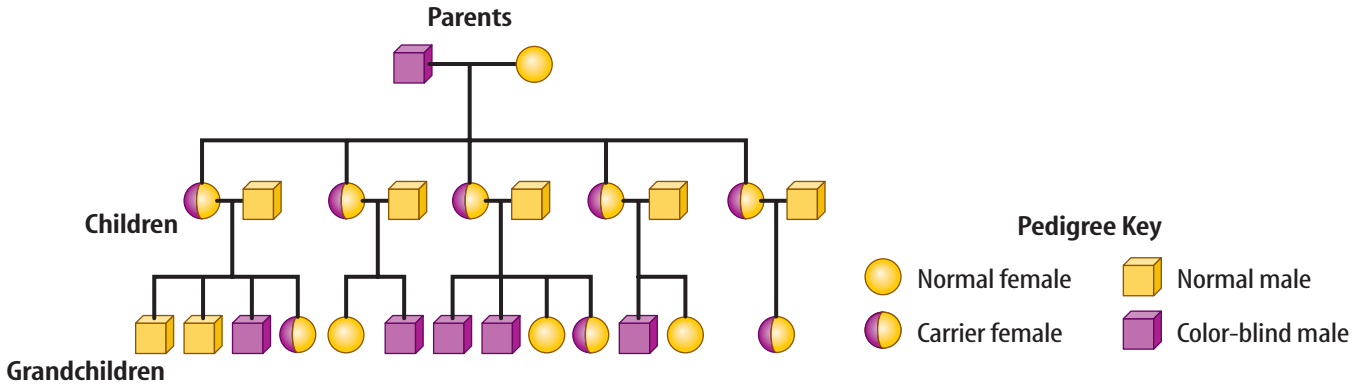


Figure 10
The symbols in this pedigree's key mean the same thing on all pedigree charts. The grandfather in this family was color-blind and married to a woman who was not a carrier of the color-blind allele. *Why are no women in this family color-blind?*

Figure 11
A variety of traits are considered when breeding dogs. A Black Labrador retrievers often are bred to be sporting dogs. B Shih tzus are usually companion or show dogs.

Using Pedigrees A pedigree is a useful tool for a geneticist. Sometimes a geneticist needs to understand who has had a trait in a family over several generations to determine its pattern of inheritance. A geneticist determines if a trait is recessive, dominant, sex-linked, or has some other pattern of inheritance. When geneticists understand how a trait is inherited, they can predict the probability that a baby will be born with a specific trait.

Reading Check ***Why is a pedigree a useful tool for a geneticist?***

Pedigrees also are important in breeding animals or plants. Because livestock and plant crops are used as sources of food, these organisms are bred to increase their yield and nutritional content. Breeders of pets and show animals, like the dogs pictured in **Figure 11,** also examine pedigrees carefully for possible desirable physical and ability traits. Issues concerning health also are considered when researching pedigrees.

Section 2 Assessment

1. Compare inheritance by multiple alleles and polygenic inheritance.
2. Explain why a trait inherited by incomplete dominance, such as the color of Appaloosa horses, is not a blend of two alleles.
3. Describe two genetic disorders and discuss how they are inherited.
4. Using a Punnett square, explain why males are affected more often than females by sex-linked genetic disorders.
5. **Think Critically** Calico male cats are rare. Explain how such a cat can exist.

Skill Builder Activities

6. **Predicting** A man with blood type B marries a woman with blood type A. Their first child has blood type O. Predict what other blood types are possible for their future children. Explain your answer using a Punnett square. **For more help, refer to the Science Skill Handbook.**
7. **Communicating** In your Science Journal, write an essay that explains why the offspring of two parents may or may not show much resemblance to either parent. **For more help, refer to the Science Skill Handbook.**

SECTION 3

Advances in Genetics

Why is genetics important?

If Mendel were to pick up a daily newspaper in any country today, he'd probably be surprised. News articles about developments in genetic research appear almost daily. The term *gene* has become a common word. The principles of heredity are being used to change the world.

Genetic Engineering

You may know that chromosomes are made of DNA and are in the nucleus of a cell. Sections of DNA in chromosomes that direct cell activities are called genes. Through **genetic engineering,** scientists are experimenting with biological and chemical methods to change the arrangement of DNA that makes up a gene. Genetic engineering already is used to help produce large volumes of medicine. Genes also can be inserted into cells to change how those cells perform their normal functions, as shown in **Figure 12.** Other research is being done to find new ways to improve crop production and quality, including the development of plants that are resistant to disease.

As You Read

What You'll Learn

- **Evaluate** the importance of advances in genetics.
- **Sequence** the steps in making genetically engineered organisms.

Vocabulary

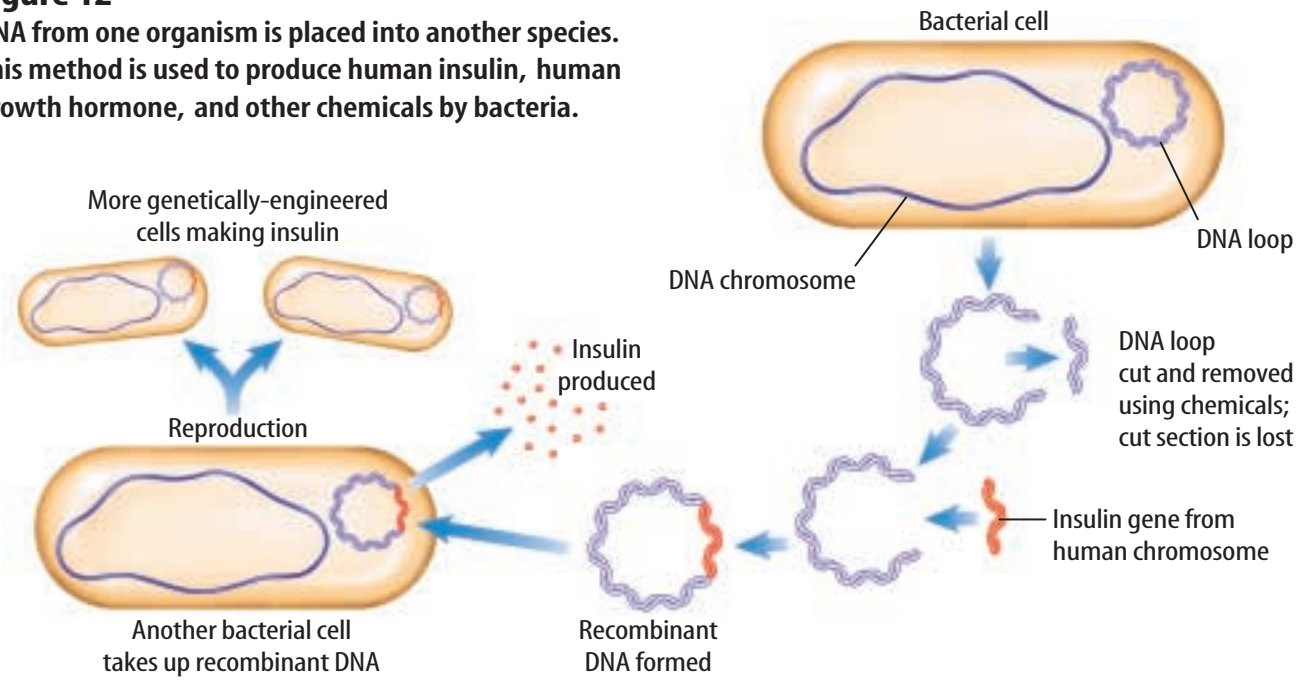
genetic engineering

Why It's Important

Advances in genetics can affect your health, the foods that you eat, and your environment.

Figure 12

DNA from one organism is placed into another species. This method is used to produce human insulin, human growth hormone, and other chemicals by bacteria.



Environmental Science

INTEGRATION

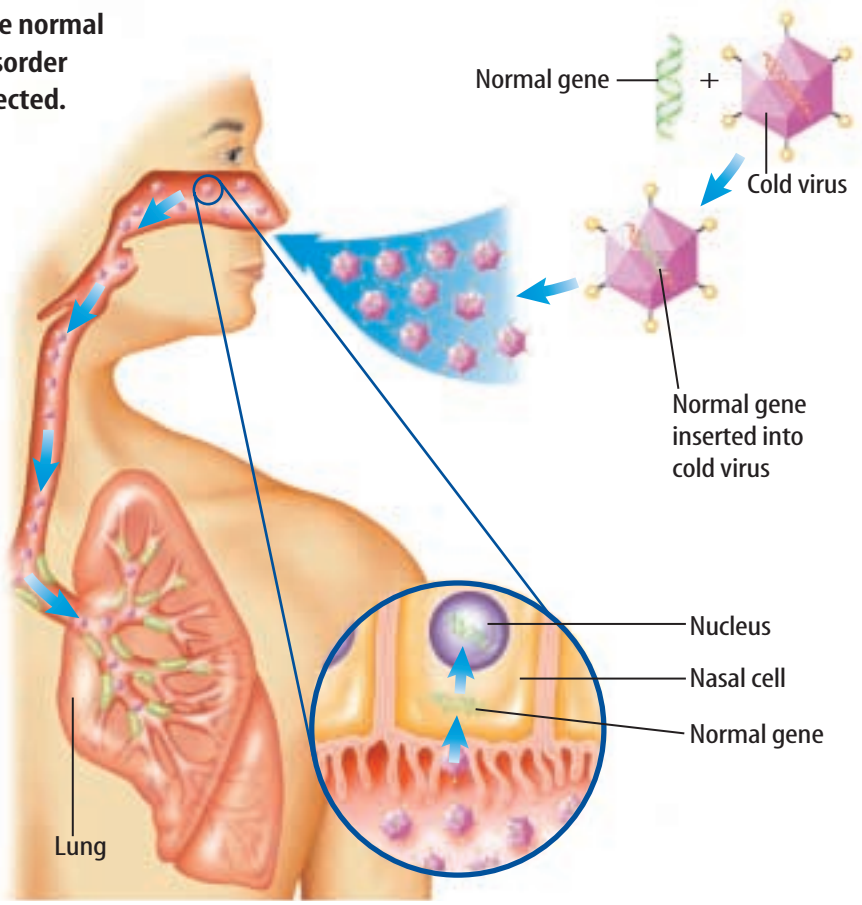
Crop plants are now being genetically engineered to produce chemicals that kill specific pests that feed on them. Some of the pollen from pesticide-resistant canola crops is capable of spreading up to 8 km from the plant, while corn and potato pollen can spread up to 1 km. What might be the effects of pollen landing on other plants?

Recombinant DNA Making recombinant DNA is one method of genetic engineering. Recombinant DNA is made by inserting a useful segment of DNA from one organism into a bacterium, as illustrated in **Figure 12.** Large quantities of human insulin are made by some genetically-engineered organisms. People with Type 1 diabetes need this insulin because their pancreases produce too little or no insulin. Other uses include the production of growth hormone to treat dwarfism and chemicals to treat cancer.

Gene Therapy Gene therapy is a kind of genetic engineering. In gene therapy, a normal allele is placed in a virus, as shown in **Figure 13.** The virus then delivers the normal allele when it infects its target cell. The normal allele replaces the defective one. Scientists are conducting experiments that use this method to test ways of controlling cystic fibrosis and some kinds of cancer. More than 2,000 people already have taken part in gene therapy experiments. Gene therapy might be a method of curing several other genetic disorders in the future.

Figure 13

Gene therapy involves placing a normal allele in a cell that has a mutation. When the normal allele begins to function, a genetic disorder such as cystic fibrosis (CF) may be corrected.



Genetically Engineered Plants For thousands of years people have improved the plants they use for food and clothing even without the knowledge of genotypes. Until recently, these improvements were the results of selecting plants with the most desired traits to breed for the next generation. This process is called selective breeding. Recent advances in genetics have not replaced selective breeding. Although a plant can be bred for a particular phenotype, the genotype and pedigree of the plants also are considered.

Genetic engineering can produce improvements in crop plants, such as corn, wheat, and rice. One type of genetic engineering involves finding the genes that produce desired traits in one plant and then inserting those genes into a different plant. Scientists recently have made genetically engineered tomatoes with a gene that allows tomatoes to be picked green and transported great distances before they ripen completely. Ripe, firm tomatoes are then available in the local market. In the future, additional food crops may be genetically engineered so that they are not desirable food for insects.

Figure 14
Genetically engineered produce is sometimes labeled. This allows consumers to make informed choices about their foods.

Reading Check ***What other types of traits would be considered desirable in plants?***

Because some people might prefer foods that are not changed genetically, some stores label such produce, as shown in **Figure 14.** The long-term effects of consuming genetically engineered plants are unknown.

Section 3 Assessment

1. Give examples of areas in which advances in genetics are important.
2. Compare and contrast the technologies of using recombinant DNA and gene therapy.
3. What are some benefits of genetically engineered crops?
4. How does selective breeding differ from genetic engineering?
5. **Think Critically** Why might some people be opposed to genetically engineered plants?

Skill Builder Activities

6. **Concept Mapping** Make an events chain concept map of the steps used in making recombinant DNA. **For more help, refer to the Science Skill Handbook.**
7. **Using a Word Processor** Use a computer word processing program to write predictions about how advances in genetics might affect your life in the next ten years. **For more help, refer to the Technology Skill Handbook.**

Activity Design Your Own Experiment

Tests for Color Blindness

What do color-blind people see? People who have inherited color blindness can see most colors, but they have difficulty telling the difference between two specific colors. You have three genes that help you see color. One gene lets you see red, another blue, and the third gene allows you to see green. In the most common type of color blindness, red-green color blindness, the green gene does not work properly. What percentage of people are color-blind?

Recognize the Problem

What percentages of males and females in your school are color-blind?

Form a Hypothesis

Based on your reading and your own experiences, form a hypothesis about how common color blindness is among males and females.

Goals

- **Design** an experiment that tests for a specific type of color blindness in males and females.
- **Calculate** the percentage of males and females with the disorder.

Possible Materials

white paper or poster board
colored markers: red, orange, yellow, bright green, dark green, blue
**computer and color printer*
**Alternate materials*

To a person with red-green color blindness, bright green appears tan in color, and dark green looks like brown. The color red also looks brown, making it difficult to tell the difference between green and red. A person without red-green color blindness will see a "6" in this test, while a red-green color-blind person will not see this number.

Test Your Hypothesis

Plan

1. Decide what type of color blindness you will test for—the common green-red color blindness or the more rare green-blue color blindness.
2. **List** the materials you will need and describe how you will create test pictures. Tests for color blindness use many circles of red, orange, and yellow as a background, with circles of dark and light green to make a picture or number. List the steps you will take to test your hypothesis.
3. Prepare a data table in your Science Journal to record your test results.
4. **Examine** your experiment to make sure all steps are in logical order.
5. **Identify** which pictures you will use as a control and which pictures you will use as variables.

Do

1. Make sure your teacher approves your plan before you start.
2. **Draw** the pictures that you will use to test for color blindness.
3. Carry out your experiment as planned and record your results in your data table.

Analyze Your Data

1. **Calculate** the percentage of males and females that tested positive for color blindness.
2. **Compare** the frequency of color blindness in males with the frequency of color blindness in females.

Draw Conclusions

1. Did the results support your hypothesis? Explain.
2. Use your results to explain why color blindness is called a sex-linked disorder.
3. **Infer** how common the color-blind disorder is in the general population.
4. **Predict** your results if you were to test a larger number of people.

Communicating Your Data

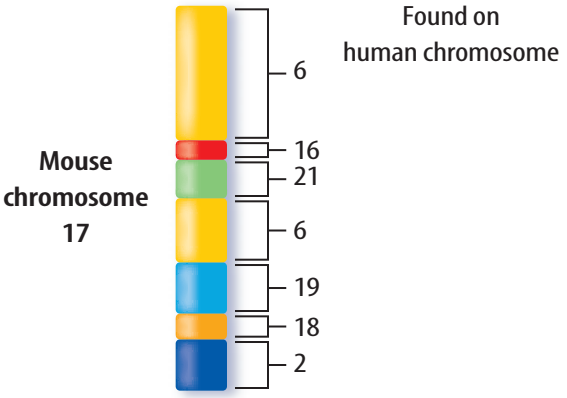
Using a word processor, **write** a short article for the advice column of a fashion magazine about how a color-blind person can avoid wearing outfits with clashing colors. **For more help, refer to the Technology Skill Handbook.**

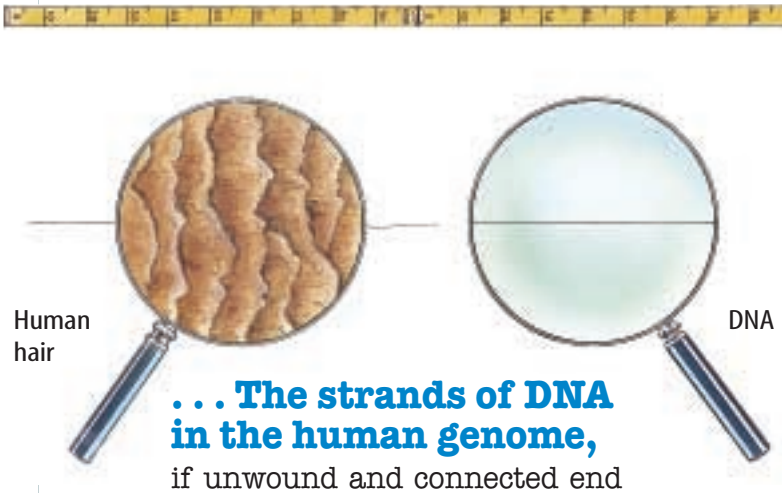
Science Stats

The Human Genome

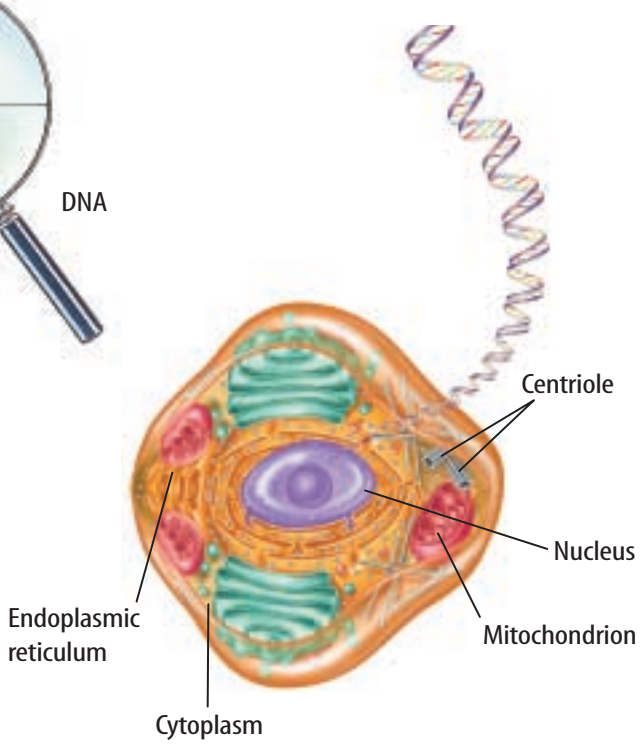
Did you know...

. . . The human genome is not very different from the genome of mice. As shown to the right, many of the genes that are found on mouse chromosome 17 are similar to genes on human chromosomes. Humans may be more closely related to other organisms than previously thought.





. . . The strands of DNA in the human genome, if unwound and connected end to end, would be more than 1.5 m long—but only about 130 trillionths of a centimeter wide. Even an average human hair is as much as 200,000 times wider than that.

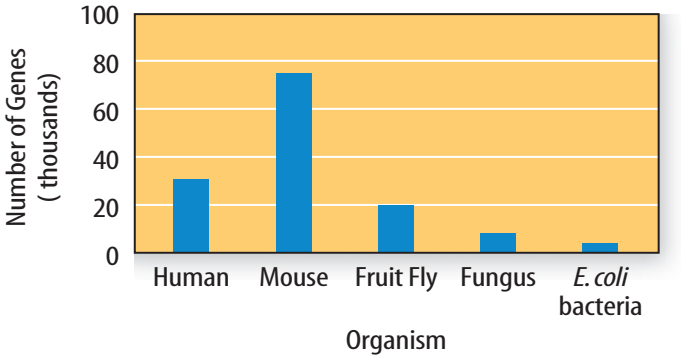


. . . The biggest advance in genetics in years took place in February 2001. Scientists successfully mapped the human genome. There are 30,000 to 40,000 genes in the human genome. Genes are in the nucleus of each of the several trillion cells in your body.



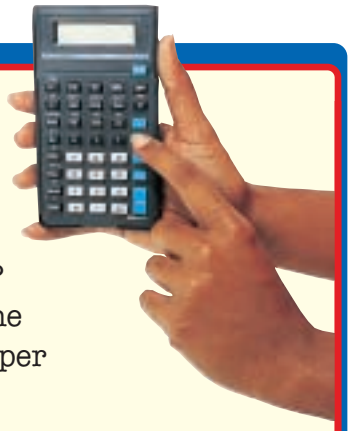

. . . It would take about nine and one-half years to read aloud without stopping the 3 billion bits of instructions (called base pairs) in your genome.

Genome Sizes of Various Organisms



. . . Not all the DNA in your genes contains useful information. About 90 percent of it is "junk" DNA—meaningless sequences located in and between genes.

Do the Math



1. If one million base pairs of DNA take up 1 megabyte of storage space on a computer, how many gigabytes (1,024 megabytes) would the whole genome fill?
2. Consult the above graph. How many more genes are in the human genome than the genome of the fruit fly?
3. If you wrote the genetic information for each gene in the human genome on a separate sheet of 0.2-mm-thick paper and stacked the sheets, how tall would the stack be?

Go Further

By decoding the human genome scientists hope to identify the location of disease-causing genes. Research a genetic disease and share your results with your class.

Chapter 13 Study Guide

Reviewing Main Ideas

Section 1 Genetics

1. Genetics is the study of how traits are inherited. Gregor Mendel determined the basic laws of genetics.
2. Traits are controlled by alleles on chromosomes in the nuclei of cells.
3. Some alleles can be dominant and others can be recessive in action.
4. When a pair of chromosomes separates during meiosis, the different alleles for a trait move into separate sex cells. Mendel found that traits followed the laws of probability and that he could predict the outcome of genetic crosses. *How can a Punnett square help predict inheritance of traits?*

	F	f
F	FF	Ff
F	FF	Ff

Section 2 Genetics Since Mendel

1. Inheritance patterns studied since Mendel include incomplete dominance, multiple alleles, and polygenic inheritance.
2. These inheritance patterns allow a greater variety of phenotypes to be produced than would result from Mendelian inheritance.
3. Some disorders are the results of inheritance and can be harmful, even deadly, to those affected.
4. Pedigree charts help reveal patterns of the inheritance of a trait in a family. Pedigrees show that sex-linked traits are expressed more often in males than in females.

Section 3 Advances in Genetics

1. Genetic engineering uses biological and chemical methods to add or remove genes in an organism's DNA.
2. Recombinant DNA is one way genetic engineering can be performed using bacteria to make useful chemicals, including hormones.
3. Gene therapy shows promise for correcting many human genetic disorders by inserting normal alleles into cells.
4. Breakthroughs in the field of genetic engineering are allowing scientists to do many things, such as producing plants that are resistant to disease. *What types of crops might benefit from advances in genetic engineering? Give examples.*

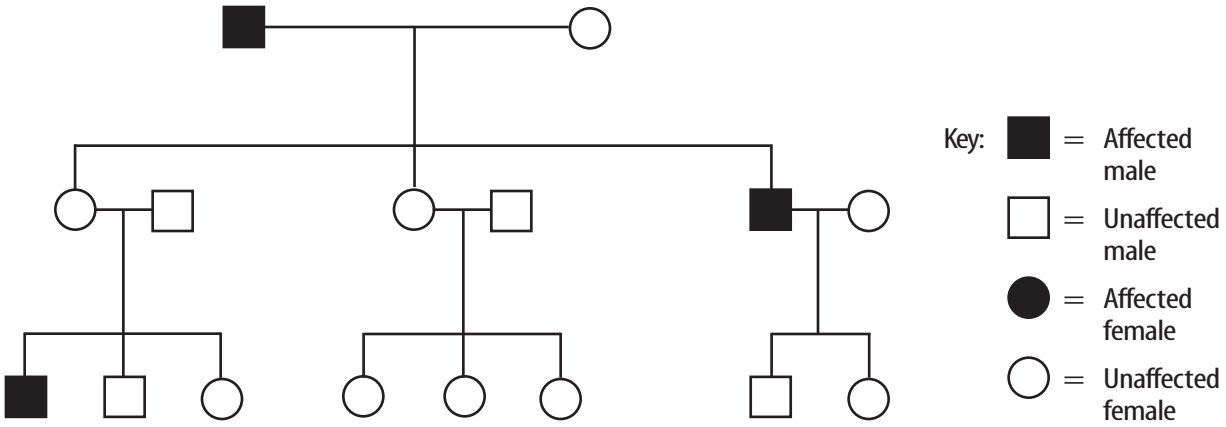
After You Read

FOLDABLES Reading & Study Skills

How many characteristics listed in your Classify Study Fold are inherited from your parents? How many are not inherited? Why are some not inherited?

Visualizing Main Ideas

Examine the following pedigree for diabetes and explain the inheritance pattern.



Vocabulary Review

Vocabulary Words

a. allele
b. dominant
c. genetic engineering
d. genetics
e. genotype
f. heredity
g. heterozygous
h. homozygous
i. hybrid
j. incomplete dominance
k. phenotype
l. polygenic inheritance
m. Punnett square
n. recessive
o. sex-linked gene

Using Vocabulary

Make the sentences to the right true by replacing the underlined word with the correct vocabulary word.

1. Alternate forms of a gene are called genetics.

2. The outward appearance of a trait is a genotype.

3. Human height, eye color, and skin color are all traits controlled by sex-linked genes.

4. An allele that produces a trait in the heterozygous condition is recessive.

5. Polygenic inheritance is the branch of biology that deals with the study of heredity.

6. The actual combination of alleles of an organism is its phenotype.

7. Hybrid is moving fragments of DNA from one organism and inserting them into another organism.

8. A phenotype is a helpful device for predicting the proportions of possible genotypes.

9. Genetics is the passing of traits from parents to offspring.

10. Red-green color blindness and hemophilia are two human genetic disorders that are caused by a genotype.

THE PRINCETON REVIEW

Study Tip

When you encounter new vocabulary, write it down in a sentence. This will help you understand, remember, and use new vocabulary words.

Chapter 13 Assessment & TEKS Review

Checking Concepts

Choose the word or phrase that best answers the question.

1. Which of the following are located in the nuclei on chromosomes?
A) genes **C)** carbohydrates
B) pedigrees **D)** zygotes

2. Which of the following describes the allele that causes color blindness?
A) dominant
B) carried on the Y chromosome
C) carried on the X chromosome
D) present only in males

3. What is it called when the presence of two different alleles results in an intermediate phenotype?
A) incomplete dominance
B) polygenic inheritance
C) multiple alleles
D) sex-linked genes

4. What separates during meiosis?
A) proteins **C)** alleles
B) phenotypes **D)** pedigrees

5. What controls traits in organisms?
A) cell membrane **C)** genes
B) cell wall **D)** Punnett squares

6. Which of the following is a use for a Punnett square?
A) to dominate the outcome of a cross
B) to predict the outcome of a cross
C) to assure the outcome of a cross
D) to number the outcome of a cross

7. What term describes the inheritance of cystic fibrosis?
A) polygenic inheritance
B) multiple alleles
C) incomplete dominance
D) recessive genes

8. What type of inheritance is eye color?
A) polygenic inheritance
B) multiple alleles
C) incomplete dominance
D) recessive genes

9. What chromosome(s) did the father contribute if a normal female is produced?
A) X **C)** Y
B) XX **D)** XY

10. What type of inheritance is blood type?
A) polygenic inheritance
B) multiple alleles
C) incomplete dominance
D) recessive genes

Thinking Critically

11. Explain the relationship among DNA, genes, alleles, and chromosomes.

12. Explain how the parents and offspring represented in this Punnett square have the same phenotype.

	F	f
F	FF	Ff
F	FF	Ff

13. Explain why two rabbits with the same genes might not be colored the same if one is raised in Maine and one is raised in Texas.

14. Why would a person who receives genetic therapy for a disorder still be able to pass the disorder to his or her children?

Developing Skills

15. Predicting Two organisms were found to have different genotypes but the same phenotype. Predict what these phenotypes might be. Explain.

16. Classifying Classify the inheritance pattern for each of the following:

a. many different phenotypes produced by one pair of alleles;

b. many phenotypes produced by more than one pair of alleles; two phenotypes from two alleles; three phenotypes from two alleles.

17. Comparing and Contrasting Compare and contrast Mendelian inheritance with incomplete dominance.

18. Interpreting Scientific Illustrations What were the genotypes of the parents that produced the following Punnett square?

Tt	Tt
Tt	Tt

Performance Assessment

19. Newspaper Article Write a newspaper article to announce a new, genetically engineered plant. Include the method of developing the plant, the characteristic changed, and the terms that you would expect to see. Read your article to the class.

TECHNOLOGY

Go to the Glencoe Science Web site at **tx.science.glencoe.com** or use the **Glencoe Science CD-ROM** for additional chapter assessment.

THE PRINCETON REVIEW

TAKS Practice

A scientist is studying pea plants. The scientist made this Punnett square to predict the color traits of the offspring of two parent pea plants. *TEKS 7.2 C; 7.10 C*

		Parent (Yy)	
		Y	y
Parent (Yy)	Y	YY	Yy
	y	Yy	??

Study the Punnett square and answer the following questions.

1. Which of these genotypes will complete this Punnett square?

A) YY
B) Yy
C) yy
D) Yx

2. In peas, the color yellow (Y) is dominant to the color green (y). According to this Punnett square, most of the offspring of the two yellow pea plants probably will be _____.

F) orange
G) green
H) yellow
J) red

Reading Comprehension

Read the passage. Then read each question that follows the passage. Decide which is the best answer to each question.

Genetic Engineering and Your Food

In recent years, scientists have made tremendous advances in the study of DNA. DNA is the material found in each cell that determines a cell's type, activities, and development. The DNA of a cell contains all the instructions that a cell inherits, including traits that help that organism survive. Scientists can now change an organism's DNA. This is called genetic engineering.

In the past, people were able to affect the DNA of organisms through breeding. The miniature poodle is a great example of this. People wanted smaller poodles, so they bred small individuals with each other that were already in the poodle population. Eventually, a new variety of poodle, called the miniature poodle, developed. It has slightly different DNA than larger poodles.

Today, however, scientists actually can take small pieces of DNA from one organism and add them to another organism's DNA. Scientists have done this a lot with plants such as corn. They wanted corn to have two different traits—a resistance to a weed-killing chemical often used by farmers and the ability to make a bug-killing substance called CryIA(b). In order for a single variety of corn to have both of those traits, scientists took DNA from bacteria that display these traits and added it to the DNA of corn. The result is a variety of corn that is not harmed by the weed-killing chemicals sprayed by farmers and that naturally produces a safe, environmentally-friendly bug-killing substance.

Imagine how surprised farmers were to learn about a variety of corn that takes care of itself!

Because scientists have identified and learned about different DNA over the last few decades, they now know which traits result from different DNA. As a result, scientists are able to genetically engineer such things as new varieties of corn. Scientists also are exploring many other ideas for advancing different crops. Soon, these new varieties of crops will be able to be used all over the world to help feed millions of people.

Test-Taking Tip Consider how the actions of scientists have changed over the years from breeding to genetic engineering.

This genetically engineered corn contains DNA from bacteria.

1. Scientists were able to create new types of corn because they _____. ***Reading TEKS 7.10 H***

A) needed to use less CryIA(b)
B) were successful dog breeders
C) asked farmers what they needed
D) used DNA from bacteria

2. According to the passage, which of the following happened first? ***Reading TEKS 7.9 B***

F) Small poodles were bred together.
G) Scientists can take small pieces of DNA.
H) Scientists are exploring other crops.
J) Bacteria genes were added to corn.

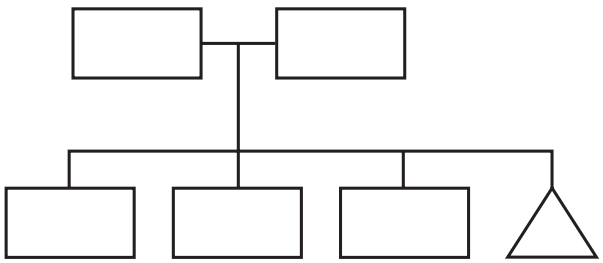
Reasoning and Skills

Read each question and choose the best answer.

1. The genetic makeup of an organism is called its genotype. Two plants are bred together and all of their offspring have a Tt genotype, yet one parent's genotype is TT. Which of the following is the most likely explanation for the Tt genotype of the offspring? ***Science TEKS 7.3 C***

A) The other parent plant's genotype is tt.
B) The offspring's phenotype is controlled by the T allele.
C) The offspring are called heterozygotes.
D) The 'T' and 't' are two alleles of the same gene.

Test-Taking Tip If a question contains a lot of information about genotypes, draw a Punnett Square to keep the information organized.



2. When an organism has a dominant and a recessive allele of a gene, only the dominant allele controls the organism's phenotype. Phenotypes can be represented by using shapes. According to the diagram above, the rectangle results from what kind of allele? ***Science TEKS 7.2 C***

F) recessive
G) mutant
H) dominant
J) incomplete dominant

Test-Taking Tip As you read the question, remember the difference between dominant and recessive alleles.

3. Some alleles have incomplete dominance, which means they make phenotypes that are intermediate between the two alleles. The drawing above shows a cross between a shaded plant and a white plant that carry alleles with incomplete dominance for flower color. Which of the following depicts what the offsprings' flowers might look like? ***Science TEKS 7.2 C***

A) 

B) 

C) 

D) 

Test-Taking Tip Cover up the answer choices, reread the question, and imagine what the correct answer should be. Then, read each answer choice.

Consider this question carefully before writing your answer on a separate sheet of paper.

4. The United States Department of Health funds many genetics research projects. How could this research help medical doctors? ***Science TEKS 7.14 C***

Test-Taking Tip Use scratch paper to list as many different ways that genetics relates to disease and medicine as you can think of. Then, write about one or two of these.