Chapter 5

Genetics: The Science of Heredity

CALIFORNIA Standards Preview

S 7.1 All living organisms are composed of cells, from just one to many trillions, whose details usually are visible only through a microscope. As a basis for understanding this concept:

a. Students know cells function similarly in all living organisms.

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.

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.

These puppies and their mother resemble each other in many ways. ▶

Video Preview

Discovery Channel School

Genetics: The Science of Heredity

Focus on the
BIG Idea

S 7.2

How are traits passed from parents to offspring?

Check What You Know

In a litter of puppies, some of the puppies have a black and white coat, and others have a red and white coat. What can you infer about how their parents look? What can you infer about the parents' DNA?

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

Use Suffixes

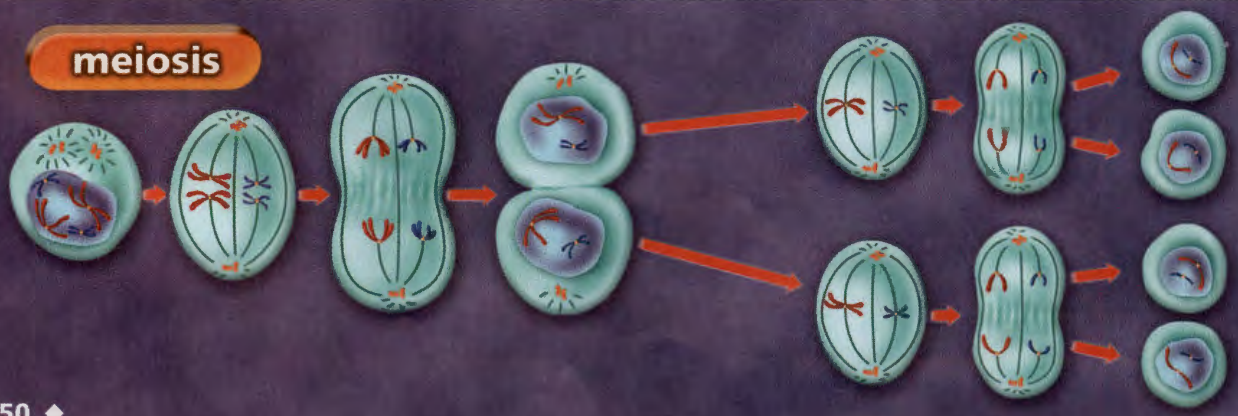
A suffix is a word part that is added to the end of a word to change its meaning. For example, the suffix *-tion* means "process of." If you add the suffix *-tion* to the verb *produce*, you get the noun *production*. *Production* means "the process of making."

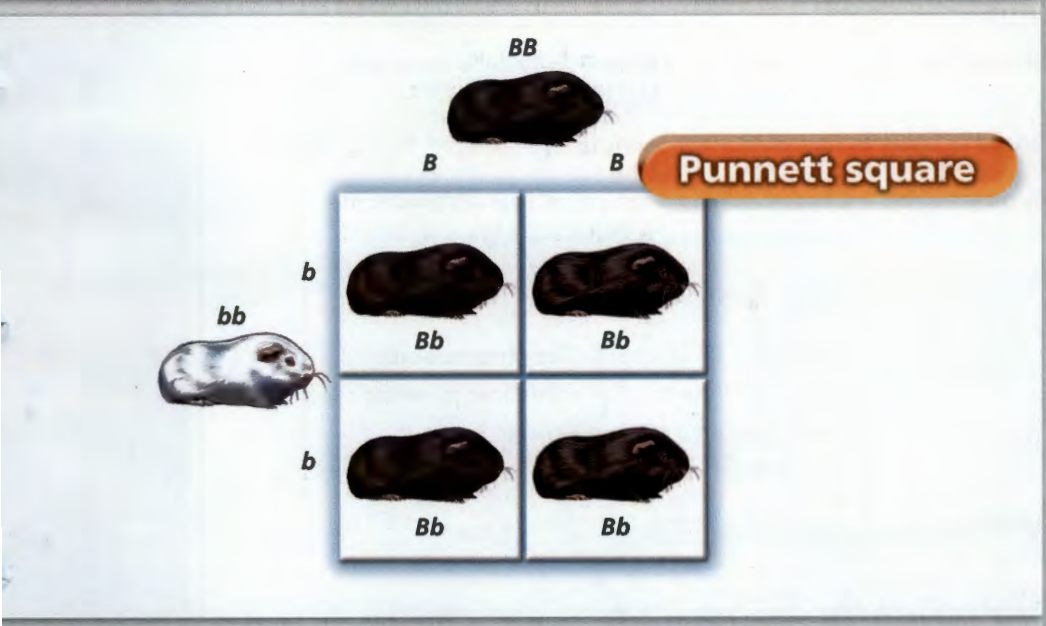
The table below lists some common suffixes and their meanings.

Suffix	Meaning of Suffix	Example and Meaning of Example
-ance, -ence	state of; quality of	**importance** State of being important
-ant, -ent	inclined to; likely to	**dependent** Likely to rely on something or someone else
-ity	state of; quality of	**simplicity** State of being simple or easy
-tion	process of; state of	**production** Process of making

Apply It!

1. What is the suffix in the word *dominant*? If the verb *dominate* means "to have control over," what do you think *dominant* means? What does *dominance* probably mean?
2. The word *probable* means "likely to happen." What does *probability* mean?





Chapter 5 Vocabulary

Section 1 (page 154)
heredity
trait
genetics
fertilization
purebred
gene
alleles
dominant allele
recessive allele
hybrid

Section 2 (page 162)
probability
Punnett square
phenotype
genotype
homozygous
heterozygous
codominance

Section 3 (page 170)
sexual reproduction
diploid
meiosis

Section 4 (page 175)
messenger RNA
transfer RNA
mutation

Interactive Textbook
Build Science Vocabulary Online
Visit: PHSchool.com
Web Code: cvj-2050

How to Read Science

Reading Skill

Take Notes

When you take notes, you write the important ideas in the textbook in shortened form.

- Use a red or blue heading as the title of your notes.
- In the left column, write questions about the text that follows the heading.
- Write the answers in the right column.
- Write a summary statement that expresses the main idea.

See the sample notes below, which are notes on part of Section 3.

Questions	Notes: Chromosomes and Inheritance
Where did Sutton find evidence that chromosomes were important in inheritance?	In grasshopper cells—body cells have 24 chromosomes, sex cells only 12.
What happens to chromosomes after fertilization?	Chromosomes form pairs. One chromosome in each pair comes from each parent.
Where are genes?	On chromosomes
	Summary Statement: The chromosome theory of inheritance says that parents pass genes to their offspring on chromosomes.

Apply It!

Review the notes in the right column.

1. What is one important idea found in the notes?
2. What question in the left column helps you recall the idea?

Finish these notes as you read Section 3. Also take notes on all of Section 4.

Lab zone

Standards Investigation

S 7.2.b

All in the Family

Did you ever wonder why some offspring resemble their parents while others do not? In this chapter, you'll learn how offspring come to have traits similar to those of their parents. You'll create a family of "paper pets" to explore how traits pass from parents to offspring.

Your Goal

To create a "paper pet" that will be crossed with a classmate's pet, and to determine what traits the offspring will have

To complete this investigation successfully, you must

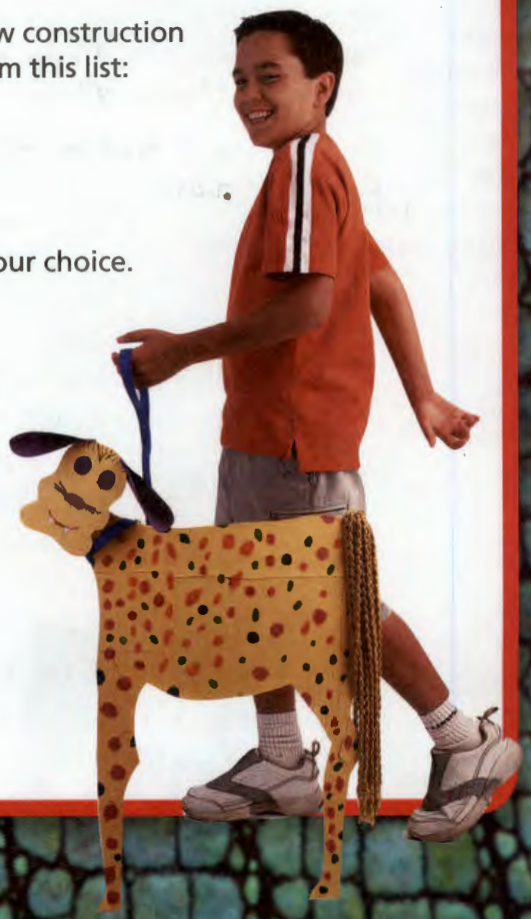
- create your own unique paper pet with five different traits
- cross your pet with another pet to produce six offspring
- determine what traits the offspring will have, and explain how they came to have those traits
- follow the safety guidelines in Appendix A

Plan It!

Cut out your pet from either blue or yellow construction paper. Choose other traits for your pet from this list:

- square eyes or round eyes
- oval nose or triangular nose
- pointed teeth or square teeth

Then create your pet using materials of your choice.



Section 1

Mendel's Work

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 were the results of Mendel's experiments, or crosses?
- What controls the inheritance of traits in organisms?

Key Terms

- heredity
- trait
- genetics
- fertilization
- purebred
- gene
- alleles
- dominant allele
- recessive allele
- hybrid

Lab zone Standards Warm-Up

What Does the Father Look Like?

1. Observe the colors of the kitten in the photo. Record the kitten's coat colors and pattern. Include as many details as you can.
2. Observe the mother cat in the photo. Record her coat color and pattern.

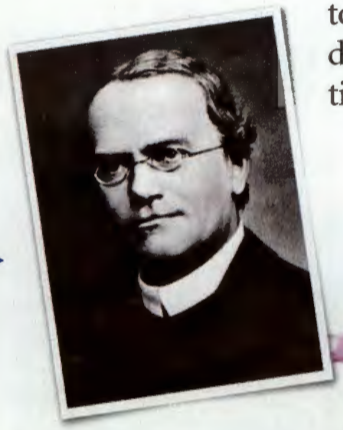
Think It Over

Inferring Based on your observations, describe what you think the kitten's father might look like. Identify the evidence on which you based your inference.

In the mid-nineteenth century, a priest named Gregor Mendel tended a garden in a central European monastery. Mendel's experiments in that peaceful garden would one day revolutionize the study of heredity. **Heredity** is the passing of physical characteristics from parents to offspring.

Mendel wondered why different pea plants had different characteristics. Some pea plants grew tall, while others were short. Some plants produced green seeds, while others had yellow seeds. Each different form of a characteristic, such as stem height or seed color, is called a **trait**. Mendel observed that the pea plants' traits were often similar to those of their parents. Sometimes, however, the plants had different traits from those of their parents.

Mendel experimented with thousands of pea plants to understand the process of heredity. Today, Mendel's discoveries form the foundation of **genetics**, the scientific study of heredity.



Gregor Mendel ▶

Mendel's Experiments

Figure 1 shows a pea plant's flower. The flower's petals surround the pistil and the stamens. The pistil produces female sex cells, or eggs. The stamens produce pollen, which contains the male sex cells, or sperm. A new organism begins to form when egg and sperm join in the process called **fertilization.** Before fertilization can happen in pea plants, pollen must reach the pistil of a pea flower. This process is called pollination.

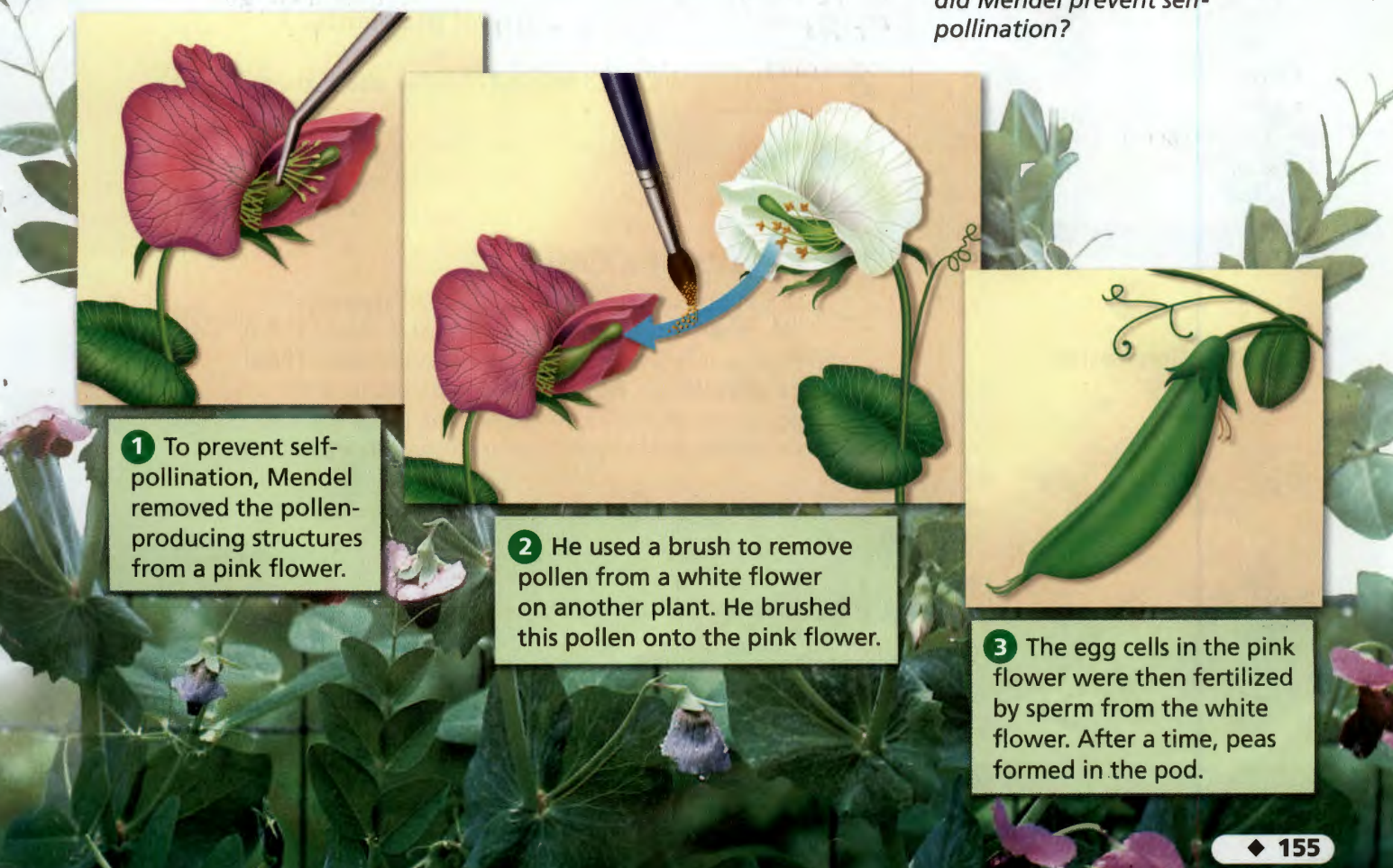
Pea plants are usually self-pollinating. In self-pollination, pollen from a flower lands on the pistil of the same flower. Mendel developed a method by which he cross-pollinated, or "crossed," pea plants. To cross two plants, he removed pollen from a flower on one plant. He then brushed the pollen onto a flower on a second plant.

Crossing Pea Plants What could you do to study the inheritance of traits in pea plants? Mendel decided to cross plants with contrasting traits—for example, tall plants and short plants. He started his experiments with true-breeding, or purebred plants. A **purebred** organism is the offspring of many generations that have the same trait. For example, purebred short pea plants always come from short parent plants.

FIGURE 1

Crossing Pea Plants

Gregor Mendel crossed pea plants that had different traits. The illustrations show how he did this. **Interpreting Diagrams** *How did Mendel prevent self-pollination?*



The F_1 Offspring In one experiment, Mendel crossed purebred tall plants with purebred short plants. Scientists today call these parent plants the parental generation, or P generation. The offspring from this cross are the first filial (FIL ee ul) generation, or the F_1 generation. The word *filial* comes from *filia* and *filius*, the Latin words for "daughter" and "son."

In Figure 2, notice that all the offspring in the F_1 generation were tall. Even though one of the parent plants was short, none of the offspring were short. The shortness trait seemed to disappear!

The F_2 Offspring When the plants in the F_1 generation were full-grown, Mendel allowed them to self-pollinate. Surprisingly, the plants in the F_2 (second filial) generation were a mix of tall and short plants. The shortness trait had reappeared, even though none of the F_1 parent plants were short. Mendel counted the tall and short plants. About three fourths of the plants were tall, while one fourth were short.

Experiments With Other Traits Mendel also crossed pea plants with other contrasting traits. Compare the two forms of each trait in Figure 3. **In all of Mendel's crosses, only one form of the trait appeared in the F_1 generation. However, in the F_2 generation, the "lost" form of the trait always reappeared in about one fourth of the plants.**

Reading Checkpoint **What did Mendel observe about the F_2 plants?**

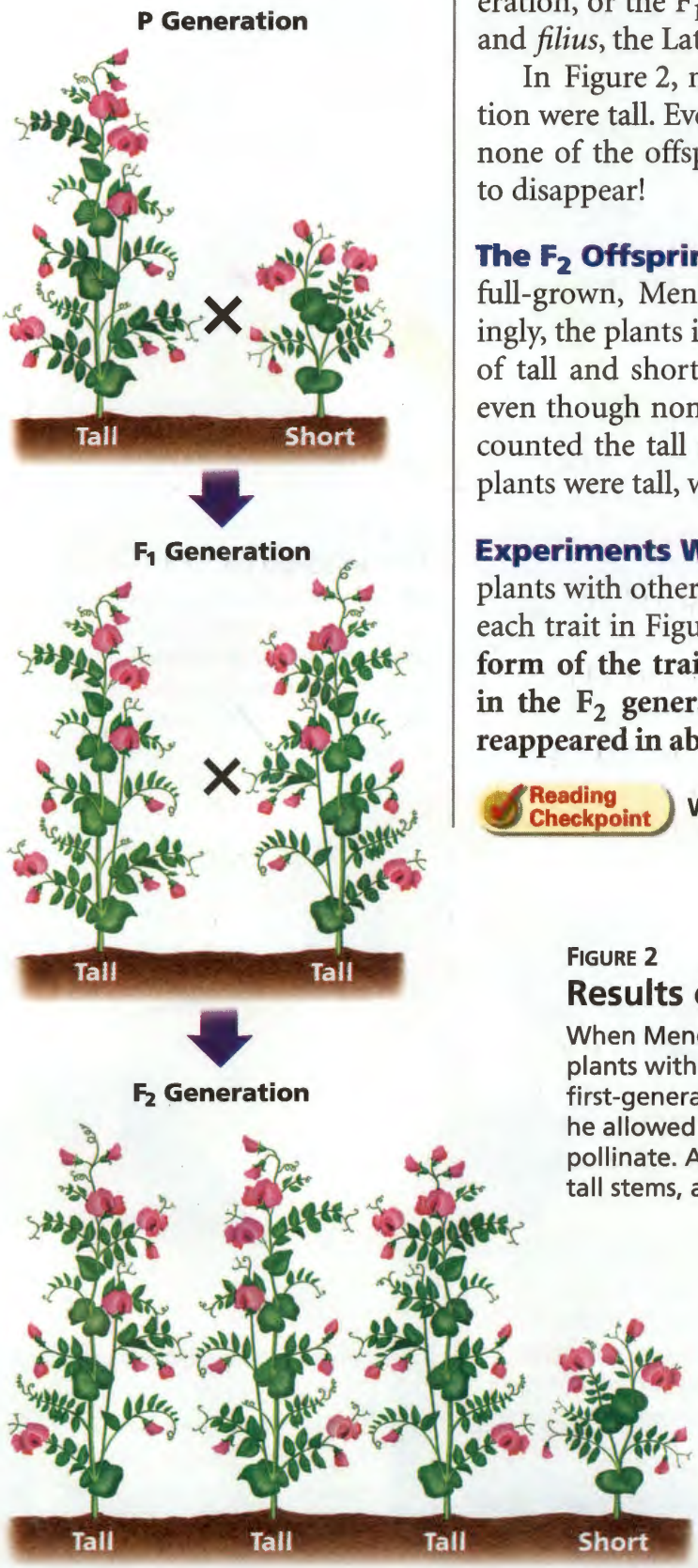


FIGURE 2
Results of a Cross
When Mendel crossed purebred tall-stemmed plants with purebred short-stemmed plants, the first-generation offspring all had tall stems. Then he allowed the first-generation plants to self-pollinate. About 75 percent of the offspring had tall stems, and about 25 percent had short stems.

Genetics of Pea Plants

Traits	Seed Shape	Seed Color	Seed Coat Color	Pod Shape	Pod Color	Flower Position	Stem Height
Controlled by Dominant Allele	 Round	 Yellow	 Gray	 Smooth	 Green	 Side	 Tall
Controlled by Recessive Allele	 Wrinkled	 Green	 White	 Pinched	 Yellow	 End	 Short

Dominant and Recessive Alleles

Mendel reached several conclusions on the basis of his experimental results. He reasoned that individual factors, or sets of genetic "information," must control the inheritance of traits in peas. The factors that control each trait exist in pairs. The female parent contributes one factor, while the male parent contributes the other factor. Finally, one factor in a pair can mask, or hide, the other factor. The tallness factor, for example, masked the shortness factor.

Genes and Alleles Today, scientists use the word **gene** for the factors that control a trait. **Alleles** (uh LEELZ) are the different forms of a gene. The gene that controls stem height in peas, for example, has one allele for tall stems and one allele for short stems. Each pea plant inherits two alleles from its parents—one allele from the egg and the other from the sperm. A pea plant may inherit two alleles for tall stems, two alleles for short stems, or one of each.

An organism's traits are determined by the alleles it inherits from its parents. Some alleles are dominant, while other alleles are recessive. A **dominant allele** is one whose trait always shows up in the organism when the allele is present. A **recessive allele,** on the other hand, is hidden whenever the dominant allele is present. A trait controlled by a recessive allele will only show up if the organism does not have the dominant allele. Figure 3 shows dominant and recessive alleles in Mendel's crosses.

FIGURE 3
Mendel studied several traits in pea plants.
Interpreting Diagrams *Is yellow seed color controlled by a dominant allele or a recessive allele?*

Lab zone Skills Activity

Predicting

In fruit flies, long wings are dominant over short wings. A scientist crossed a purebred long-winged male fruit fly with a purebred short-winged female. Predict the wing length of the F_1 offspring. If the scientist crossed a hybrid male F_1 fruit fly with a hybrid F_1 female, what would their offspring probably be like?

In pea plants, the allele for tall stems is dominant over the allele for short stems. Pea plants with one allele for tall stems and one allele for short stems will be tall. The allele for tall stems masks the allele for short stems. Only pea plants that inherit two recessive alleles for short stems will be short.

Alleles in Mendel's Crosses In Mendel's cross for stem height, the purebred tall plants in the P generation had two alleles for tall stems. The purebred short plants had two alleles for short stems. The F_1 plants each inherited an allele for tall stems from the tall parent and an allele for short stems from the short parent. Therefore, each F_1 plant had one allele for tall stems and one for short stems. The F_1 plants are called hybrids. A **hybrid** (HY brid) organism has two different alleles for a trait. All the F_1 plants are tall because the dominant allele for tall stems masks the recessive allele for short stems.

When Mendel crossed the F_1 plants, some of the offspring in the F_2 generation inherited two dominant alleles for tall stems. These plants were tall. Other F_2 plants inherited one dominant allele for tall stems and one recessive allele for short stems. These plants were also tall. The rest of the F_2 plants inherited two recessive alleles for short stems. These plants were short.

Symbols for Alleles Geneticists use letters to represent alleles. A dominant allele is represented by a capital letter. For example, the allele for tall stems is represented by *T*. A recessive allele is represented by the lowercase version of the letter. So, the allele for short stems would be represented by *t*. When a plant inherits two dominant alleles for tall stems, its alleles are written as *TT*. When a plant inherits two recessive alleles for short stems, its alleles are written as *tt*. When a plant inherits one allele for tall stems and one allele for short stems, its alleles are written as *Tt*.

FIGURE 4
Black Fur, White Fur
In rabbits, the allele for black fur is dominant over the allele for white fur. **Inferring** *What combination of alleles must the white rabbit have?*

Significance of Mendel's Contribution Mendel's work eventually changed scientists' ideas about heredity. Before Mendel, most people thought that genetic information could be blended to produce new traits. They thought that traits could be blended to form a combined version, the same way red and white paint can be mixed to make pink paint. According to this incorrect model, if a tall plant and a short plant were crossed, the offspring would all have medium height.

However, when Mendel crossed purebred tall and purebred short pea plants, the offspring were all tall. Mendel's experiments demonstrated that parents' traits do not simply blend in the offspring. Instead, traits are determined by individual, separate alleles inherited from each parent. Some of these alleles are recessive. If a trait is determined by a recessive allele, the trait can seem to disappear in the offspring.

Unfortunately, the importance of Mendel's discovery was not recognized during his lifetime. Then, in 1900, three different scientists rediscovered Mendel's work. These scientists quickly recognized the importance of Mendel's ideas. Because of his work, Mendel is often called the Father of Genetics.

Reading Checkpoint **If an allele is represented by a capital letter, what does this indicate?**

FIGURE 5
The Mendel Medal
Every year, to honor the memory of Gregor Mendel, an outstanding scientist is awarded the Mendel Medal.

Section 1 Assessment

S 7.2.d, E-LA: Reading 7.1.2

Vocabulary Skill **Suffixes** In the key term *fertilization*, what does the suffix *-tion* mean?

Reviewing Key Concepts

1. a. **Identifying** In Mendel's cross for stem height, what contrasting traits did the pea plants in the P generation exhibit?
   b. **Explaining** What trait or traits did the plants in the F_1 generation exhibit? When you think of the traits of the parent plants, why is this result surprising?
   c. **Comparing and Contrasting** Contrast the offspring in the F_1 generation to the offspring in the F_2 generation. What did the differences in the F_1 and F_2 offspring show Mendel?
2. a. **Defining** What is a dominant allele? What is a recessive allele?
   b. **Relating Cause and Effect** Explain how dominant and recessive alleles for the trait of stem height determine whether a pea plant will be tall or short.
   c. **Applying Concepts** Can a short pea plant ever be a hybrid for the trait of stem height? Why or why not? As part of your explanation, write the letters that represent the alleles for stem height of a short pea plant.

Lab zone At-Home Activity

Gardens and Heredity Some gardeners save the seeds produced by flowers and plant them in the spring. If there are gardeners in your family, ask them how closely the plants that grow from these seeds resemble the parent plants. Are the offspring's traits ever different from those of the parents?

Lab zone **Skills Lab**

Go Online PHSchool.com
For: Data sharing
Visit: PHSchool.com
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Take a Class Survey

S 7.2.d

Problem

Are traits controlled by dominant alleles more common than traits controlled by recessive alleles?

Skills Focus

developing hypotheses, interpreting data

Materials

- mirror (optional)

Procedure

PART 1 Dominant and Recessive Alleles

1. Write a hypothesis reflecting your ideas about the problem. Then copy the data table.
2. For each of the traits listed in the data table, work with a partner to determine which trait you have. Circle that trait in your data table.
3. Count the number of students in your class who have each trait. Record that number in your data table. Also record the total number of students.

PART 2 Are Your Traits Unique?

4. Look at the circle of traits on the opposite page. All the traits in your data table appear in the circle. Place the eraser end of your pencil on the trait in the small central circle that applies to you—either free ear lobes or attached ear lobes.
5. Look at the two traits touching the space your eraser is on. Move your eraser onto the next description that applies to you. Continue using your eraser to trace your traits until you reach a number on the outside rim of the circle. Share that number with your classmates.

Analyze and Conclude

1. **Observing** The traits listed under Trait 1 in the data table are controlled by dominant alleles. The traits listed under Trait 2 are controlled by recessive alleles. Which traits controlled by dominant alleles were shown by a majority of students? Which traits controlled by recessive alleles were shown by a majority of students?


Free ear lobe


Widow's peak


Cleft chin

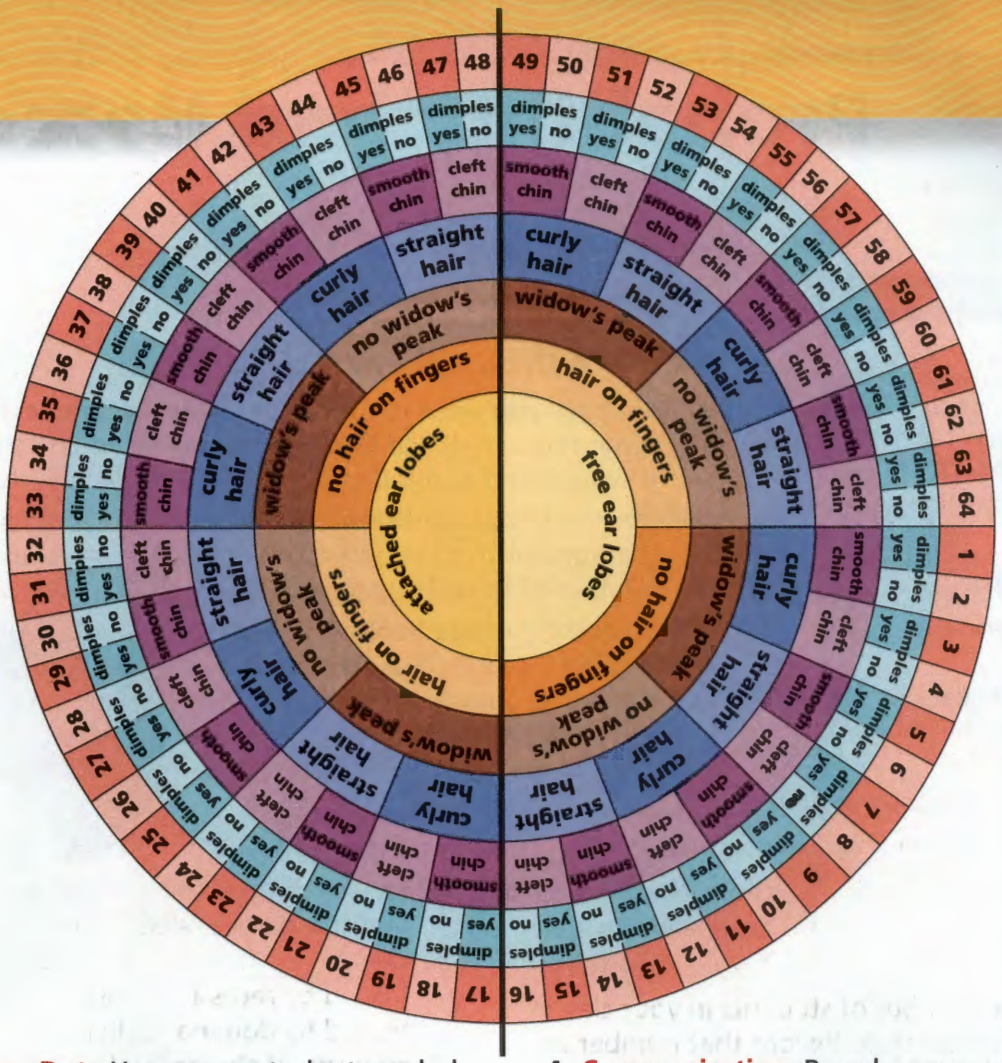

Dimple


Attached ear lobe


No widow's peak


No cleft chin


No dimple



2. **Interpreting Data** How many students ended up on the same number on the circle of traits? How many students were the only ones to have their number? What do the results suggest about each person's combination of traits?

3. **Developing Hypotheses** Do your data support the hypothesis you proposed in Step 1? Write an answer with examples.

4. **Communicating** Based on your observation of traits in this lab, write a paragraph explaining why people look so different from one another.

Design an Experiment

Do people who are related to each other show more genetic similarity than unrelated people? Write a hypothesis. Then design an experiment to test your hypothesis. *Obtain your teacher's permission before carrying out your investigation.*

Data Table

Total Number of Students_____

	Trait 1	Number	Trait 2	Number
A	Free ear lobes		Attached ear lobes	
B	Hair on fingers		No hair on fingers	
C	Widow's peak		No widow's peak	
D	Curly hair		Straight hair	
E	Cleft chin		Smooth chin	
F	Smile dimples		No smile dimples	

Probability and Heredity

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 is probability and how does it help explain the results of genetic crosses?
- What is meant by genotype and phenotype?
- What is codominance?

Key Terms

- probability
- Punnett square
- phenotype
- genotype
- homozygous
- heterozygous
- codominance

Lab zone Standards Warm-Up

What's the Chance?

1. Suppose you were to toss a coin 20 times. Predict how many times the coin would land with heads up and how many times it would land with tails up.
2. Now test your prediction by tossing a coin 20 times. Record the number of times the coin lands with heads up and the number of times it lands with tails up.
3. Combine the data from the entire class. Record the total number of tosses, the number of heads, and the number of tails.

Think It Over

Predicting How did your results in Step 2 compare to your prediction? How can you account for any differences between your results and the class results?

On a brisk fall afternoon, the stands are packed with cheering football fans. Today is the big game between North Shore and South Shore high schools, and it's almost time for the kickoff. Suddenly, the crowd becomes silent, as the referee is about to toss a coin. The outcome of the coin toss will decide which team kicks the ball and which receives it. The captain of the visiting North Shore team says "heads." If the coin lands with heads up, North Shore High wins the toss and the right to decide whether to kick or receive the ball.

What is the chance that North Shore High will win the coin toss? To answer this question, you need to understand the principles of probability.

Principles of Probability

If you did the Standards Warm-Up activity, you used the principles of **probability** to predict the results of a particular event. In this case, the event was the toss of a coin. **Probability is a number that describes how likely it is that a certain event will occur.**

Go Online NSTA SciLinks
For: Links on probability and genetics
Visit: www.SciLinks.org
Web Code: scn-0332

Mathematics of Probability Each time you toss a coin, there are two possible ways that the coin can land—heads up or tails up. Each of these two events is equally likely to occur. In mathematical terms, you can say that the probability that a tossed coin will land with heads up is 1 in 2. There is also a 1 in 2 probability that the coin will land with tails up. A 1 in 2 probability can also be expressed as the fraction $\frac{1}{2}$ or as a percent—50 percent.

The laws of probability predict what is likely to occur, not necessarily what will occur. If you tossed a coin 20 times, you might expect it to land with heads up 10 times and with tails up 10 times. However, you might not get these results. You might get 11 heads and 9 tails, or 8 heads and 12 tails. The more tosses you make, the closer your actual results will be to the results predicted by probability.

Independence of Events When you toss a coin more than once, the results of one toss do not affect the results of the next toss. Each event occurs independently. For example, suppose you toss a coin five times and it lands with heads up each time. What is the probability that it will land with heads up on the next toss? Because the coin landed heads up on the previous five tosses, you might think that it would be likely to land heads up on the next toss. However, this is not the case. The probability of the coin landing heads up on the next toss is still 1 in 2, or 50 percent. The results of the first five tosses do not affect the result of the sixth toss.

Reading Checkpoint **What is probability?**

Math Skills

Percentage

One way you can express a probability is as a percentage. A percentage (%) is a number compared to 100. For example, 50% means 50 out of 100.

Suppose that 3 out of 5 tossed coins landed with heads up. Here's how you can calculate what percent of the coins landed with heads up.

1. Write the comparison as a fraction.

$$\text{3 out of 5} = \frac{3}{5}$$

2. Multiply the fraction by 100% to express it as a percentage.

$$\frac{3}{5} \times \frac{100\%}{1} = 60\%$$

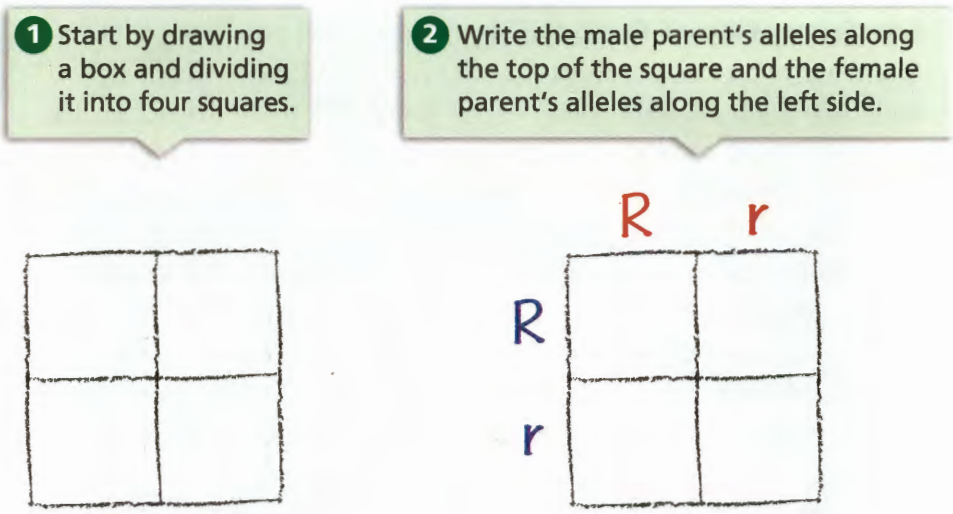
Practice Problem Suppose 3 out of 12 coins landed with tails up. How can you express this as a percent?

FIGURE 6
A Coin Toss
The result of a coin toss can be explained by probability.

FIGURE 7

How to Make a Punnett Square

The diagrams show how to make a Punnett square. In this cross, both parents are heterozygous for the trait of seed shape. *R* represents the dominant round allele, and *r* represents the recessive wrinkled allele.



Probability and Genetics

How is probability related to genetics? To answer this question, think back to Mendel's experiments with peas. Remember that Mendel carefully counted the offspring from every cross that he carried out. When Mendel crossed two plants that were hybrid for stem height (*Tt*), three fourths of the F_1 plants had tall stems. One fourth of the plants had short stems.

Each time Mendel repeated the cross, he obtained similar results. Mendel realized that the mathematical principles of probability applied to his work. He could say that the probability of such a cross producing a tall plant was 3 in 4. The probability of producing a short plant was 1 in 4. Mendel was the first scientist to recognize that the principles of probability can be used to predict the results of genetic crosses.

Punnett Squares A tool that can help you understand how the laws of probability apply to genetics is called a Punnett square. A **Punnett square** is a chart that shows all the possible combinations of alleles that can result from a genetic cross. Geneticists use Punnett squares to show all the possible outcomes of a genetic cross, and to determine the probability of a particular outcome.

Figure 7 shows how to construct a Punnett square. In this case, the Punnett square shows a cross between two hybrid pea plants with round seeds (*Rr*). The allele for round seeds (*R*) is dominant over the allele for wrinkled seeds (*r*). Each parent can pass either of its alleles, *R* or *r*, to its offspring. The boxes in the Punnett square represent the possible combinations of alleles that the offspring can inherit.

Reading Checkpoint **What is a Punnett square?**

Lab zone Try This Activity

Coin Crosses

Here's how you can use coins to model Mendel's cross between two *Tt* pea plants.

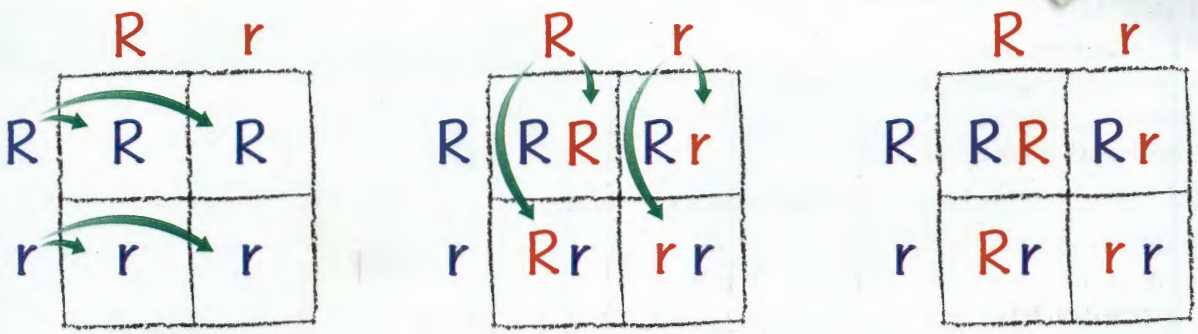
1. Place a small piece of masking tape on each side of two coins.
2. Write a *T* (for tall) on one side of each coin and a *t* (for short) on the other.
3. Toss both coins together 20 times. Record the letter combinations that you obtain from each toss.

Interpreting Data How many of the offspring would be tall plants? (*Hint:* What different letter combinations would result in a tall plant?) How many would be short? Convert your results to percentages. Then compare your results to Mendel's.

3 Copy the female parent's alleles into the boxes to their right.

4 Copy the male parent's alleles into the boxes beneath them.

5 The completed Punnett square shows all the possible allele combinations in the offspring.

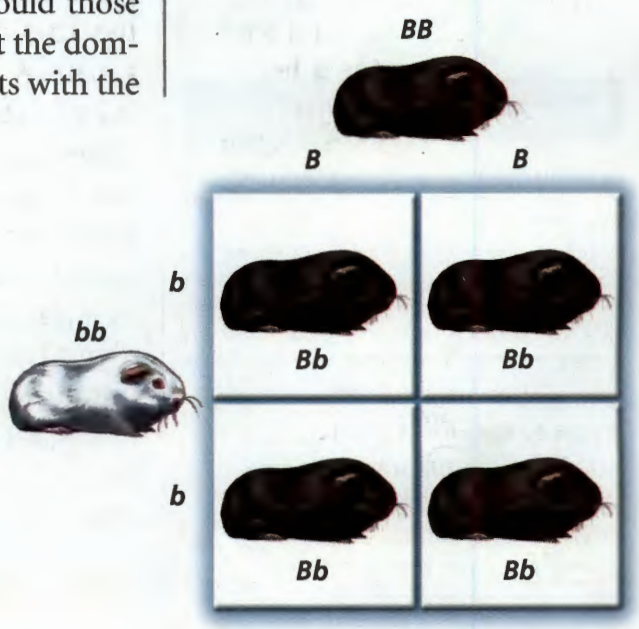


Using a Punnett Square You can use a Punnett square to calculate the probability that offspring with a certain combination of alleles will result. **In a genetic cross, the allele that each parent will pass on to its offspring is based on probability.** The completed Punnett square in Figure 7 shows four possible combinations of alleles. The probability that an offspring will be *RR* is 1 in 4, or 25 percent. The probability that an offspring will be *rr* is also 1 in 4, or 25 percent. Notice, however, that the *Rr* allele combination appears in two boxes in the Punnett square. This is because there are two possible ways in which this combination can occur. So the probability that an offspring will be *Rr* is 2 in 4, or 50 percent.

When Mendel crossed hybrid plants with round seeds, he discovered that about three fourths of the plants (75 percent) had round seeds. The remaining one fourth of the plants (25 percent) produced wrinkled seeds. Plants with the *RR* allele combination would produce round seeds. So too would those plants with the *Rr* allele combination. Remember that the dominant allele masks the recessive allele. Only those plants with the *rr* allele combination would have wrinkled seeds.

Predicting Probabilities You can use a Punnett square to predict probabilities. For example, Figure 8 shows a cross between a purebred black guinea pig and a purebred white guinea pig. The allele for black fur is dominant over the allele for white fur. Notice that only one allele combination is possible in the offspring—*Bb*. All of the offspring will inherit the dominant allele for black fur. Because of this, all of the offspring will have black fur. There is a 100 percent probability that the offspring will have black fur.

FIGURE 8
Guinea Pig Punnett Square
This Punnett square shows a cross between a black guinea pig (*BB*) and a white guinea pig (*bb*).
Calculating *What is the probability that an offspring will have white fur?*



Reviewing Math: Algebra and Functions 7.1.5

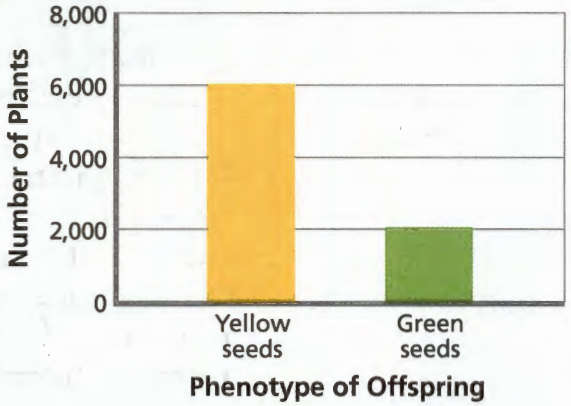
Math Analyzing Data

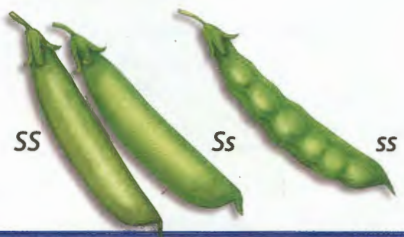
What Are the Genotypes?

Mendel allowed several F_1 pea plants with yellow seeds to self-pollinate. The graph shows the approximate numbers of the F_2 offspring with yellow seeds and with green seeds.

1. **Reading Graphs** How many F_2 offspring had yellow seeds? How many had green seeds?
2. **Calculating** Use the information in the graph to calculate the total number of offspring that resulted from this cross. Then calculate the percentage of the offspring with yellow peas, and the percentage with green peas.
3. **Inferring** Use the answers to Question 2 to infer the probable genotypes of the parent plants. (*Hint:* Construct Punnett squares with the possible genotypes of the parents.)

One of Mendel's Crosses





Phenotypes and Genotypes

Phenotype	Genotype
Smooth pods	*SS*
Smooth pods	*Ss*
Pinched pods	*ss*

FIGURE 9
The phenotype of an organism is its physical appearance. Its genotype is its genetic makeup.
Interpreting Tables *How many genotypes are there for the smooth-pod phenotype?*

Phenotypes and Genotypes

Two terms that geneticists use are **phenotype** (FEE noh typ) and **genotype** (JEN uh typ). **An organism's phenotype is its physical appearance, or visible traits. An organism's genotype is its genetic makeup, or allele combinations.**

To understand the difference between phenotype and genotype, look at Figure 9. The allele for smooth pea pods (*S*) is dominant over the allele for pinched pea pods (*s*). All of the plants with at least one dominant allele have the same phenotype—they all produce smooth pods. However, the plants can have two different genotypes—*SS* or *Ss*. If you were to look at the plants with smooth pods, you would not be able to tell the difference between those with the *SS* genotype and those with the *Ss* genotype. The plants with pinched pods, on the other hand, would all have the same phenotype—pinched pods—as well as the same genotype—*ss*.

Geneticists use two additional terms to describe genotypes. An organism that has two identical alleles for a trait is said to be **homozygous** (hoh moh ZY gus) for that trait. A smooth-pod plant that has the alleles *SS* and a pinched-pod plant with the alleles *ss* are both homozygous. An organism that has two different alleles for a trait is **heterozygous** (het ur oh ZY gus). A smooth-pod plant with the alleles *Ss* is heterozygous. Mendel used the term *hybrid* to describe heterozygous pea plants.

Codominance

For all of the traits that Mendel studied, one allele was dominant while the other was recessive. This is not always the case. For some alleles, an inheritance pattern called **codominance** exists. **In codominance, the alleles are neither dominant nor recessive. As a result, both alleles are expressed in the offspring.**

Look at Figure 10. Mendel's principle of dominant and recessive alleles does not explain why the heterozygous chickens have both black and white feathers. The alleles for feather color are codominant—neither dominant nor recessive. As you can see, neither allele is masked in the heterozygous chickens. Notice also that the codominant alleles are written as capital letters with superscripts—F^B for black feathers and F^W for white feathers. As the Punnett square shows, heterozygous chickens have the F^BF^W allele combination.

Reading Checkpoint **How are the symbols for codominant alleles written?**

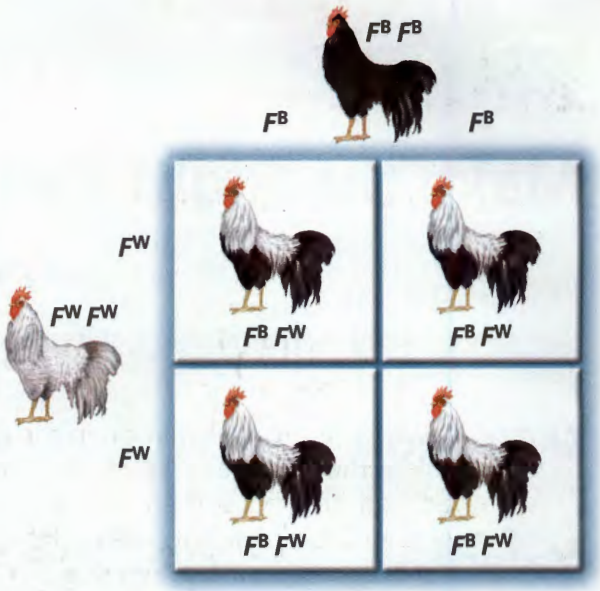


FIGURE 10
Codominance
The offspring of the cross in this Punnett square will have both black and white feathers. **Classifying** *Will the offspring be heterozygous or homozygous? Explain your answer.*

Section 2 Assessment

S 7.2.d, E-LA: Reading 7.1.2

Vocabulary Skill **Suffixes** Use the meanings of the suffixes *-ant* and *-ance* to contrast the meanings of *codominant* and *codominance*.

Reviewing Key Concepts

1. a. **Reviewing** What is probability?
   b. **Explaining** If you know the parents' alleles for a trait, how can you use a Punnett square to predict the probable genotypes of the offspring?
   c. **Predicting** A pea plant with round seeds has the genotype *Rr*. You cross this plant with a wrinkled-seed plant, genotype *rr*. What is the probability that the offspring will have wrinkled seeds? (Use a Punnett square.)
2. a. **Defining** Define *genotype* and *phenotype*.
   b. **Relating Cause and Effect** Explain how two organisms can have the same phenotype but different genotypes. Give an example.
   c. **Applying Concepts** A pea plant has a tall stem. What are its possible genotypes?
3. a. **Explaining** What is codominance? Give an example of codominant alleles and explain why they are codominant.
   b. **Applying Concepts** What is the phenotype of a chicken with the genotype F^BF^W?

Math Practice

4. **Ratios** A scientist crossed a tall pea plant with a short pea plant. Of the offspring, 13 were tall and 12 were short. Write the ratio of each phenotype to the total number of offspring. Express the ratios as fractions.
5. **Percentage** Use the fractions to calculate the percentage of the offspring that were tall and the percentage that were short.

Make the Right Call!

S 7.2.d

Problem

How can you predict the possible results of genetic crosses?

Skills Focus

making models, interpreting data

Materials

- 2 small paper bags
- marking pen
- 3 blue marbles
- 3 white marbles

Procedure

1. Label one bag "Bag 1, Female Parent." Label the other bag "Bag 2, Male Parent." Then read over Part 1, Part 2, and Part 3 of this lab. Write a prediction about the kinds of offspring you expect from each cross.

PART 1 Crossing Two Homozygous Parents

2. Copy the data table and label it *Data Table 1*. Then place two blue marbles in Bag 1. This pair of marbles represents the female parent's alleles. Use the letter *B* to represent the dominant allele for blue color.
3. Place two white marbles in Bag 2. Use the letter *b* to represent the recessive allele for white color.
4. For Trial 1, remove one marble from Bag 1 without looking in the bag. Record the result in your data table. Return the marble to the bag. Again, without looking in the bag, remove one marble from Bag 2. Record the result in your data table. Return the marble to the bag.
5. In the column labeled Offspring's Alleles, write *BB* if you removed two blue marbles, *bb* if you removed two white marbles, or *Bb* if you removed one blue marble and one white marble.
6. Repeat Steps 4 and 5 nine more times.

PART 2 Crossing Homozygous and Heterozygous Parents

7. Place two blue marbles in Bag 1. Place one white marble and one blue marble in Bag 2. Copy the data table again, and label it *Data Table 2*.
8. Repeat Steps 4 and 5 ten times.

Data Table

Number _____

Trial	Allele From Bag 1 (Female Parent)	Allele From Bag 2 (Male Parent)	Offspring's Alleles
1			
2			
3			
4			
5			
6			

PART 3 Crossing Two Heterozygous Parents

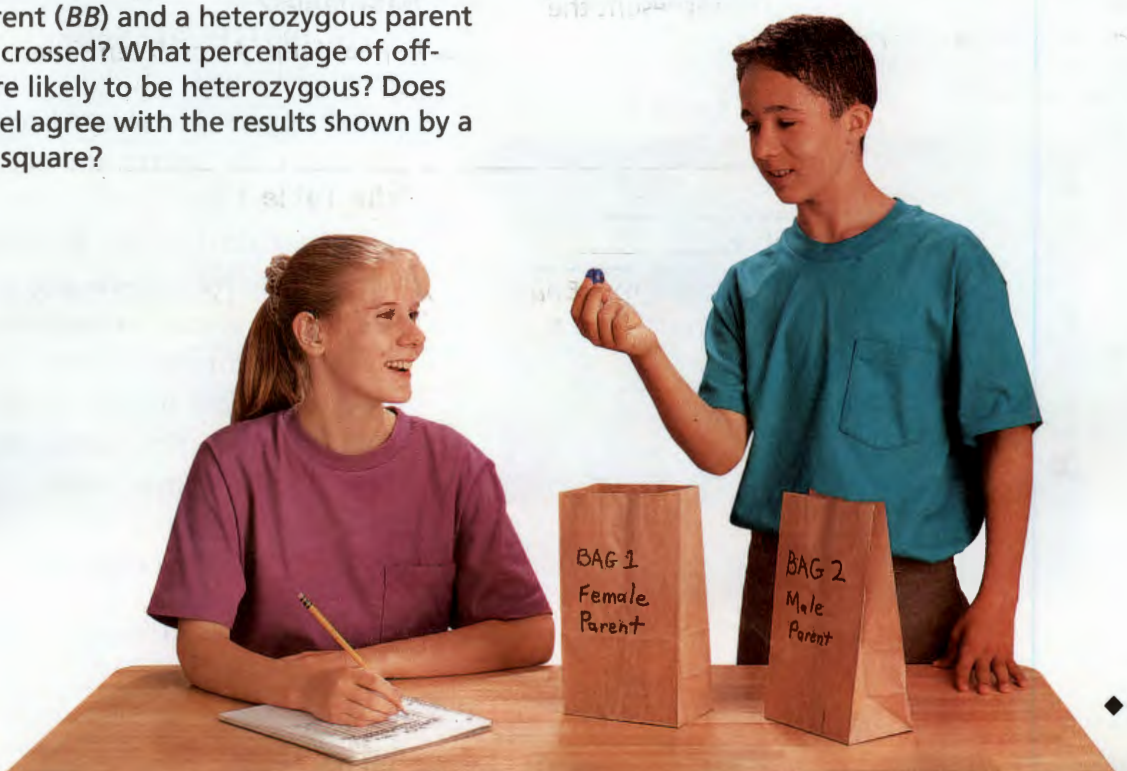
9. Place one blue marble and one white marble in Bag 1. Place one blue marble and one white marble in Bag 2. Copy the data table again and label it *Data Table 3*.
10. Repeat Steps 4 and 5 ten times.

Analyze and Conclude

1. **Making Models** Make a Punnett square for each of the crosses you modeled in Part 1, Part 2, and Part 3.
2. **Interpreting Data** According to your results in Part 1, how many different kinds of offspring are possible when the homozygous parents (*BB* and *bb*) are crossed? Do the results you obtained using the marble model agree with the results shown by a Punnett square?
3. **Predicting** According to your results in Part 2, what percentage of offspring are likely to be homozygous when a homozygous parent (*BB*) and a heterozygous parent (*Bb*) are crossed? What percentage of offspring are likely to be heterozygous? Does the model agree with the results shown by a Punnett square?
4. **Making Models** According to your results in Part 3, what different kinds of offspring are possible when two heterozygous parents (*Bb* × *Bb*) are crossed? What percentage of each type of offspring are likely to be produced? Does the model agree with the results of a Punnett square?
5. **Inferring** For Part 3, if you did 100 trials instead of 10 trials, would your results be closer to the results shown in a Punnett square? Explain.
6. **Communicating** In a paragraph, explain how the marble model compares with a Punnett square. How are the two methods alike? How are they different?

More to Explore

In peas, the allele for yellow seeds (*Y*) is dominant over the allele for green seeds (*y*). What possible crosses do you think could produce a heterozygous plant with yellow seeds (*Yy*)? Use the marble model and Punnett squares to test your predictions.



Section 3

The Cell and Inheritance

CALIFORNIA Standards Focus

S 7.2.b Students know sexual reproduction produces offspring that inherit half their genes from each parent.

- What role do chromosomes play in inheritance?
- What events occur during meiosis?
- What is the relationship between chromosomes and genes?

Key Term

- sexual reproduction
- diploid
- meiosis

Lab zone Standard Warm-Up

Which Chromosome Is Which?

Mendel did not know about chromosomes or their role in genetics. Today we know that genes are located on chromosomes.

1. Label two craft sticks with the letter *A*. The craft sticks represent a pair of chromosomes in the female parent. Turn the sticks face down on a piece of paper.
2. Label two more craft sticks with the letter *a*. These represent a pair of chromosomes in the male parent. Turn the sticks face down on another piece of paper.
3. Turn over one craft stick "chromosome" from each piece of paper. Move both sticks to a third piece of paper. These represent a pair of chromosomes in the offspring. Note the allele combination that the offspring received.

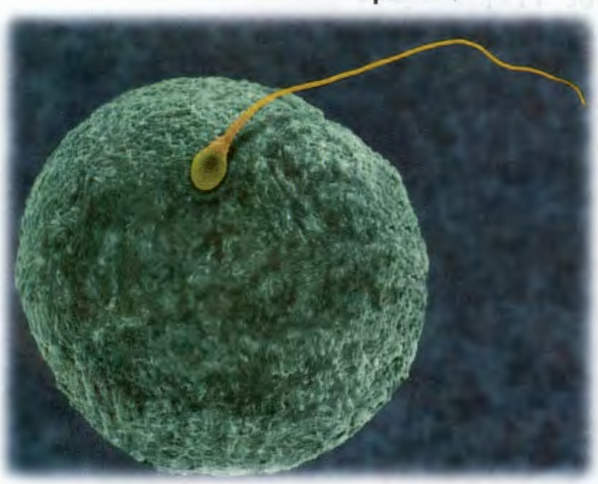
Think It Over

Making Models Use this model to explain how chromosomes are involved in the inheritance of alleles.

Mendel's work showed that genes exist. But scientists in the early twentieth century did not know what structures in cells contained genes. The search for the answer to this puzzle is something like a mystery story. The story could be called "The Clue in the Grasshopper's Cells."

In 1903, Walter Sutton, an American geneticist, was studying the cells of grasshoppers. He wanted to understand how sex cells (sperm and egg) form. Sutton focused on the movement of chromosomes during the formation of sex cells. Sex cells form during sexual reproduction. In **sexual reproduction,** genetic material from two parents combines to produce a new organism, which differs from both parents. Sutton hypothesized that chromosomes were the key to understanding how offspring have traits similar to those of their parents.

Sperm ▼



Egg ▶

FIGURE 11
Sex Cells
The large egg is a female sex cell, and the smaller sperm is a male sex cell.

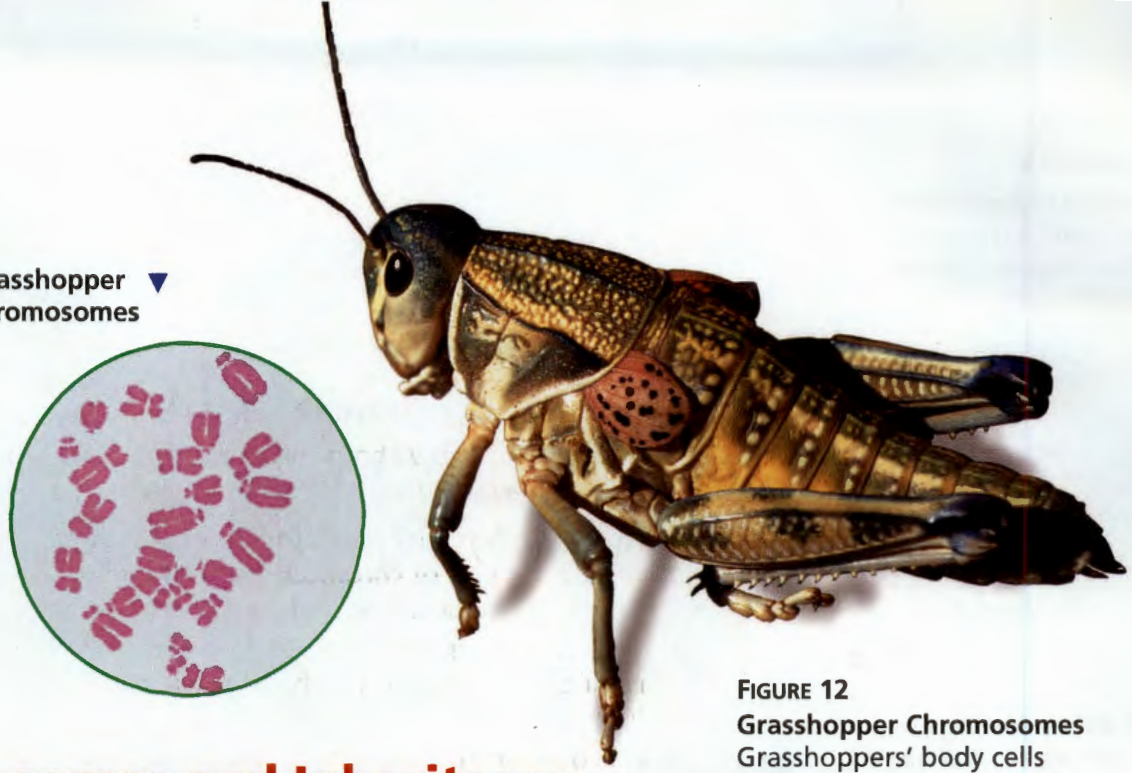


FIGURE 12
Grasshopper Chromosomes Grasshoppers' body cells have twice the number of chromosomes as their sex cells. **Applying Concepts** *What is the function of chromosomes?*

Chromosomes and Inheritance

Sutton needed evidence to support his hypothesis that chromosomes were important in the inheritance of traits. He found that evidence in grasshoppers' cells. The body cells of a grasshopper have 24 chromosomes. To his surprise, Sutton found that the grasshopper's sex cells have only 12 chromosomes. In other words, a grasshopper's sex cells have exactly half the number of chromosomes found in its body cells.

Chromosome Pairs Sutton observed what happened when a sperm cell and an egg cell joined during fertilization. The fertilized egg that formed was diploid. A **diploid** cell contains two sets of chromosomes, one set from each parent. The fertilized grasshopper egg had 24 chromosomes, or 12 pairs. One chromosome in each pair came from each parent. As result, the grasshopper offspring had exactly the same number of chromosomes in its cells as did each of its parents.

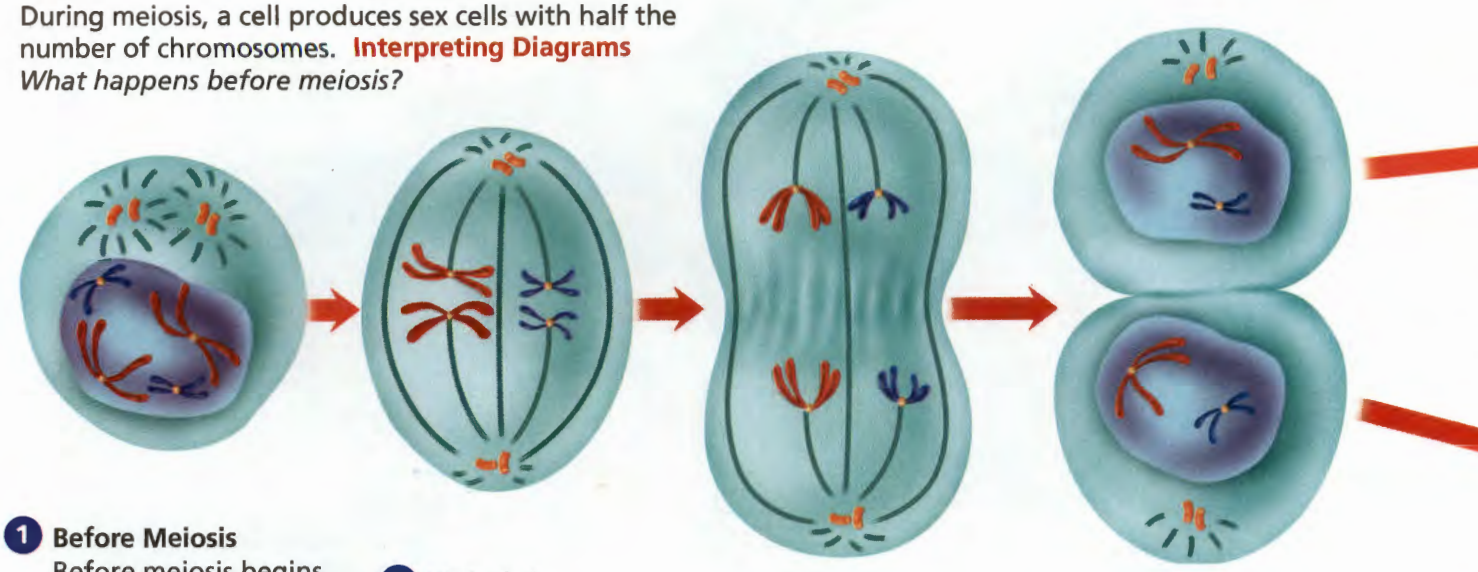
Genes on Chromosomes Recall that alleles are different forms of a gene. From the results of Mendel's work, Sutton knew that alleles exist in pairs in an organism. One allele in a pair comes from the organism's female parent and the other allele comes from the male parent. Sutton realized that paired alleles were carried on paired chromosomes. Sutton's idea came to be known as the chromosome theory of inheritance. **According to the chromosome theory of inheritance, genes are carried from parents to their offspring on chromosomes.**

Reading Checkpoint **What is the relationship between alleles and chromosomes?**

FIGURE 13

Meiosis

During meiosis, a cell produces sex cells with half the number of chromosomes. **Interpreting Diagrams** *What happens before meiosis?*



1 Before Meiosis
Before meiosis begins, every chromosome in the parent cell is copied. Centromeres hold the two chromatids together.

2 Meiosis I

A The chromosome pairs line up in the center of the cell.

B The pairs separate and move to opposite ends of the cell.

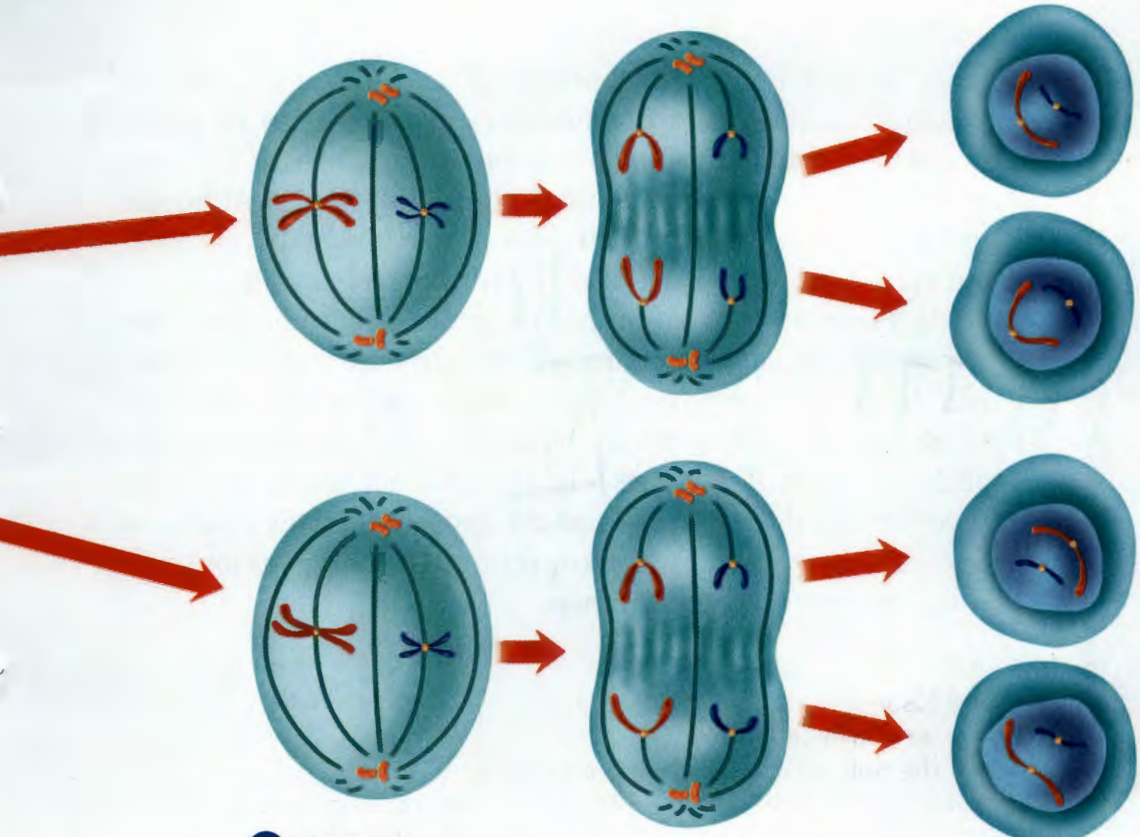
C Two cells form, each with half the number of chromosomes. Each chromosome still has two chromatids.

Meiosis

How do sex cells end up with half the number of chromosomes as body cells? To answer this question, you need to understand the events that occur during meiosis. **Meiosis** (my OH sis) is the process by which the number of chromosomes is reduced by half to form sex cells—sperm and eggs.

What Happens During Meiosis You can trace the events of meiosis in Figure 13. In this example, each parent cell has four chromosomes arranged in two pairs. **During meiosis, the chromosome pairs separate and are distributed to two different cells. The resulting sex cells have only half as many chromosomes as the other cells in the organism.** The sex cells in Figure 13 end up with only two chromosomes each—half the number found in the parent cell. Each sex cell has one chromosome from each original pair.

When sex cells combine to form an organism, each sex cell contributes half the normal number of chromosomes. Thus, the offspring gets the normal number of chromosomes—half from each parent.



3 Meiosis II

A The chromosomes with their two chromatids move to the center of the cell.

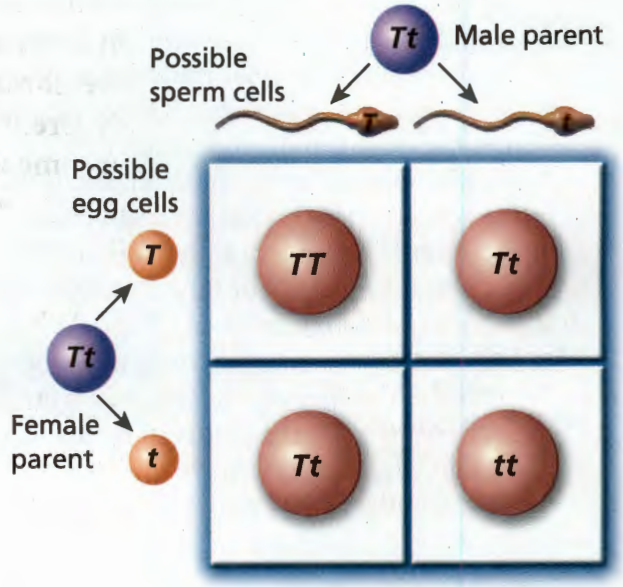
B The centromeres split, and the chromatids separate. Single chromosomes move to opposite ends of the cell.

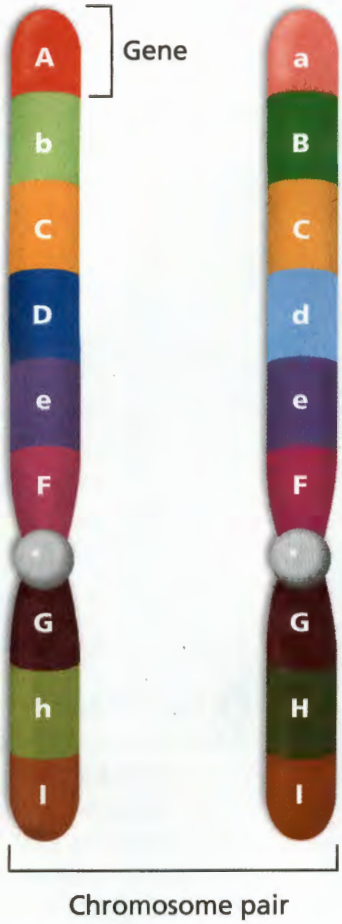
4 End of Meiosis
Four sex cells have been produced. Each cell has only half the number of chromosomes that the parent cell had at the beginning of meiosis. Each cell has only one chromosome from each original pair.

Meiosis and Punnett Squares A Punnett square is actually a way to show the events that occur at meiosis. When the chromosome pairs separate and go into two different sex cells, so do the alleles carried on each chromosome. One allele from each pair goes to each sex cell.

In Figure 14, you can see how the Punnett square accounts for the separation of alleles during meiosis. As shown across the top of the Punnett square, half of the sperm cells from the male parent will receive the chromosome with the *T* allele. The other half of the sperm cells will receive the chromosome with the *t* allele. In this example, the same is true for the egg cells from the female parent, as shown down the left side of the Punnett square. Depending on which sperm cell combines with which egg cell, one of the allele combinations shown in the boxes will result.

FIGURE 14
Meiosis Punnett Square
Suppose both parents are heterozygous for the trait of stem height. The Punnett square shows the possible allele combinations after fertilization.





A Lineup of Genes

Each human body cell contains 23 chromosome pairs, or 46 chromosomes. **Chromosomes are made up of many genes joined together like beads on a string.** Plant and animal chromosomes contain many thousands of genes. Although you have only 23 pairs of chromosomes, your body cells each contain about 35,000 genes. Each gene controls a trait.

In Figure 15, one chromosome in the pair came from the female parent. The other chromosome came from the male parent. There are usually two copies of every gene. The genes are lined up in the same order on both chromosomes. However, the alleles for some of the genes might be different. For example, the organism has the *A* allele on one chromosome and the *a* allele on the other. As you can see, this organism is heterozygous for some traits and homozygous for others.

FIGURE 15
Genes on Chromosomes
The chromosomes in a pair may have different alleles for some genes and the same alleles for others. **Classifying** *For which genes is this organism homozygous? For which genes is it heterozygous?*

Section 3 Assessment

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

Target Reading Skill **Take Notes** Use your notes to help answer the questions below.

Reviewing Key Concepts

1. a. **Comparing and Contrasting** According to Sutton's observations, how does the number of chromosomes in a grasshopper's body cells compare to the number in its sex cells?
   b. **Describing** Describe what happens to the number of chromosomes when two grasshopper sex cells join in fertilization.
   c. **Explaining** How do Sutton's observations about chromosome number support the chromosome theory of inheritance?
2. a. **Defining** What is meiosis?
   b. **Interpreting Diagrams** Briefly describe meiosis I and meiosis II. Refer to Figure 13.
   c. **Sequencing** Use the events of meiosis to explain why a sex cell normally does not receive both chromosomes from a pair.
3. a. **Describing** How are genes arranged on a chromosome?
   b. **Comparing and Contrasting** How does the order of genes in one member of a chromosome pair compare to the order of genes on the other chromosome?

Writing in Science

Newspaper Interview You are a newspaper reporter in the early 1900s. You want to interview Walter Sutton about his work with chromosomes. Write three questions you would like to ask Sutton. Then, for each question, write answers that Sutton might have given.

Section 4

Genes, DNA, and Proteins

CALIFORNIA Standards Focus

S 7.1.a Students know cells function similarly in all living organisms.

- What forms the genetic code?
- How does a cell produce proteins?
- How can mutations affect an organism?

Key Terms

- messenger RNA
- transfer RNA
- mutation

Lab zone Standards Warm-Up

Can You Crack the Code?

1. Use the Morse code in the chart to decode the question in the message below. The letters are separated by slash marks.

•– – –/• • •/•/•–•/•/•–/•–•/
•/– –•/•/–•/•/• • •/•–••/– – –
/–•–•/•–/–/•/–••/

2. Write your answer to the question in Morse code.
3. Exchange your coded answer with a partner. Then decode your partner's answer.

Think It Over

Forming Operational Definitions

Based on your results from this activity, write a definition of the word *code*. Then compare your definition to one in a dictionary.

A •–	N –•
B –•••	O –––
C –•–•	P •––•
D –••	Q ––•–
E •	R •–•
F ••–•	S •••
G ––•	T –
H ••••	U ••–
I ••	V •••–
J •–––	W•––
K –•–	X –••–
L •–••	Y –•––
M ––	Z ––••

The white kangaroo in the photograph below was born at the San Francisco zoo. The young kangaroo beside her is her offspring. Notice that the offspring's coat is much darker—the natural coat color for eastern grey kangaroos. White kangaroos are extremely rare. Why was the mother born with such an uncommon phenotype? To answer this question, you need to know how the genes on a chromosome determine an organism's inherited traits.

◀ **A white kangaroo and her offspring**

The Genetic Code

The main function of genes is to control the production of proteins in an organism's cells. Many proteins serve as enzymes that control chemical reactions in the cell. Proteins also help to determine the size, shape, color, and many other traits of an organism.

Genes and DNA In Figure 16, you can see the relationship between chromosomes and DNA. Notice that a DNA molecule is made up of four different nitrogen bases—adenine (A), thymine (T), guanine (G), and cytosine (C). These bases form the rungs of the DNA "ladder."

A gene is a section of a DNA molecule that contains the information to code for one specific protein. A gene is made up of a series of bases in a row. The bases in a gene are arranged in a specific order—for example, ATGACGTAC. A single gene on a chromosome may contain anywhere from several hundred to a million or more of these bases. Each gene is located at a specific place on a chromosome.

Order of the Bases A gene contains the code that determines the structure of a protein. **The order of the nitrogen bases along a gene forms a genetic code that specifies what type of protein will be produced.** Remember that proteins are long-chain molecules made of individual amino acids. In the genetic code, a group of three DNA bases codes for one specific amino acid. For example, the base sequence CGT (cytosine-guanine-thymine) always codes for the amino acid alanine. The order of the three-base code units determines the order in which amino acids are put together to form a protein.

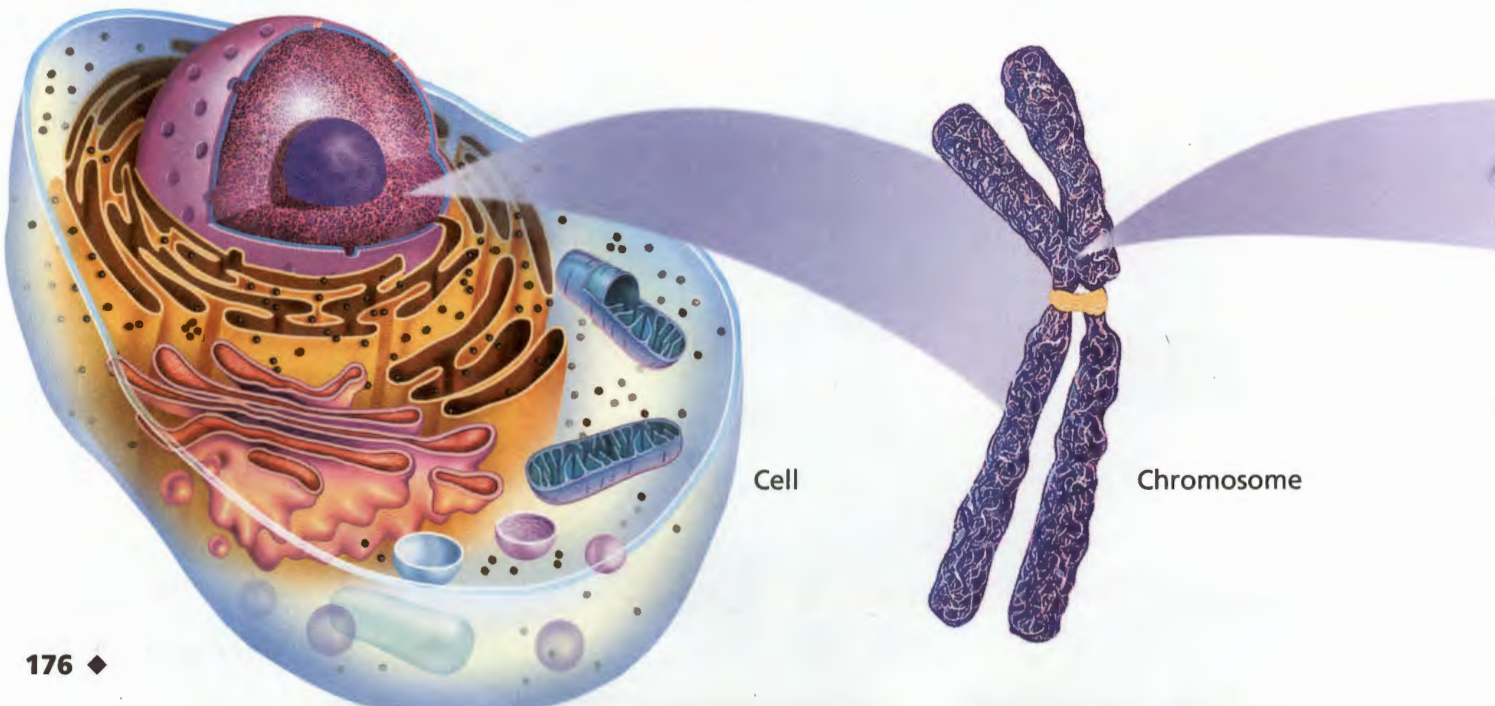


FIGURE 16
The DNA Code
Chromosomes are made of DNA. Each chromosome contains thousands of genes. The sequence of bases in a gene forms a code that tells the cell what protein to produce. **Interpreting Diagrams** *Where in the cell are chromosomes located?*

How Cells Make Proteins

The production of proteins in cells is called protein synthesis. **During protein synthesis, the cell uses information from a gene on a chromosome to produce a specific protein.** Protein synthesis takes place on the ribosomes in the cytoplasm of a cell. As you know, the cytoplasm is outside the nucleus. The chromosomes, however, are found inside the nucleus. How, then, does the information needed to produce proteins get out of the nucleus and into the cytoplasm?

The Role of RNA Before protein synthesis can take place, a "messenger" must first carry the genetic code from the DNA inside the nucleus into the cytoplasm. This genetic messenger is called ribonucleic acid, or RNA.

Although RNA is similar to DNA, the two molecules differ in some important ways. Unlike DNA, which has two strands, RNA has only one strand. RNA also contains a different sugar molecule from the sugar found in DNA. Another difference between DNA and RNA is in their nitrogen bases. Like DNA, RNA contains adenine, guanine, and cytosine. However, instead of thymine, RNA contains uracil (YOOR uh sil).

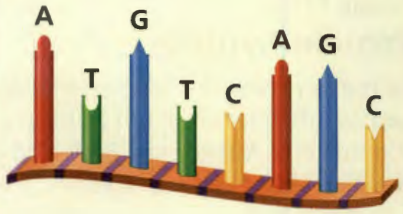
Types of RNA There are several types of RNA involved in protein synthesis. **Messenger RNA** copies the coded message from the DNA in the nucleus, and carries the message to the ribosome in the cytoplasm. Another type of RNA, called **transfer RNA**, carries amino acids to the ribosome and adds them to the growing protein.

Reading Checkpoint How is RNA different from DNA?

Lab zone Skills Activity

Drawing Conclusions

The following is a sequence of nitrogen bases on a strand of nucleic acid.



Is the strand part of a DNA molecule or RNA molecule? Explain your answer.

Translating the Code The process of protein synthesis is shown in Figure 17. Look at the illustration as you read the following steps.

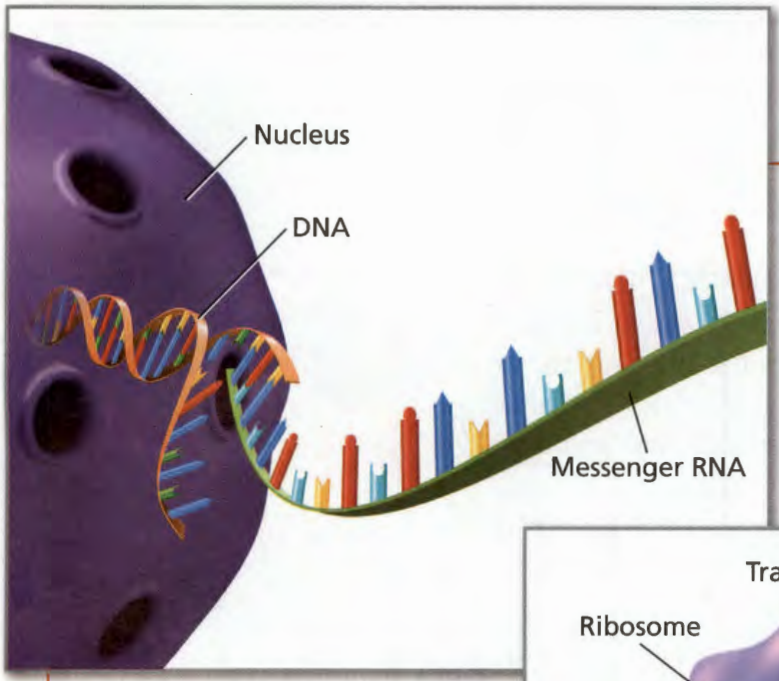
1 The first step is for a DNA molecule to "unzip" between its base pairs. Then one of the strands of DNA directs the production of a strand of messenger RNA. To form the RNA strand, RNA bases pair up with the DNA bases. The process is similar to the process in which DNA replicates. Cytosine always pairs with guanine. However, uracil—not thymine— pairs with adenine.

2 The messenger RNA then leaves the nucleus and enters the cytoplasm. In the cytoplasm, messenger RNA attaches to a ribosome. On the ribosome, the messenger RNA provides the code for the protein molecule that will form. During protein synthesis, the ribosome moves along the messenger RNA strand.

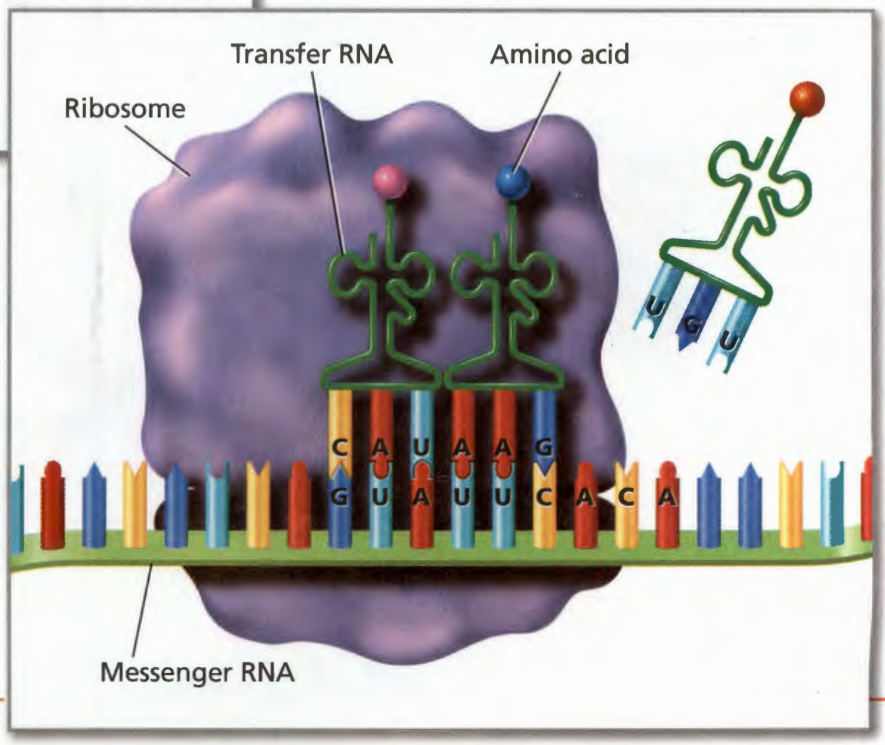
FIGURE 17

Protein Synthesis

To make proteins, messenger RNA copies information from DNA in the nucleus. Messenger RNA and transfer RNA then use this information to produce proteins.
Interpreting Diagrams *In which organelle of the cell are proteins manufactured?*



2 Messenger RNA Attaches to a Ribosome
When the messenger RNA enters the cytoplasm, it attaches to a ribosome, where production of the protein chain begins. The ribosome moves along the messenger RNA strand.



1 Messenger RNA Production
In the nucleus, a DNA molecule serves as a "pattern" for making messenger RNA. The DNA molecule "unzips" between base pairs. RNA bases match up along one of the DNA strands. The genetic information in the DNA is transferred to the messenger RNA strand.

❸ Molecules of transfer RNA attach to the messenger RNA. The bases on the transfer RNA "read" the message by pairing up three-letter codes to bases on the messenger RNA. For example, you can see that a molecule of transfer RNA with the bases AAG pairs with the bases UUC on the messenger RNA. The molecules of transfer RNA carry specific amino acids. The amino acids link in a chain. The order of the amino acids in the chain is determined by the order of the three-letter codes on the messenger RNA.

❹ The protein molecule grows longer as each transfer RNA molecule puts the amino acid it is carrying along the growing protein chain. Once an amino acid is added to the protein chain, the transfer RNA is released into the cytoplasm and can pick up another amino acid. Each transfer RNA molecule always picks up the same kind of amino acid.

Reading Checkpoint **What is the function of transfer RNA?**

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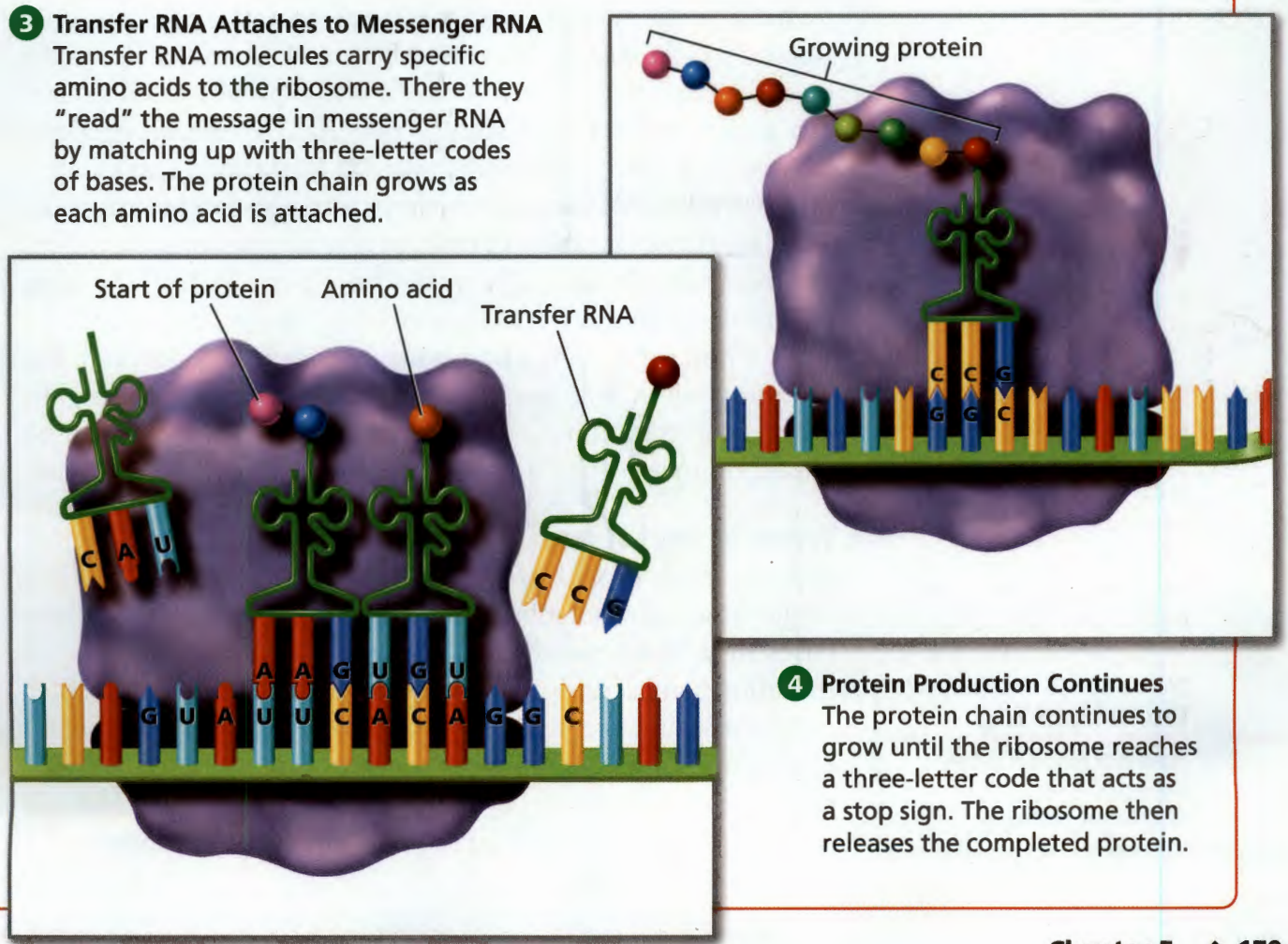

❸ **Transfer RNA Attaches to Messenger RNA** Transfer RNA molecules carry specific amino acids to the ribosome. There they "read" the message in messenger RNA by matching up with three-letter codes of bases. The protein chain grows as each amino acid is attached.

❹ **Protein Production Continues** The protein chain continues to grow until the ribosome reaches a three-letter code that acts as a stop sign. The ribosome then releases the completed protein.

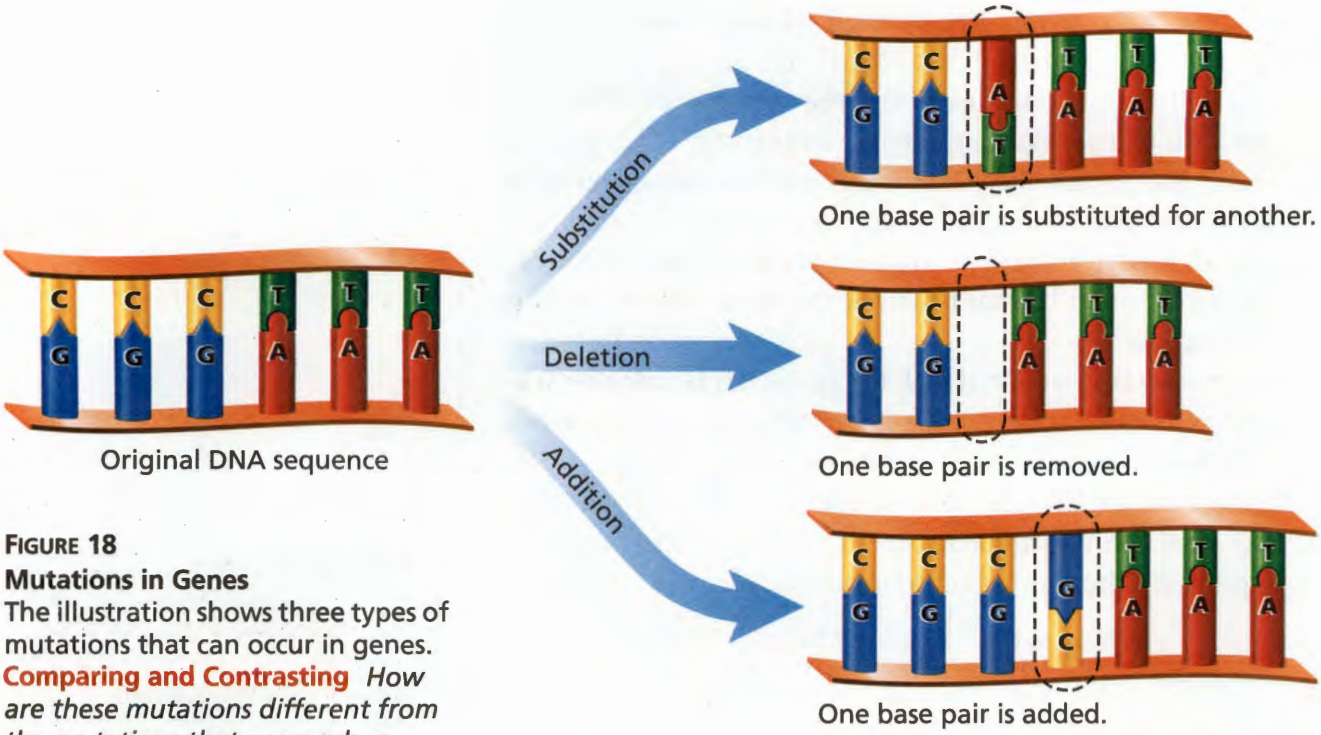

FIGURE 18
Mutations in Genes
The illustration shows three types of mutations that can occur in genes. **Comparing and Contrasting** *How are these mutations different from the mutations that occur when chromosomes do not separate during meiosis?*

Mutations

Suppose that a mistake occurred in one gene of a chromosome. Instead of the base A, for example, the DNA molecule might have the base G. Such a mistake is one type of mutation that can occur in a cell's hereditary material. A **mutation** is any change in a gene or chromosome. **Mutations can cause a cell to produce an incorrect protein during protein synthesis. As a result, the organism's trait, or phenotype, may be different from what it normally would have been.** In fact, the term *mutation* comes from a Latin word that means "change."

If a mutation occurs in a body cell, such as a skin cell, the mutation will not be passed on to the organism's offspring. If, however, a mutation occurs in a sex cell, the mutation can be passed on to an offspring and affect the offspring's phenotype.

Types of Mutations Some mutations are the result of small changes in an organism's hereditary material. For example, a single base may be substituted for another, or one or more bases may be removed from a section of DNA. This type of mutation can occur during the DNA replication process. Other mutations may occur when chromosomes don't separate correctly during meiosis. When this type of mutation occurs, a cell can end up with too many or too few chromosomes. The cell could also end up with extra segments of chromosomes.

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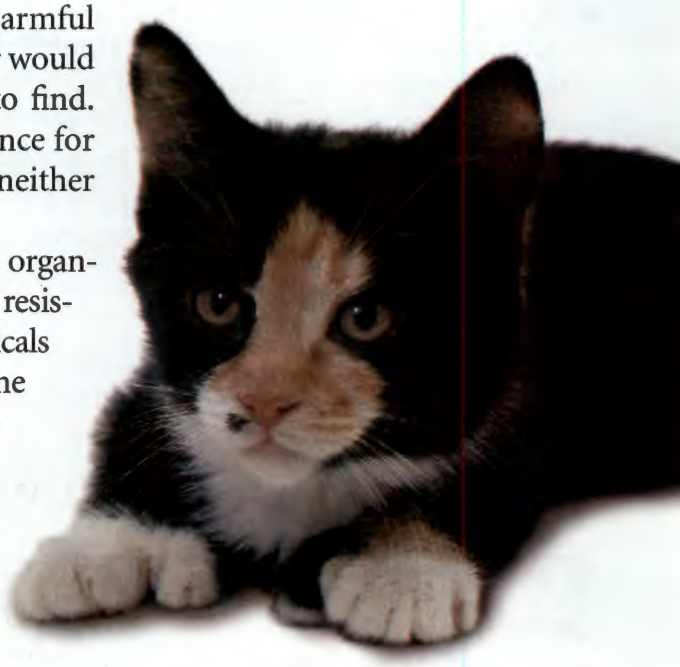
Effects of Mutations Because mutations can introduce changes in an organism, they can be a source of genetic variety. Some mutations are harmful to an organism. A few mutations, however, are helpful, and others are neither harmful nor helpful. A mutation is harmful to an organism if it reduces the organism's chance for survival and reproduction.

Whether a mutation is harmful or not depends partly on the organism's environment. The mutation that led to the production of a white kangaroo would probably be harmful to an organism in the wild. The kangaroo's white color would make it more visible, and thus easier for predators to find. However, a white kangaroo in a zoo has the same chance for survival as a brown kangaroo. In a zoo, the mutation neither helps nor harms the kangaroo.

Helpful mutations, on the other hand, improve an organism's chances for survival and reproduction. Antibiotic resistance in bacteria is an example. Antibiotics are chemicals that kill bacteria. Gene mutations have enabled some kinds of bacteria to become resistant to certain antibiotics—that is, the antibiotics do not kill the bacteria that have the mutations. The mutations have improved the bacteria's ability to survive and reproduce.

Reading Checkpoint **What are two types of mutations?**

FIGURE 19
Six-Toed Cat
Because of a mutation in one of its ancestors, this cat has six toes on each front paw.



Section 4 Assessment

S 7.1.a E-LA: Reading 7.2.0, Writing 7.2.0

Target Reading Skill **Take Notes** Use your notes to help answer the questions below.

Reviewing Key Concepts

1. a. **Explaining** What is the relationship between a gene, a DNA molecule, and a protein?
   b. **Relating Cause and Effect** How does a DNA molecule determine the structure of a specific protein?
   c. **Inferring** The DNA base sequence GGG codes for the amino acid proline. Could this same base sequence code for a different amino acid? Why or why not?
2. a. **Listing** List the sequence of events that happens during protein synthesis.
   b. **Describing** What is messenger RNA? Describe how it performs its function.
   c. **Inferring** Does transfer RNA perform its function in the nucleus or cytoplasm? Explain.
3. a. **Reviewing** How does a mutation in a gene affect the order of DNA bases?
   b. **Relating Cause and Effect** How can a mutation in a gene cause a change in an organism's phenotype?

Writing in Science

Compare/Contrast Paragraph Write a paragraph comparing and contrasting gene mutations and chromosome mutations. In your paragraph, explain what the two types of mutations are, and how they are similar and different.

Chapter 5 Study Guide

The BIG Idea Organisms produced by sexual reproduction inherit half their DNA from each parent. The new combination of DNA determines an organism's traits.

1 Mendel's Work

Key Concepts S 7.2.d

- In all of Mendel's crosses, only one form of the trait appeared in the F_1 generation. However, in the F_2 generation, the "lost" form of the trait reappeared in about one fourth of the plants.
- An organism's traits are controlled by the alleles it inherits from its parents. Some alleles are dominant, while other alleles are recessive.

Key Terms

heredity
trait
genetics
fertilization
purebred
gene
alleles
dominant allele
recessive allele
hybrid

2 Probability and Heredity

Key Concepts S 7.2.d

- Probability is the likelihood that a particular event will occur.
- In a genetic cross, the allele that each parent will pass on to its offspring is based on probability.
- An organism's phenotype is its physical appearance, or visible traits. An organism's genotype is its genetic makeup, or allele combinations.
- In codominance, the alleles are neither dominant nor recessive. As a result, both alleles are expressed in the offspring.

Key Terms

probability
Punnett square
phenotype
genotype
homozygous
heterozygous
codominance

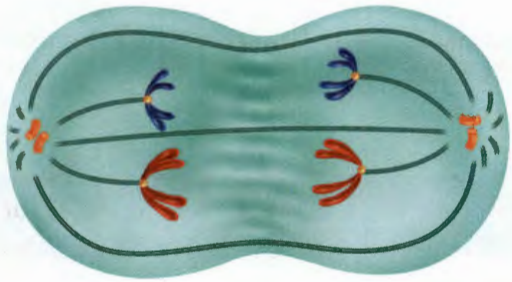
3 The Cell and Inheritance

Key Concepts S 7.2.b

- According to the chromosome theory of inheritance, genes are carried from parents to their offspring on chromosomes.
- During meiosis, the chromosome pairs separate and are distributed to two different cells. The resulting sex cells have half as many chromosomes as the other cells in the organism.
- Chromosomes are made up of many genes joined together like beads on a string.

Key Term

sexual reproduction
diploid
meiosis



4 Genes, DNA, and Proteins

Key Concepts S 7.1.a

- The order of the nitrogen bases along a gene forms a genetic code that specifies what type of protein will be produced.
- During protein synthesis, the cell uses information from a gene on a chromosome to produce a specific protein.
- Mutations can cause a cell to produce an incorrect protein during protein synthesis. As a result, the organism's trait, or phenotype, may be different from what it normally would have been.

Key Terms

messenger RNA
mutation
transfer RNA

Review and Assessment

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Target Reading Skill

Take Notes To help review Section 2, take notes on the text that follows the heading Principles of Probability (pages 162–163). The notes have been started for you as shown at the right.

Questions	Notes: Principles of Probability
What is probability?	Probability is a number that descibes how likely it is that an event will occur.
What are three ways of expressing the probability that a coin will land heads up?	

Reviewing Key Terms

Choose the letter of the best answer.

1. The different forms of a gene are called
   a. alleles.
   b. chromosomes.
   c. phenotypes.
   d. genotypes.
2. The likelihood that a particular event will occur is called
   a. mutation.
   b. Punnett square.
   c. probability.
   d. recessive.
3. An organism with two identical alleles for a trait is
   a. heterozygous.
   b. homozygous.
   c. recessive.
   d. dominant.
4. The process by which the number of chromosomes is reduced by half to form sperm and eggs is called
   a. hybrid.
   b. mitosis.
   c. meiosis.
   d. purebred.
5. During protein synthesis, which of the following provides a code from DNA in the nucleus?
   a. amino acid
   b. transfer RNA
   c. guanine
   d. messenger RNA

Complete the following sentences so that the second part further explains the first part.

6. Round seed shape in peas is an example of a trait controlled by a **dominant allele** because _____.
7. An organism with a genotype of *Hh* is a **hybrid** because _____.
8. The results of a genetic cross can be shown in a **Punnett square,** which is _____.
9. Having dimples is an example of a **phenotype,** which is _____.
10. The deletion of a base pair of DNA during meiosis is an example of a **mutation** because _____.

Writing in Science

Science Article You are a science reporter for a newspaper. Write an article about gene mutations. Explain what a mutation is and what determines whether it is helpful or harmful.

Video Assessment
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Review and Assessment

Checking Concepts

11. Describe what happened when Mendel crossed purebred tall pea plants with purebred short pea plants.

12. You toss a coin five times and it lands heads up each time. What is the probability that it will land heads up on the sixth toss? Explain.

13. In guinea pigs, the allele for black fur (*B*) is dominant over the allele for white fur (*b*). In a cross between a heterozygous black guinea pig (*Bb*) and a homozygous white guinea pig (*bb*), what is the probability that an offspring will have white fur? Use a Punnett square to answer the question.

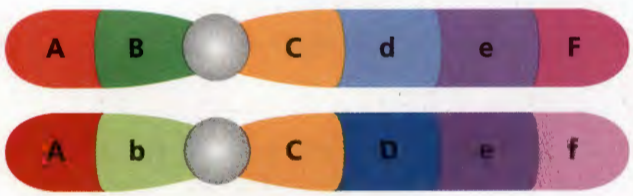
14. Describe the role of transfer RNA in protein synthesis.

15. How can mutations affect protein synthesis?

Thinking Critically

16. **Applying Concepts** In rabbits, the allele for a spotted coat is dominant over the allele for a solid-colored coat. A spotted rabbit was crossed with a solid-colored rabbit. The offspring all had spotted coats. What are the probable genotypes of the parents? Explain.

17. **Interpreting Diagrams** The diagram below shows a chromosome pair. For which genes is the organism heterozygous?



18. **Predicting** A new mutation in mice causes the coat to be twice as thick as normal. In what environments would this mutation be helpful? Why?

19. **Applying Concepts** If the body cells have 12 chromosomes, how many will the sex cells have?

20. **Relating Cause and Effect** Why are mutations that occur in an organism's body cells not passed on to its offspring?

Math Practice

21. **Percentage** A garden has 80 pea plants. Of the plants, 20 have short stems and 60 have tall stems. What percentage of the plants have short stems? What percentage have tall stems?

Applying Skills

Use the information in the table to answer Questions 22–24.

In peas, the allele for green pods (G) is dominant over the allele for yellow pods (g). The table shows the phenotypes of offspring produced from a cross of two plants with green pods.

Phenotype	Number of Offspring
Green pods	27
Yellow pods	9

22. **Calculating Percent** Calculate what percent of the offspring produce green pods. Calculate what percent have yellow pods.

23. **Inferring** What is the genotype of the offspring with yellow pods? What are the possible genotypes of the offspring with green pods?

24. **Drawing Conclusions** What are the genotypes of the parents? How do you know?

Lab zone Standards Investigation

Performance Assessment Finalize your display of your pet's family. Be prepared to discuss the inheritance patterns in your pet's family. Examine your classmates' exhibits. See which offspring look most like, and least like, their parents. Can you find any offspring that "break the laws" of inheritance?

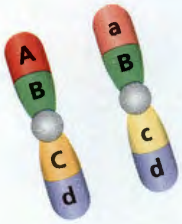
Choose the letter of the best answer.

1. Which of the following is the first step in the formation of sex cells in an organism that has eight chromosomes?

A The two chromatids of each chromosome separate.
B Chromosome pairs line up next to each other in the center of the cell.
C The DNA in the eight chromosomes is copied.
D The chromatids move apart, producing cells with four chromosomes each.

S 7.2.b

An organism contains two chromosomes with the genes shown.



2. Which of the following most likely represents the genotypes of each parent?

A Father: Aa CC
Mother: BB dd
B Father: Aa Cc
Mother: BB dd
C Father: AA BB CC dd
Mother: aa BB cc dd
D Father: AA BB CC dd
Mother: AA bb cc DD

S 7.2.d

3. Which of the following events begins the process of protein synthesis?

A Messenger RNA enters the cytoplasm and attaches to a ribosome.
B The coded message in DNA is copied when a molecule of messenger RNA is formed.
C The protein chain grows until a stop code is reached.
D Transfer RNA molecules carrying amino acids attach to messenger RNA.

S 7.1.a

Use the Punnett square below to answer Questions 4–6.

The Punnett square below shows a cross between two pea plants, each with round seeds.

	R	R
R	RR	
r	Rr	Rr

4. The missing genotype in the empty square is correctly written as

A Rr.
B rR.
C rr.
D RR.

S 7.2.d

5. Which statement is true about the cross shown in the Punnett square?

A Both parents are heterozygous for the trait.
B Both parents are homozygous for the trait.
C One parent is heterozygous and the other is homozygous for the trait.
D The trait is controlled by codominant alleles.

S 7.2.d

6. What percentage of the offspring of this cross will produce round seeds?

A 0%
B 25%
C 50%
D 100%

S 7.2.d

7. A section of DNA has the base sequence GCTTAA. The corresponding messenger RNA made from this strand will have the base sequence

A GCTTAA.
B CGAAUU.
C CGAATT.
D UUTTCG.

S 7.1.a

Apply the BIG Idea

8. Summarize the stages of meiosis. S 7.2.b