

## 4.2

## KEY CONCEPT

# Patterns of heredity can be predicted.

## BEFORE, you learned

- Genes are passed from parents to offspring
- Offspring inherit genes in predictable patterns

## NOW, you will learn

- How Punnett squares can be used to predict patterns of heredity
- How ratios and probability can be used to predict patterns of heredity

## VOCABULARY

Punnett square p. 110

ratio p. 112

probability p. 112

percentage p. 112

## EXPLORE Probability

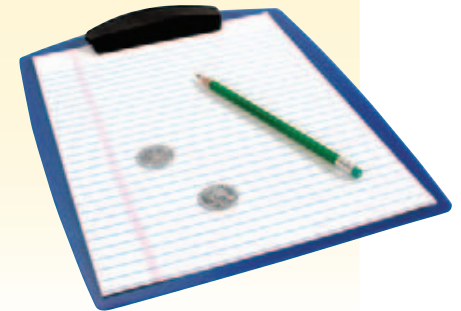
### How can probability help predict results?

#### PROCEDURE

- 1 Toss both coins 10 times. For each toss, record the combination of heads and/or tails.
- 2 For each combination (two heads, two tails, or a head and a tail), add up the number of tosses.

#### MATERIALS

- two coins
- pencil and paper



#### WHAT DO YOU THINK?

- Which combination happened most often?
- If you tossed both coins one more time, which combination would be the most likely result? Can you know for sure? Why or why not?

## Punnett squares show possible outcomes for inheritance.

### NOTETAKING STRATEGY

Use a strategy from an earlier chapter or design one of your own to take notes on how Punnett squares show possible patterns of heredity.

Mendel noticed that traits are inherited in patterns. One tool for understanding the patterns of heredity is a graphic called a Punnett square. A **Punnett square** illustrates how the parents' alleles might combine in offspring.

Each parent has two alleles for a particular gene. An offspring receives one allele from each parent. A Punnett square shows how the parents' alleles may be passed on to potential offspring.

The Punnett square on page 111 shows how alleles for pea-plant height would be distributed among offspring in Mendel's first-generation cross. The dominant allele (D) is regular height, and the recessive allele (d) is dwarf height.

The top of the Punnett square shows one parent's alleles for this trait—two dominant regular alleles (DD). The side of the Punnett square shows the other parent's alleles for this trait—two recessive dwarf alleles (dd).

Each box in the Punnett square shows a way the alleles from each parent would combine in potential offspring. You can see that each potential offspring would have the same genotype: one dominant and one recessive allele (Dd). The phenotype of each offspring would show the dominant allele, in this case regular height.

**READING TIP**

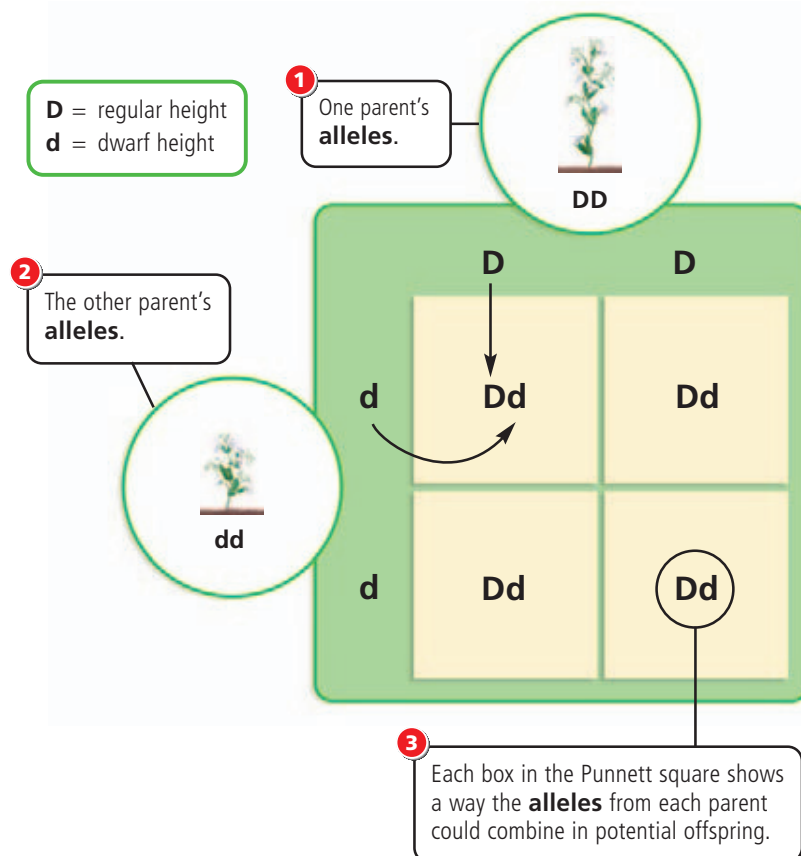
As you read about Punnett squares, connect each sentence with the diagram below.

**CHECK YOUR READING**

What is a Punnett square?

**Using Punnett Squares**

The Punnett square below shows the possible allele combinations for an offspring of one parent with two dominant (D) regular-height alleles and one parent with two recessive (d) dwarf-height alleles.

**READING VISUALS**

What genotype will each offspring have? What phenotype?

**SIMULATION**  
CLASSZONE.COM

Predict offspring traits with virtual Punnett squares.

## Ratios and percentages can express the probability of outcomes.

### VOCABULARY

Remember to create a word magnet diagram for the term *ratio*.



The Punnett square on page 111 for the first generation of pea plants shows that all potential offspring will be of regular height, because they all have one dominant allele. You can say that 100 percent of the offspring will be of regular height. Or you could say that the ratio of regular-height offspring to total offspring is four to four. A **ratio** compares, or shows the relationship between, two quantities. A ratio is usually written 4:4 and read as “four to four.” This can be interpreted as “four out of four.” The Punnett square shows that four out of four offspring will express the dominant gene for regular height.



4:4

ratio of blue squares to total squares



1:4 red

3:4 blue

Punnett squares and the ratios they show express probability. **Probability** is the likelihood, or chance, of a specific outcome in relation to the total number of possible outcomes. The ratios derived from a Punnett square tell you the probability that any one offspring will get certain genes and express a certain trait. Another way of expressing probability is as a percentage. A **percentage** is a ratio that compares a number to 100. That is, it states the number of times a particular outcome might happen out of a hundred chances.

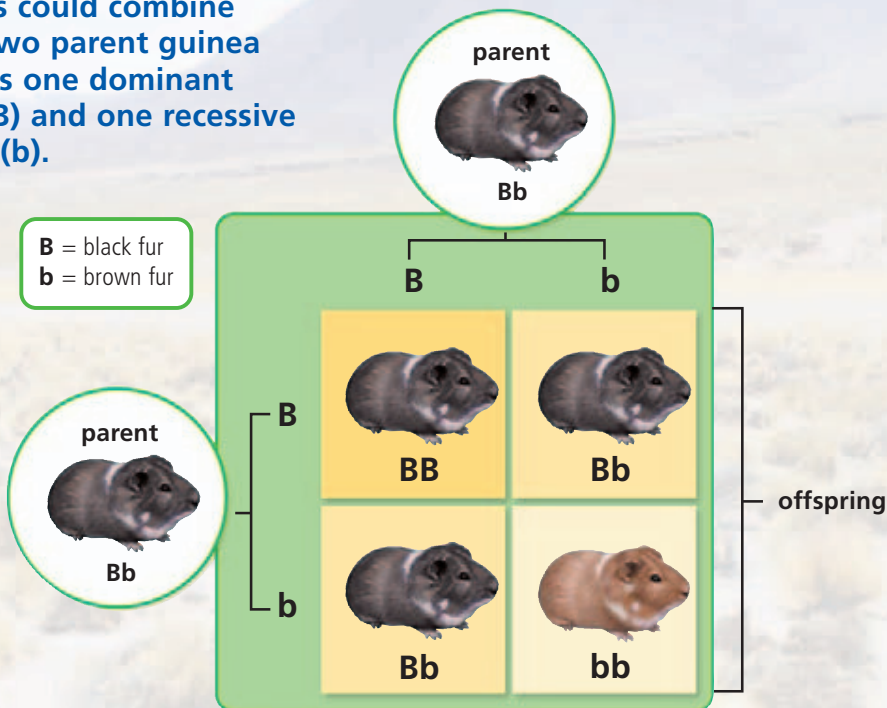
### CHECK YOUR READING

What are two ways that you can express a probability?

Look at the guinea-pig Punnett square on page 113. This cross is between two parents, each with one dominant allele (black) and one recessive allele (brown) for the trait fur color. In this cross, only one in four (ratio 1:4) offspring gets two dominant alleles. That is, there is a one in four chance that an offspring from this cross will have two dominant alleles for black fur (BB). The likelihood that the offspring will get one dominant and one recessive allele (Bb) is 2:4—two out of every four offspring would have this genotype. Like the one offspring with two dominant alleles (BB), the two offspring with the genotype Bb will have black fur. This makes a total of three offspring (3:4) with the phenotype black fur. Only 1:4 offspring of this cross will have the genotype and phenotype brown fur (bb).

## Punnett Square and Probability

The Punnett square below shows the possible ways alleles could combine in the offspring of two parent guinea pigs. Each parent has one dominant allele for black fur (B) and one recessive allele for brown fur (b).



The table below shows the probability of the various genotypes and phenotypes from the Punnett square above. Each probability is shown as both a ratio and a percentage.

Genotype	Ratio	Percentage	Phenotype	Ratio	Percentage
BB	1:4	25%	Black fur	3:4	75%
Bb	2:4	50%			
bb	1:4	25%	Brown fur	1:4	25%

**READING VISUALS**

Connect the four shaded sections of the Punnett square to the matching genotypes in the chart.

When one parent has two dominant alleles and the other has two recessive alleles, there is a 100 percent chance that an offspring will have the dominant phenotype. The pea-plant example on page 111 shows this pattern. All the offspring are of regular height. When both parents have one dominant and one recessive allele, there is a 75 percent chance that an offspring will have the dominant phenotype. The guinea-pig example on page 113 shows this pattern. Chances are that more offspring will have black fur than brown fur.



**CHECK YOUR READING**

What is the probability that an offspring from the pea plant cross on page 111 will be of dwarf height?

In humans, females have two X-chromosomes (XX), and males have an X- and a Y-chromosome (XY). The Punnett square on page 115 shows the possible sexes of human offspring. Unlike the guinea-pig Punnett square, this one shows only two possible outcomes, XX and XY. The diagram also shows how to find the percentage chance that a potential offspring will be female.

## INVESTIGATE Multiple Probabilities

### Do probabilities affect each other?

#### PROCEDURE

- Put a square of masking tape on each side of all four coins. On both large coins, write the letter *Y* for yellow peas on one side and the letter *y* on the other, for green peas. On both small coins, write the letter *R* for round peas on one side and the letter *r* on the other, for wrinkled peas.
- Toss all four coins together 40 times and record the letter combinations of each toss.
- For each of the three small-coin letter combinations, add up the number of tosses, and calculate the ratio and percentage chance of each. Do the same for the three large-coin letter combinations.

#### WHAT DO YOU THINK?

- What letter combinations happened most often?
- Do the results of the small-coin letter combinations affect the results of the large-coin letter combinations? How might this observation apply to heredity?

**CHALLENGE** Design a version of this experiment to model Mendel's first-generation cross. Explain why it would be a boring experiment to perform.

**SKILL FOCUS**  
Analyzing data

#### MATERIALS

- two large coins
- two small coins
- masking tape
- marker

**TIME**  
30 minutes



## Calculating Probability

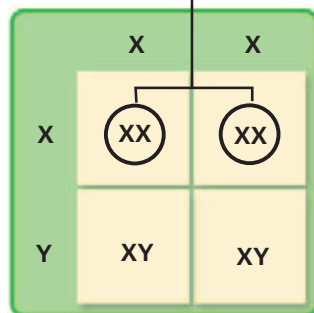
Two humans, a female (XX) and a male (XY), have an offspring. The Punnett square below can be used to calculate the probability that an offspring will be female or male.

1

To find the percentage chance of a female offspring, first find the ratio by counting the number of XX offspring out of the four possible outcomes.

2

Two out of 4 (ratio 2:4, or  $\frac{2}{4}$ ) offspring will be female.



3

Multiply this ratio by 100 to find the probability as a percentage.

4

Two fourths equal  $\frac{1}{2}$ , and  $\frac{1}{2}$  of 100 is 50. So there is a 50 percent chance that an offspring will be female.

### READING VISUALS

Compare this Punnett square with the pea-plant Punnett square on page 111 and the guinea-pig Punnett square on page 113. How is it similar? How is it different?

It is important to realize that Punnett squares and probability do not guarantee the outcome of a genetic cross. They indicate the probability of different outcomes. While there is a 75 percent chance that an offspring will have black fur according to the Punnett square on page 113, you cannot know with any certainty what color fur a particular offspring will actually have. Actual experimental results may not match predicted outcomes.



### CHECK YOUR READING

Can a Punnett square tell you the specific outcome of a genetic cross? Why or why not?

## 4.2 Review

### KEY CONCEPTS

1. Explain how Punnett squares predict the outcomes of heredity.
2. How are ratio and percentages related?
3. How can you find a percentage chance from a Punnett square?

### CRITICAL THINKING

4. **Predict** Mendel studied the colors of seeds in his experiments with pea plants. Let G stand for green and g stand for yellow. Green is dominant. Make a Punnett square for seed color. Find the percentage chance for each outcome.

### CHALLENGE

5. **Apply** In pea plants, the allele for smooth peas is dominant over the allele for wrinkled peas. Create a Punnett square and calculate the probability that two smooth-pea plants will have an offspring with wrinkled peas if each parent has one smooth and one wrinkled allele.