SECTION 2

Traits and Inheritance

Mendel calculated the ratio of dominant traits to recessive traits. He found a ratio of 3:1. What did this tell him about how traits are passed from parents to offspring?

READING WARM-UP

Objectives

- Explain how genes and alleles are related to genotype and phenotype.
- Use the information in a Punnett square.
- Explain how probability can be used to predict possible genotypes in offspring.
- Describe three exceptions to Mendel's observations.

Terms to Learn

gene
allele
phenotype
genotype
probability

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

A Great Idea

Mendel knew from his experiments with pea plants that there must be two sets of instructions for each characteristic. The first-generation plants carried the instructions for both the dominant trait and the recessive trait. Scientists now call these instructions for an inherited trait **genes.** Each parent gives one set of genes to the offspring. The offspring then has two forms of the same gene for every characteristic—one from each parent. The different forms (often dominant and recessive) of a gene are known as **alleles** (uh LEELZ). Dominant alleles are shown with a capital letter. Recessive alleles are shown with a lowercase letter.

Reading Check **What is the difference between a gene and an allele?** *(See the Appendix for answers to Reading Checks.)*

Phenotype

Genes affect the traits of offspring. An organism's appearance is known as its **phenotype** (FEE noh TIEP). In pea plants, possible phenotypes for the characteristic of flower color would be purple flowers or white flowers. For seed color, yellow and green seeds are the different phenotypes.

Phenotypes of humans are much more complicated than those of peas. Look at **Figure 1** below. The man has an inherited condition called *albinism* (AL buh NIZ uhm). Albinism prevents hair, skin, and eyes from having normal coloring.

gene one set of instructions for an inherited trait

allele one of the alternative forms of a gene that governs a characteristic, such as hair color

phenotype an organism's appearance or other detectable characteristic

Figure 1 *Albinism is an inherited disorder that affects a person's phenotype in many ways.*

Genotype

Both inherited alleles together form an organism's **genotype.** Because the allele for purple flowers (*P*) is dominant, only one *P* allele is needed for the plant to have purple flowers. A plant with two dominant or two recessive alleles is said to be *homozygous* (HOH moh ZIE guhs). A plant that has the genotype *Pp* is said to be *heterozygous* (HET uhr OH ZIE guhs).

Punnett Squares

A Punnett square is used to organize all the possible combinations of offspring from particular parents. The alleles for a true-breeding, purple-flowered plant are written as *PP*. The alleles for a true-breeding, white-flowered plant are written as *pp*. The Punnett square for this cross is shown in **Figure 2.** All of the offspring have the same genotype: *Pp*. The dominant allele, *P*, in each genotype ensures that all of the offspring will be purple-flowered plants. The recessive allele, *p*, may be passed on to the next generation. This Punnett square shows the results of Mendel's first experiments.

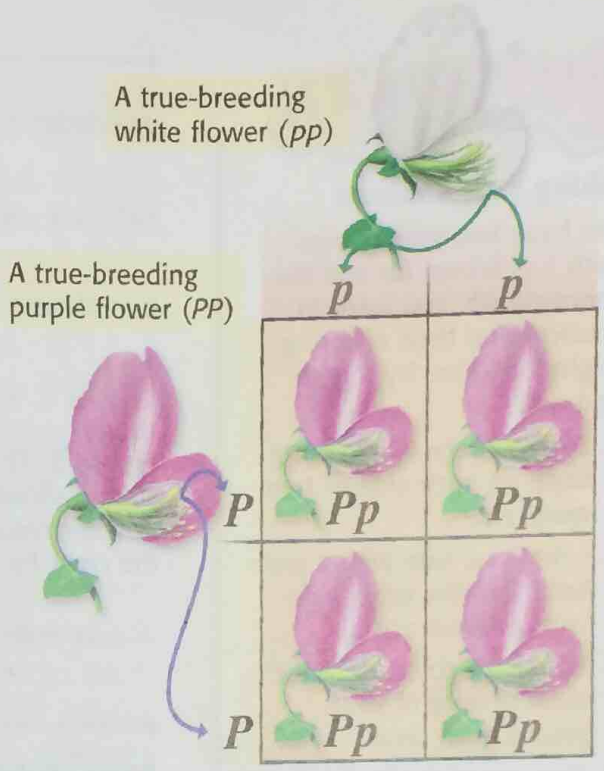
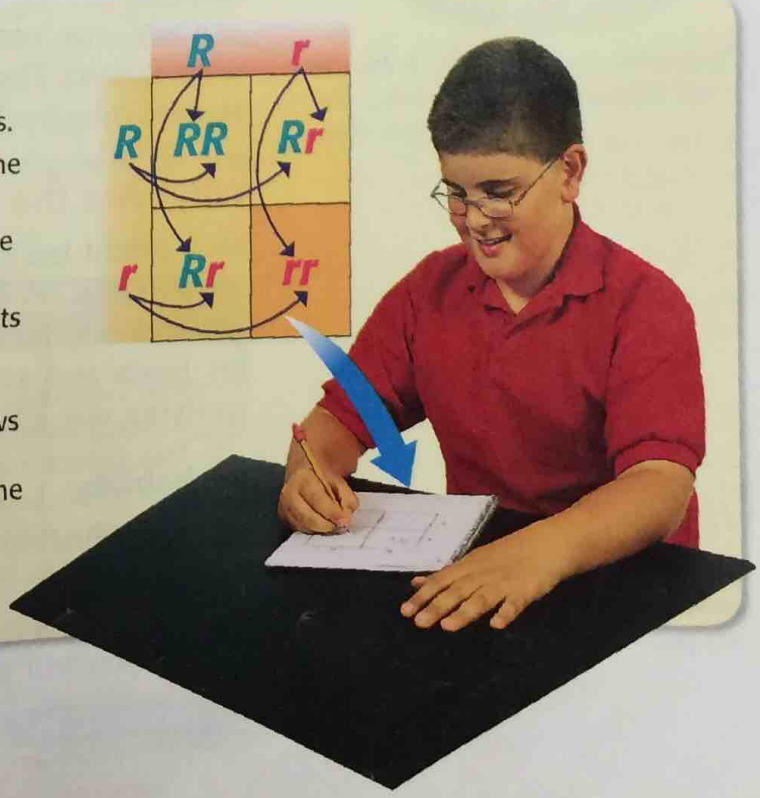


Figure 2 *All of the offspring for this cross have the same genotype*—Pp.

genotype the entire genetic makeup of an organism; also the combination of genes for one or more specific traits

Making a Punnett Square

1. Draw a square, and divide it into four sections.
2. Write the letters that represent alleles from one parent along the top of the box.
3. Write the letters that represent alleles from the other parent along the side of the box.
4. The cross shown at right is between two plants that produce round seeds. The genotype for each is *Rr*. Round seeds are dominant, and wrinkled seeds are recessive. Follow the arrows to see how the inside of the box was filled. The resulting alleles inside the box show all the possible genotypes for the offspring from this cross. What would the phenotypes for these offspring be?



Quick Lab

Taking Your Chances

You have two guinea pigs. Each has brown fur and the genotype *Bb*. You want to predict what their offspring might look like. Try this to find out.

1. Stick a **piece of masking tape** on each side of **two quarters.**
2. Label one side with a capital *B* and the other side with a lowercase *b*.
3. Toss both coins 10 times, making note of your results each time.
4. How many times did you get the *bb* combination?
5. What is the probability that the next toss will result in *bb*?
6. What are the chances that the guinea pigs' offspring will have white fur (with the genotype *bb*)?

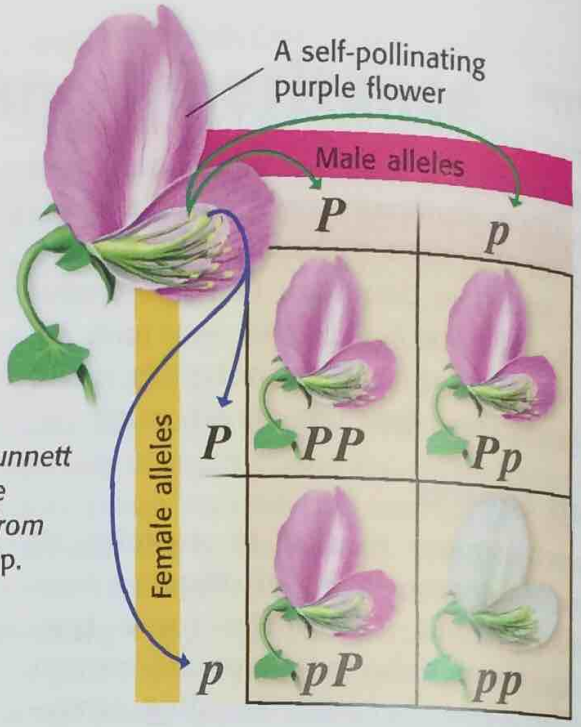


Figure 3 *This Punnett square shows the possible results from the cross* Pp × Pp.

More Evidence for Inheritance

In Mendel's second experiments, he allowed the first generation plants to self-pollinate. **Figure 3** shows a self-pollination cross of a plant with the genotype *Pp*. What are the possible genotypes of the offspring?

Notice that one square shows the genotype *Pp*, while another shows *pP*. These are exactly the same genotype. The other possible genotypes of the offspring are *PP* and *pp*. The combinations *PP*, *Pp*, and *pP* have the same phenotype—purple flowers. This is because each contains at least one dominant allele (*P*).

Only one combination, *pp*, produces plants that have white flowers. The ratio of dominant to recessive is 3:1, just as Mendel calculated from his data.

What Are the Chances?

Each parent has two alleles for each gene. When these alleles are different, as in *Pp*, offspring are equally likely to receive either allele. Think of a coin toss. There is a 50% chance you'll get heads and a 50% chance you'll get tails. The chance of receiving one allele or another is as random as a coin toss.

Probability

The mathematical chance that something will happen is known as **probability.** Probability is most often written as a fraction or percentage. If you toss a coin, the probability of tossing tails is 1/2—you will get tails half the time.

probability the likelihood that a possible future event will occur in any given instance of the event

Reading Check What is probability?

MATH FOCUS

Probability If you roll a pair of dice, what is the probability that you will roll 2 threes?

Step 1: Count the number of faces on a single die. Put this number in the denominator: 6.

Step 2: Count how many ways you can roll a three with one die. Put this number in the numerator: 1/6.

Step 3: To find the probability that you will throw 2 threes, multiply the probability of throwing the first three by the probability of throwing the second three: $1/6 \times 1/6 = 1/36$.

Now It's Your Turn

If you roll a single die, what is the probability that you will roll an even number?

Calculating Probabilities

To find the probability that you will toss two heads in a row, multiply the probability of tossing the first head (1/2) by the probability of tossing the second head (1/2). The probability of tossing two heads in a row is 1/4.

Genotype Probability

To have white flowers, a pea plant must receive a *p* allele from each parent. Each offspring of a $Pp \times Pp$ cross has a 50% chance of receiving either allele from either parent. So, the probability of inheriting two *p* alleles is $1/2 \times 1/2$, which equals 1/4, or 25%. Traits in pea plants are easy to predict because there are only two choices for each trait, such as purple or white flowers and round or wrinkled seeds. Look at **Figure 4.** Do you see only two distinct choices for fur color?

Figure 4 *These kittens inherited one allele from their mother for each trait.*

CONNECTION TO Chemistry

Round and Wrinkled Round seeds may look better, but wrinkled seeds taste sweeter. The dominant allele for seed shape, *R*, causes sugar to be changed into starch (which is a storage molecule for sugar). This change makes the seed round. Seeds with the genotype *rr* do not make or store this starch. Because the sugar has not been changed into starch, the seed tastes sweeter. If you had a pea plant with round seeds (*Rr*), what would you cross it with to get some offspring with wrinkled seeds? Draw a Punnett square showing your cross.

ACTIVITY

More About Traits

Things are often more complicated than they first appear to be. Gregor Mendel uncovered the basic principles of how genes are passed from one generation to the next. But scientists have found exceptions to Mendel's principles.

Incomplete Dominance

Since Mendel's discoveries, researchers have found that sometimes one trait is not completely dominant over another. These traits do not blend together, but each allele has its own degree of influence. This is known as *incomplete dominance*. A curly-haired parent and a straight-haired parent have wavy-haired children because of incomplete dominance.

A classic example of incomplete dominance is found in the snapdragon flower. **Figure 5** shows a cross between a true-breeding red snapdragon (R^1R^1) and a true-breeding white snapdragon (R^2R^2). As you can see, all of the possible phenotypes for their offspring are pink because both alleles of the gene have some degree of influence.

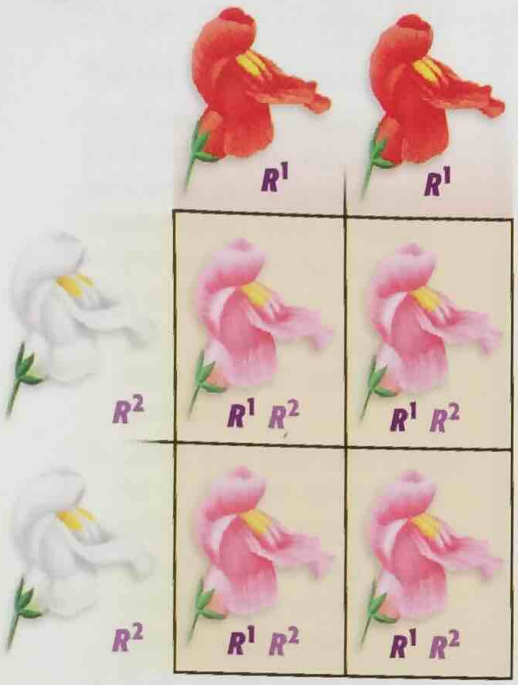


Figure 5 *Cross-breeding two true-breeding snapdragons provides a good example of incomplete dominance.*

Reading Check **What is incomplete dominance?**

One Gene, Many Traits

Sometimes one gene influences more than one trait. An example of this phenomenon is shown by the white tiger in **Figure 6.** The white fur is caused by a single gene, but this gene influences more than just fur color. If you look closely, you'll see that the tiger has blue eyes. Here, the gene that controls fur color also influences eye color.

Many Genes, One Trait

Some traits, such as the color of your skin, hair, and eyes, are the result of several genes acting together. Therefore, it's difficult to tell if some traits are the result of a dominant or a recessive gene. Different combinations of alleles result in different eye-color shades.

Figure 6 *The gene that gave this tiger white fur also influenced its eye color.*

The Importance of Environment

Genes aren't the only influences on traits. A guinea pig could have the genes for long fur, but its fur could be cut. In the same way, your environment influences how you grow. Your genes may make it possible that you will grow to be tall, but you need a healthy diet to reach your full potential height. Lifestyle choices can also affect a person's traits. The foods a person chooses to eat and the activities a person chooses to take part in affect how that person grows and develops. Choosing healthy foods and healthy activities can help you develop healthy traits. Together, the combination of genes, environmental factors, and lifestyle choices determine an individual's characteristics.

SECTION Review

Summary

- Instructions for an inherited trait are called *genes*. For each gene, there are two alleles, one inherited from each parent. Both alleles make up an organism's genotype. Phenotype is an organism's appearance.
- Punnett squares show all possible offspring genotypes.
- Probability can be used to describe possible outcomes in offspring and the likelihood of each outcome.
- Incomplete dominance occurs when one allele is not completely dominant over the other allele.
- Some genes influence more than one trait.

Using Key Terms

1. Use the following terms in the same sentence: *gene* and *allele*.
2. In your own words, write a definition for each of the following terms: *genotype* and *phenotype*.

Understanding Key Ideas

3. Use a Punnett square to determine the possible genotypes of the offspring of a $BB \times Bb$ cross.
   - **a.** all *BB*
   - **b.** *BB*, *Bb*
   - **c.** *BB*, *Bb*, *bb*
   - **d.** all *bb*
4. How are genes and alleles related to genotype and phenotype?
5. Describe three exceptions to Mendel's observations.

Math Skills

6. What is the probability that the offspring of a homozygous dominant parent and a heterozygous parent will show a recessive phenotype?

Critical Thinking

7. **Applying Concepts** The allele for a cleft chin, *C*, is dominant among humans. What are the results of a cross between parents with genotypes *Cc* and *cc*?

Interpreting Graphics

The Punnett square below shows the alleles for fur color in rabbits. Black fur, *B*, is dominant over white fur, *b*.

	?	?
?	Bb	Bb
?	Bb	Bb

8. Given the combinations shown, what are the genotypes of the parents?
9. If black fur had incomplete dominance over white fur, what color would the offspring be?