① Start by drawing a box and dividing it into four squares.

② Write the male parent's alleles along the top of the square and the female parent's alleles along the left side.
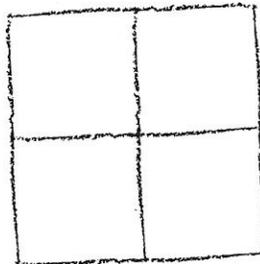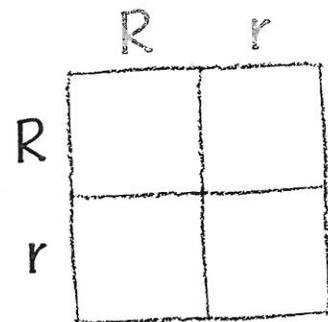
FIGURE 7
How to Make a Punnett Square

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.
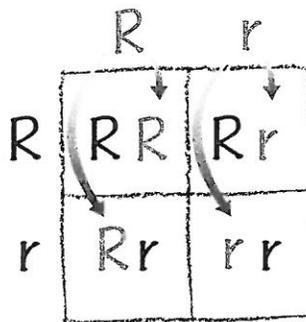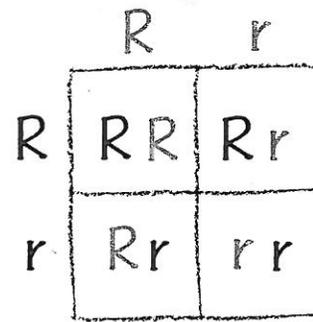
Using a Punnett Square
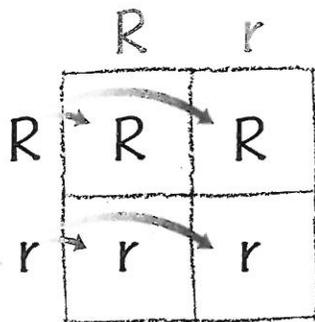
You can use a Punnett square to calculate the probability that offspring with a certain combination of alleles will result. **In a genetic cross, the allele that each parent will pass on to its offspring is based on probability.** The completed Punnett square in Figure 7 shows four possible combinations 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?*