

Using Punnett Squares to Predict the Outcomes of Crosses

The possible gene combinations in the offspring that result from a genetic cross can be determined by drawing a diagram known as a Punnett square. A Punnett square shows the genes (represented by letters) in the parents' gametes along the top and left-hand side of a square and the possible gene combinations in the offspring, within the square.

A completed Punnett square gives the probable outcome of a given cross. However, actual results may vary from the probable results, especially if only a few organisms are considered.

ONE-FACTOR CROSSES

Crosses that involve one trait, such as seed coat color, are called one-factor crosses. For the one-factor crosses in this activity, we will use some of the traits Mendel observed in pea plants. The expressions of the dominant and recessive alleles for the genes controlling these traits are described in the following chart. The chart also assigns letters to represent the different alleles.

Trait	Dominant Allele	Recessive Allele
Pod shape	Smooth (<i>N</i>)	Constricted (<i>n</i>)
Pod color	Green (<i>G</i>)	Yellow (<i>g</i>)
Flower position	Axial (<i>A</i>)	Terminal (<i>a</i>)
Plant height	Tall (<i>T</i>)	Short (<i>t</i>)

In the example that follows, we will predict the results of a cross between a plant that is heterozygous for green pods and a plant that has yellow pods.

Sample Problem

A plant that is heterozygous for green pods is crossed with a plant that has yellow pods. What are the probable genotypic and phenotypic ratios in the offspring resulting from this cross?

Step 1 Choose a letter to represent the alleles in the cross.

In this case, the letters have already been selected—*G* for the dominant green allele and *g* for the recessive yellow allele.

Step 2 Write the genotypes of the parents.

Since the plant with the green pods is heterozygous for the trait, its genotype must be *Gg*. The problem does not state whether the plant with yellow pods is homozygous or heterozygous. But we know that yellow pods are a recessive character, and that recessive characters are expressed only in a homozygous recessive individual. Thus the genotype of this plant must be *gg*. The cross, therefore, is *Gg* X *gg*.

Step 3 Determine the possible gametes (reproductive cells) that the parents can produce.

The two alleles of any gene are segregated during the formation of gametes. Thus the green-pod parent (Gg) will produce two kinds of gametes— G and g . The yellow-pod parent (gg) will produce g gametes.

Step 4 Enter the possible gametes at the top and side of the Punnett square.

At this point, the Punnett square for this problem would look like this:

	G	g
g		
g		

Step 5 Complete the Punnett square by writing the alleles from the gametes in the appropriate boxes.

This step represents the process of fertilization, in which a male gamete from one parent combines with a female gamete from the other parent. To predict all possible offspring genotypes, each type of possible gamete from one parent is combined with each possible type of gamete from the other parent.

The completed Punnett square for this problem would look like this:

	G	g
g	Gg	gg
g	Gg	gg

As you can see, $1/2$ of the offspring are genotype Gg and $1/2$ are gg .

Step 6 Determine the phenotypes of the offspring.

Since green (G) is dominant over yellow (g), plants that have G in their genotypes have green pods. Only plants with genotype gg have yellow pods. In this example, $1/2$ of the offspring have green pods and $1/2$ have yellow pods.

Step 7 Using the results of Steps 5 and 6, answer the problem.

In this example, the genotypic ratio is 2 Gg :2 gg , or 1:1. The phenotypic ratio is 2 green:2 yellow, or 1:1.

Practice Problems

For each of the following problems, draw a Punnett square in the space provided and fill in the information on the indicated lines. Refer to the table on page 183 of your textbook for a description of pea traits.

1. $Nn \times NN$

Genotypic ratio: _____

Phenotypic ratio: _____

2. $Aa \times aa$

Genotypic ratio: _____

Phenotypic ratio: _____

3. $Tt \times Tt$

Genotypic ratio: _____

Phenotypic ratio: _____

4. Cross two plants that are heterozygous for green pods.

Genotypic ratio: _____

Phenotypic ratio: _____

5. Cross a plant that is heterozygous for axial flowers with a plant that has terminal flowers.

Genotypic ratio: _____

Phenotypic ratio: _____

6. Cross a homozygous tall plant with a short plant.

Genotypic ratio: _____

Phenotypic ratio: _____

7. Cross a plant that is heterozygous for smooth pods with a plant that has constricted pods.

Genotypic ratio: _____

Phenotypic ratio: _____

8. When a tall plant is crossed with a short plant, some of the offspring are short. What are the genotypes of the parents and the offspring? What is the phenotypic ratio in the offspring?

Parent genotypes: _____

Offspring genotypes: _____

Phenotypic ratio: _____

9. Three-fourths ($\frac{3}{4}$) of the plants produced by a cross between two unknown pea plants have axial flowers and $\frac{1}{4}$ have terminal flowers. What are the genotypes of the parent plants?

Parent genotypes: _____

10. What cross would result in $\frac{1}{2}$ of the offspring having green pods and $\frac{1}{2}$ of the offspring having yellow pods?

Cross: _____