

Punnett Square Exercises

Solving Monohybrid Punnett Squares

PURPOSE

In this activity you will use Punnett squares to determine possible gene combinations for the offspring from several sets of parents.

PROCEDURE

1. Read and study Genetics: Helpful Terms and Key Concepts pages.
2. To start, pay close attention to the VOCABULARY section. Genetics is in many ways, like a foreign language with many new terms. Your teacher will review the concepts with you.
3. Read and study the next section, KEY CONCEPTS, paying very close attention to the Gene-Chromosome Theory section.
4. Finally, read through USING PUNNETT SQUARES TO PREDICT OFFSPRING section, studying the diagram and instructions. Your teacher will assist you with an example..
5. Work through the remainder of the Punnett square problems on the student answer page. Be sure to provide a Punnett square for each answer as well as all written work to show how you solved each problem.

Name _____

Period _____

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CONCLUSION QUESTIONS

1. Explain why there are at least two alleles that make up the gene coding for a particular trait.
2. Explain the term “heterozygous”. How can an organism have two different alleles for one single trait but only show one observable trait?

PRACTICE PUNNETT SQUARES: Draw all Punnett Squares with a ruler. Each side of the square should be at least 4 cm long.

3. A common recessive trait in dogs is deafness. A homozygous line of normal-hearing dogs was crossed with a homozygous line of deaf dogs. F₁ and F₂ generations were produced.
 - a. What percentage of the F₁ generation is expected to have normal hearing?
 - b. What is the phenotypic ratio of the F₂ generation?
4. Black color in horses is dominant over chestnut color. If a homozygous black horse is mated to a chestnut horse, what percent of the offspring will be chestnut colored? Use a Punnett square to show how you derived your answer.

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5. A gene that codes for black fur color in guinea pigs has two alleles. Two recessive copies of this allele will result in a guinea pig that cannot produce black fur; it will therefore have white fur. Construct a Punnett Square to show all possible combinations of gametes that could result from the cross of a heterozygous black guinea pig with a white guinea pig.

Construct a Punnett Square to show all possible combinations of gametes that could result from the cross of a black guinea pig that is heterozygous for black fur and a guinea pig that is homozygous recessive for black fur (which results in white fur coloration).

- What is the probability that the offspring will have black fur? [Answer should be a ratio.]
 - What percent of the offspring will be homozygous recessive?
6. George is the youngest child in a family that includes 4 children. All of the children have the recessive phenotype — attached earlobes. Yet both parents have unattached earlobes, the dominant trait. What are the possible genotypes for the parents? Use Punnett squares to prove your answer.
7. Explain why it is possible for two parents with a dominant trait like freckles to produce 10 children, all of whom do not have freckles. Use a Punnett square to illustrate your answer.

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Genetics: Helpful Terms and Key Concepts

VOCABULARY

- **heredity:** passing traits from parent to offspring.
- **genetics:** the study of heredity and variation in organisms.
- **DNA or deoxyribonucleic acid:** a double-stranded helical nucleic acid molecule that codes and stores genetic information; it determines the inherited structure of a cell's proteins
- **chromosomes:** threadlike strands of DNA and protein in a cell nucleus that carry the code for the inherited characteristics of an organism.
- **gene:** a distinct unit of hereditary material found in chromosomes; the region of DNA that directs the making of a specific protein, thus controlling traits that are passed to offspring.
- **allele:** different forms of a gene controlling a particular trait; e.g., one allele for height may be short, while another allele may be tall.
- **dominant allele:** the form of a gene that appears to dominate or mask another form of the same trait. The form of the allele that is expressed in the phenotype.
- **recessive allele:** the form of a gene that is often masked by the dominant allele and is therefore often not expressed in the phenotype.
- **homologous chromosomes:** a pair of chromosomes having the same size and shape and carrying alleles for the same traits.
- **incomplete dominance:** a type of inheritance in which two contrasting alleles contribute to the individual a trait not exactly like either parent; blending inheritance; when both alleles are expressed in offspring and neither is dominant.
- **codominance:** a type of inheritance in which two dominant alleles are expressed at the same time without blending of traits.
- **heterozygous:** organism that has two different alleles for a trait.
- **homozygous:** organism that has two identical alleles for a trait.
- **genotype:** the genetic makeup of an individual.
- **phenotype:** the physical traits that appear in an individual as a result of its genetic makeup.

- **gamete:** a reproductive cell that joins with another in fertilization; most often, the joining of an egg and a sperm cell; a haploid cell.
- **mitosis:** the process by which the nucleus of a cell divides, while maintaining its correct chromosome number; in mitosis, the cell makes an exact (though smaller) copy of itself.
- **meiosis:** cell division in diploid cells that results in haploid cells; reduction division; in meiosis, the sex cells are produced; sex cells are nonidentical.
- **haploid:** having only one chromosome from each pair of homologous chromosomes; sex cells are haploid and are designated as n .
- **diploid:** having two sets of chromosomes, designated as $2n$; the cells of the body are diploid with the exception of the sex cells.
- **cross:** gamete union resulting in offspring.
- **P generation:** parent generation; the starting generation in a breeding experiment.
- **F₁ generation:** first filial generation; the first generation produced in a breeding experiment.
- **F₂ generation:** second filial generation; the second generation produced in a breeding experiment; offspring of the F₁ generation.
- **Punnett square:** diagram in which all possible types of gametes from one parent are lined up vertically and all possible types of gametes from the other parent are lined up horizontally and every possible fertilization combination is considered; a tool that shows how genes can combine; used to predict results in genetics.

KEY CONCEPTS

- **The Law of Dominance:** When an organism is heterozygous for a pair of contrasting traits, only the dominant trait can be seen in the organism.
- **The Law of Segregation:** Genes that occur in pairs are separated from each other during gamete formation and recombined at fertilization.
- **The Law of Probability:** If there are several possible events that could occur, and one is no more likely to happen than any other, then the events will all occur equally when a large number of trials are studied. This law allows you to predict the results of breeding experiments. However, remember that these predictions apply only when large numbers of individuals are involved.
- **Gene-Chromosome Theory:**

Gregor Mendel conducted his experiments with pea plants from 1857 to 1865. He stated that each trait in an individual was controlled by a pair of “factors.” The idea that Mendel’s “factors” might be genes carried by homologous chromosomes was suggested first in 1903 by an American graduate student,

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W. S. Sutton. He observed the pairs of homologous chromosomes in diploid grasshopper cells separate during sperm formation (spermatogenesis). After reviewing Mendel's work, Sutton concluded that the factors of Mendel's theory were carried on the chromosomes since the chromosomes were separating and recombining, as Mendel's factors were theorized to do. Figure 1 shows how Sutton's chromosome theory would apply to a Mendelian cross of two tall heterozygous plants.

As you can see in figure 1, the separation of homologous chromosome pairs during meiosis and their recombination during fertilization would account for the separation and recombination of the Mendelian factors.

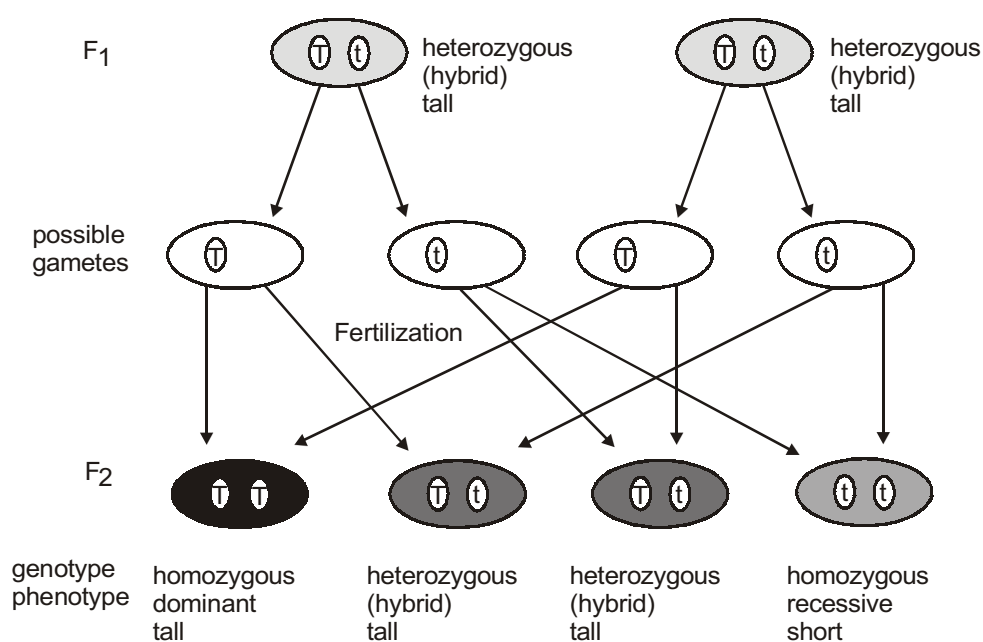


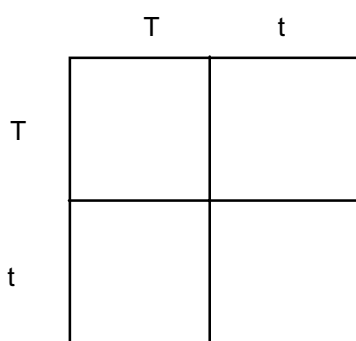
Figure 1. The Gene-Chromosome Theory. T represents the allele (factor) for tallness and t the allele for shortness. Each allele is on a homologous chromosome. When the pairs of homologous chromosomes separate during gamete formation, they form two kinds of gametes: one with T and the other with t. Upon fertilization chromosomes from each parent reunite to form a new homologous pair.

Following the publication of Sutton's paper, titled "The Chromosomes in Heredity," in 1903, many experiments showed that this hypothesis was correct. At that time, the term *gene* was used in place of Mendel's "factor." Research showed not only that chromosomes carry genes but also that the genes are in a definite order along each chromosome. This work led to the modern gene-chromosome theory of heredity.

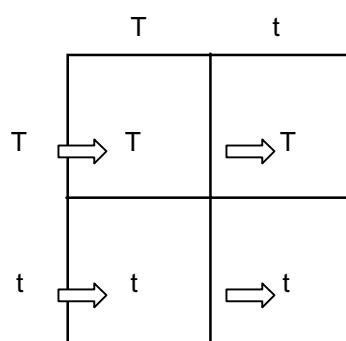
USING PUNNETT SQUARES TO PREDICT OFFSPRING

A Punnett square is used to determine all possible gene combinations in the offspring of a set of parents. Remember that each gene is made up of at least two alleles — one allele from the mother and one from the father. Biologists represent a particular allele in a Punnett square by using a symbol. The dominant allele is represented by a capital letter. The recessive allele is represented by the corresponding lowercase letter. In Mendel's pea plant experiments, for example, T represents the dominant allele for tallness and t represents the recessive allele for shortness.

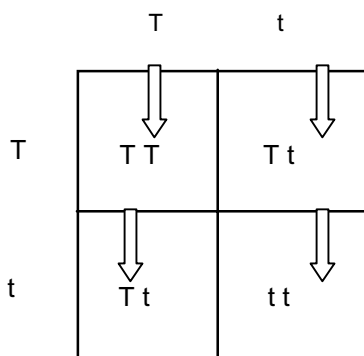
The Punnett squares in Figure 2 below show the types of reproductive cells, or *gametes*, produced by the F₁ generation parents along the top and left-hand side of the square. It includes directions on how to complete the square. Finally, it shows each possible gene combination for the F₂ offspring in the four boxes that make up the square.



Step 1. Place the alleles of the parents on the outside of the square.



Step 2. Fill in each square with the allele that is to the left on the outside of the box.



Step 3. Fill in each square with the allele that is above on the outside of the box.

Figure 2. Steps used in constructing a Punnett square. Note that the final square shows all possible gene combinations for the offspring. In addition, the Punnett square allows you to predict the probability of obtaining any particular outcome from a given cross. In this example, 2 out of 4, or 50%, of the offspring will have the Tt genotype.

Figure 2

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You can see the probable results of the cross of two F_1 generation plants from the Punnett square: 1/4 of the F_2 generation plants have two dominant alleles (TT); 2/4 or 1/2 of the F_2 plants have one dominant allele and one recessive allele (Tt); and 1/4 of the F_2 plants have two recessive alleles (tt). Because tall is dominant over short, 3/4 of the F_2 plants would be tall and 1/4 of the F_2 plants would be short. These numbers are often expressed as ratios. For example, there are 3 tall plants for every 1 short plant in the F_2 generation. Thus the phenotypic ratio of tall plants to short plants is 3:1.

Look again at figure 2. You will see that three of the possible combinations result in tall plants. Because all these plants appear tall, we can say that they have the same *phenotype*, or physical characteristic. They do not, however, have the same *genotype*, or genetic makeup. The genotype of 1/3 of the tall plants (or 1/4 of all offspring) is pure dominant (homozygous dominant), or TT, whereas the genotype of 2/3 of the tall plants is mixed dominant and recessive (heterozygous dominant), or Tt. The short plants, tt, are known as homozygous recessive.

Organisms that have two identical alleles for a particular trait (TT or tt in our example) are said to be *homozygous*. Organisms that have two different alleles for the same trait are *heterozygous*. In other words, homozygous organisms are pure-bred for a particular trait and heterozygous organisms are *hybrid* for a particular trait. See Table 1 for a comparison of genotypes and phenotypes.

Table 1. Comparison of genotype to phenotype.		
Genotype Abbreviation	Genotype	Phenotype
TT	Homozygous dominant	Tall
Tt	Heterozygous	Tall
tt	Homozygous recessive	Short