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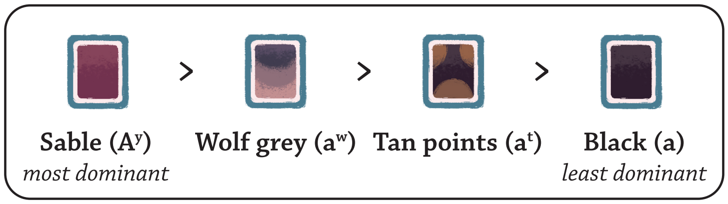
G. More than two alleles

It's rare in nature for a gene to come in just two "flavors" or alleles. More often, a gene comes in many alleles, each a little different. So even though an individual can have only two alleles, a population can have many. With multiple, there can be more variation in a group. This is one reason why traits across a population often fall into more than two or three categories, or "bins."

EXAMPLE

In Mutt Mixer, there are 4 Color alleles that follow a hierarchy of dominance.

The most-dominant allele in a pair determines a dog's phenotype.



PRACTICE

11. Fill in the table *(Tip: Use Mutt Mixer to input the phenotype and see the genotype)*

Genotype	Phenotype
$A^y\ a^w$	
$a\ a^w$	
$a^t\ a^w$	
$a\ A^y$	
$a^t\ a$	
a a	

12. Consider a cross between two dog parents with the following genotypes: $a^t\ a$ X $a\ a^w$

a. Make a model, such as a Punnett square, to show all the possible genotypes for the offspring.

b. Fill in the phenotypes for the parents and all the possible offspring.

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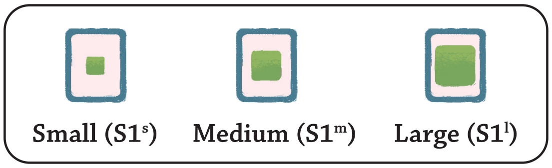
13. The Size 1 gene in Mutt Mixer comes in 3 alleles, which are all co-dominant.



a. Make a model, such as a Punnett square, to show all the possible offspring for these parents:

$S1^s$ $S1^m$ X $S1^s$ $S1^l$

b. How many possible sizes could the puppies be?

c. How does having more than two possible alleles in the parents contribute to variation in the offspring?

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H. Independent assortment

In the earlier examples and problems, you modeled one gene at a time. But gametes (reproductive cells, like eggs and sperm) get **one allele for each gene**. Importantly, different genes are inherited independently of one another. This idea is known as independent assortment.

The process that shuffles alleles into all their possible combinations in reproductive cells is **recombination**. Recombination contributes to genetic variation in a population.

EXAMPLE

In pea plants, separate genes affect plant height and seed color. When a plant makes gametes, the allele a gamete gets for height has no effect on the allele it gets for seed color.

As this model shows, every allele combination is possible in the gametes:

Phenotype: Tall, Yellow seeds

Genotype: T t Y y

Possible gametes: (T Y) (T y) (t Y) (t y)

PRACTICE

14. For the pea plant below, draw a model to show all the possible allele combinations in the gametes.

Phenotype: Tall, Green seeds

Genotype: T t y y

Possible gametes:

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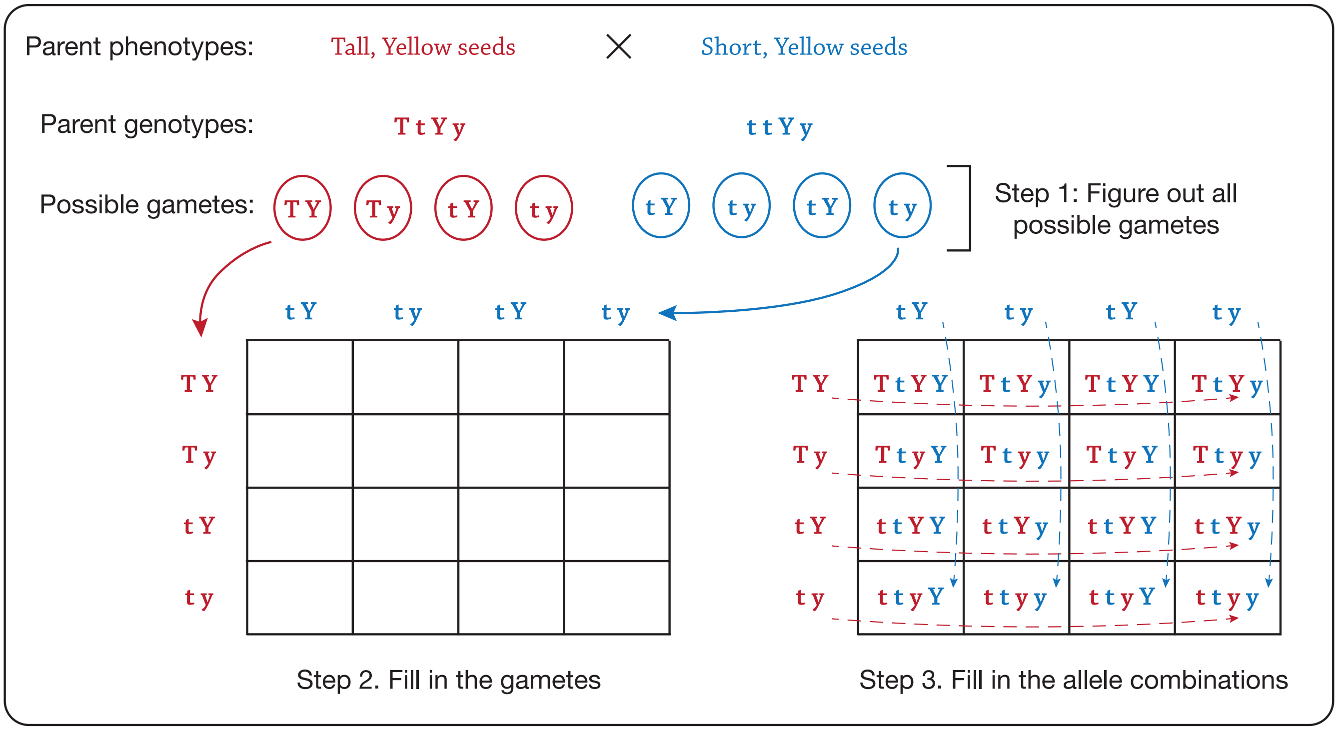
I. Two-factor cross: two traits in one Punnett square

You can use a model, such as Punnett square, to track the possible allele combinations offspring can have for two (or more) genes. Since alleles for different genes are inherited independently from each other, you need to account for many more possible allele combinations in the offspring!

EXAMPLE

This Punnett square models a two-factor cross:



From here, you could calculate the probability for each phenotype. Since there are 16 cells in the Punnett square, the probability for each cell is 1/16.

For example, the genotype ttyy appears in 2 cells.

So the probability of getting a short offspring with green seeds is 1/16 + 1/16 = 2/16 (or 1/8)

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PRACTICE

15. Make a two-factor Punnett square for a cross between two dog parents with furnishings and semi-floppy ears (F f E^p e^f).

16. Fill in the genotypes and calculate the probability that an offspring will have:

a. No furnishings and pointy ears

Genotype(s):

Probability:

b. Furnishings and floppy ears

Genotype(s):

Probability:

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17. Come up with your own two-factor cross that involves furnishings and color.

18. What phenotypes, if any, are visible in the offspring that were not visible in the parents?

19. For the cross above, explain how having more than two possible color alleles in the parents increases genetic variation in the offspring.