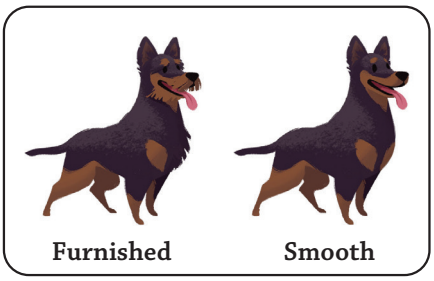
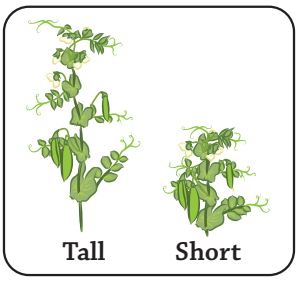
Complex Traits: Beyond the Punnett Square

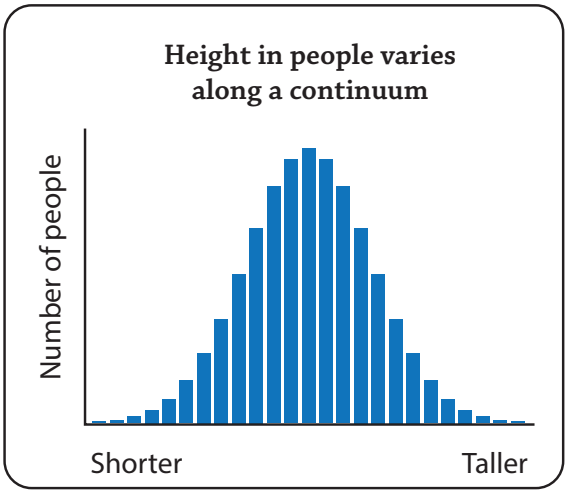
Part 1. Most traits are influenced by multiple genes

You've seen how to use a Punnett square to model inheritance for a trait strongly influenced by one gene. It's useful for modeling traits that fall neatly into "bins," like furnishings vs. smooth fur in dogs, or short vs. tall pea plants.





But traits like this are rare. Much more often, traits vary along a continuum. Like body size in dogs, or height in people.



Geneticists call these ***continuous*** or ***quantitative*** traits. These traits—like most—are complex. They are influenced by multiple genes. And their inheritance patterns are hard, if not impossible, to predict.

Below, we'll use what we've already learned to model the inheritance of a complex trait. We'll follow height in pea plants in three cases, A, B, and C. Each case adds a little more complexity.

In all 3 cases, each gene has two alleles. Upper case alleles (like A) are tall, and lower case alleles (like a) are short. All the alleles are co-dominant.

Case A: One gene affects height

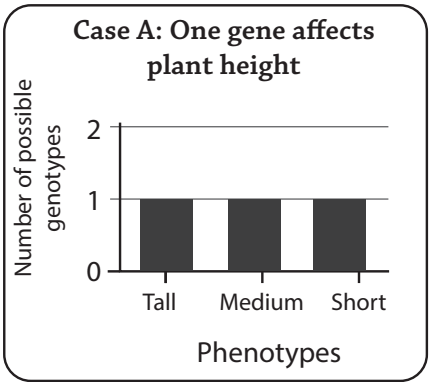
In this simple case, the A gene in pea plants affects height. It has two co-dominant alleles, A (tall) and a (short). That means there are 3 possible genotypes.

NAME _____ DATE _____

1. Fill in the possible phenotypes:

Genotype (allele combination)	**Phenotype** (visible trait)
AA	
Aa	
aa	

Here's one way to graph the possible genotypes and phenotypes across a population:



Case B: Two genes affect height

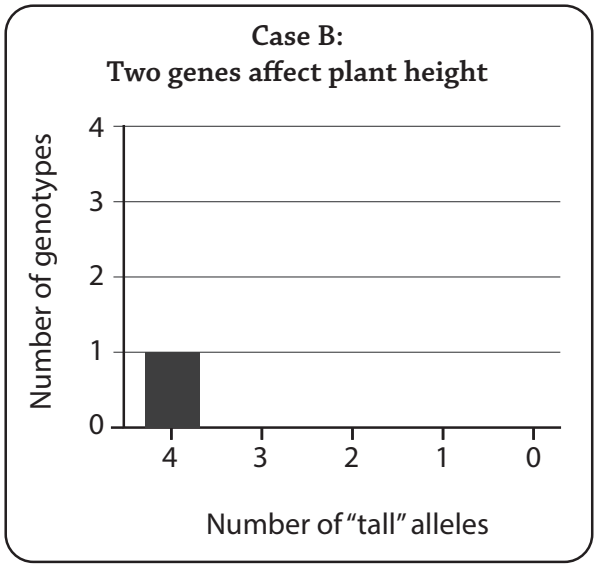
In this case, two genes in pea plants affect height: A and B. Each gene has two co-dominant alleles. Because of independent assortment, every allele combination is possible across a population. There are nine possible genotypes:

AABB	AaBB	aaBB
AABb	AaBb	aaBb
AAbb	Aabb	aabb

2. An individual's height phenotype is determined by the number of "tall" alleles it has. Next to the genotypes above, write in the number of "tall" alleles. (Hint: AABB has 4 "tall" alleles)

3. Fill in the table (the first row has been filled in for you) and the bar graph:

Number of "tall" alleles	**How many genotypes in this category?**
4	1
3	
2	
1	
0	



4. Under the graph, add labels for tall, medium, and short.

NAME _____ DATE _____

5. In Case B, how many different **phenotypes** are possible across a population? _____

Case C: Three genes affect height

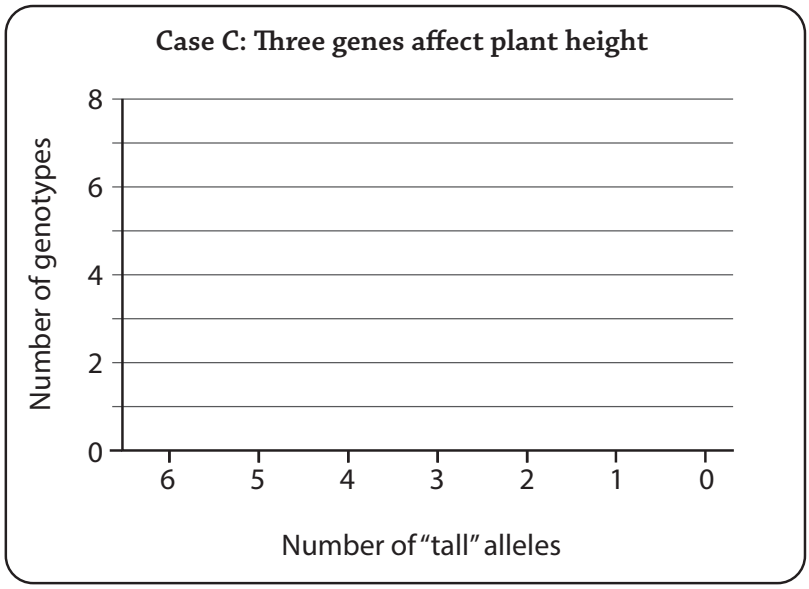
Three genes in pea plants affect height: A, B, and C. As in the other cases, each gene has two co-dominant alleles. Across a population, there are 27 possible genotypes:

AABBCC	AaBBCC	aaBBCC
AABBCc	AaBBCc	aaBBCc
AABBcc	AaBBcc	aaBBcc
AABbCC	AaBbCC	aaBbCC
AABbCc	AaBbCc	aaBbCc
AABbcc	AaBbcc	aaBbcc
AAbbCC	AabbCC	aabbCC
AAbbCc	AabbCc	aabbCc
AAbbcc	Aabbcc	aabbcc

6. Next to each genotypes above, write in the number of "tall" alleles.

7. Fill in the table and the bar graph.

Number of "tall" alleles	How many genotypes in this category?
6	
5	
4	
3	
2	
1	
0	



8. Under the graph, add labels for tall, medium, and short

9. In Case C, how many different **phenotypes** are possible across a population? _____

10. Look at the bar graphs for Cases A, B, and C. Which one looks most like the graph of human height on page 1? Why?

NAME _____ DATE _____

11. How do you think the possible height phenotypes would change in pea plants if we added a fourth gene that affects height?

Scientists have found 423 genes (and 697 variations within them) that influence human height!

Part 2: Genes plus environmental factors

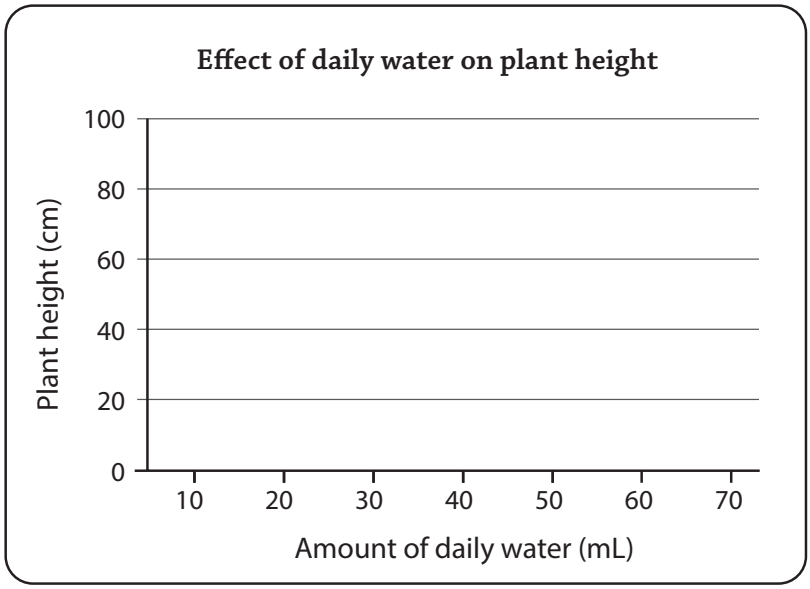
Punnett squares and other inheritance models focus on the effects of genes. Yet most traits are also affected by environmental factors. For example, adult height is affected by health and nutrition during childhood.

12. What are some environmental factors that could influence height in pea plants?

A scientist sets up an experiment to see how the amount of daily water affects height in pea plants. Using plants from Case A (one gene affects plant height), she collected many seeds that all had the genotype Aa. She grew the seeds with different amounts of water, with 10 seeds in each condition. After 30 days, she measured the height of all the plants.

The table shows the results:

Amount of daily water (mL)	**Average plant height** (cm)
10	15
20	40
30	70
40	85
50	70
60	40
70	15



13. Fill in the bar graph.

14. What is the best amount of daily water for growing tall pea plants?

15. Explain what happens if pea plants get too much or too little water.

NAME _____ DATE _____

16. Make a prediction: The scientist grows seeds of all 3 genotypes (AA, Aa, and aa) in different amounts of water. Sketch a rough graph showing the variation in height that you would expect to see.

17. How could you grow a population of pea plants that looks even more like the graph of human height on page 1?