

Chapter 19 Project

Rolling the Dice for Evolution

Project Goal + Timeline

In this project, you will apply your knowledge of evolution and changes to gene frequencies. The goal will be to directly observe, via simulation, the different ways in which a population can evolve. This project should be completed by yourself or within a group in a two-hour time frame and will require either a set of 10 dice or a dice simulation like the one found on this website (hawkes.biz/diceroller).

The project will simulate the evolution of different pigmentation traits in the peppered moth (*Biston betularia*). Before the 1700s, the white-bodied phenotype and associated alleles were most frequent in this species in England because it provided effective camouflage against the light-colored bark of the region's trees. However, with the advent of the Industrial Revolution and pollution from burning of fossil fuels, soot accumulated on the trees. This inverted the selection for pigmentation in the moth; now, black-bodied moths were more fit for the environment, and white-bodied moths became easier prey for predator species to see. The frequency of the allele changed accordingly, demonstrating the most classic example of evolution. To learn more about the history of the peppered moth, check out this video (hawkes.biz/pepperedmothevolution).

Directions

In this project, you will simulate the evolution of melanism, or dark pigmentation, in the peppered moth (*Biston betularia*). The way the white- or black-bodied alleles changed in frequency during the Industrial Revolution is a classic example of natural selection. In this project, we will suppose that the black-bodied allele (*B*) is dominant, and the white-bodied allele (*b*) is recessive.

Part 1: Genetic Drift and Bottleneck Effect

First, let's imagine that you are studying these moths in a series of small islands in the North Atlantic. We will start our observations on an island that has an equal distribution of black- and white-bodied individuals: 25 of each.

1. Using the Hardy-Weinberg equation, calculate the frequency of each genotype and predict how many black- and white-bodied individuals you should observe in the next generation. Record this in the appropriate rows in the first column of Table 1.
2. You will then simulate genetic drift by allowing some of these moths to survive and mate at random. First, simulate survival of some moths and deaths of the others. Roll 10 dice; for each even number, remove a white moth from the population, and for each odd number, removed a black moth from the population. You should record what the result of your dice roll is in the next two rows on Table 1.
3. Using these 40 survivors, build the population back to 50 moths. You can do this by once again use the Hardy-Weinberg equation. Using the proportion of white moths (*bb*), you can find the frequency of each allele, and then predict how many of each genotype (and phenotype) you should see. If you obtain a fraction in your answer, you should round to the nearest integer and ensure that you have 50 moths total. Record the new frequencies in the bottom two rows of the table. Write this total in the starting population rows for the next column.
4. Repeat the preceding steps again, simulating another round of genetic drift. Note that the frequencies at the bottom of the column for generation 1 are effectively repeated in the middle rows of column 2.
5. For the third round, we will suppose that a small amount of these moths has left to populate a nearby island. This is a simulation of the bottleneck effect on genetic drift. This time, you will throw 10 dice, but this will represent the founding moths of a new population. (Even still represents white, and odd still represents black.)

6. Reconstitute the population as before; calculate the frequency in this founding population and use it to bring the total up to 50. (If it helps, you can imagine this as the carrying capacity of the environment in this project.)
7. For the fourth and final generation, you can repeat steps 2 and 3.

TABLE 1

Generation	1	2	3	4
Starting White	25			
Starting Black	25			
(B) Allele Frequency				
(b) Allele Frequency				
White Removed (Remaining)			Survivors:	
Black Removed (Remaining)			Survivors:	
(B) Remaining Allele Frequency				
(b) Remaining Allele Frequency				

Answer the following questions:

- a. According to the Hardy-Weinberg equation, did evolution occur across any of the generations?
- b. Did the frequency of alleles in the population change in a particular direction each generation, or did it drift randomly?
- c. Did the frequency of alleles in the population change more significantly after the bottleneck effect? How does this impact the evolution of this species?
- d. In the final generation, what proportion of each genotype do you expect to find?

Part 2: Natural Selection

Now, we will suppose that the moths have colonized an island in which there is a predator that can more easily pick out the white-bodied individuals against a darker background environment. This mimics what was observed during the Industrial Revolution, in which pollution darkened tree bark and made it harder for predators to identify the black-bodied individuals.

Here, you will simulate survival like before, except we now expect black-bodied individuals to have a better chance of survival and a lower chance of predation. Starting from the same population of 25 moths of each type, roll 10 dice and determine which moths were eliminated. Here, a roll of 1–5 will represent a white moth, while a roll of 6 will represent a black moth.

1. Using the Hardy-Weinberg equation, calculate the frequency of each genotype and predict how many black- and white-bodied individuals you should observe in the next generation.
2. You will then simulate natural selection by allowing some of these moths to survive, but in a way that favors one phenotype over another. Here, you will simulate predation of these moths in which the black-bodied individuals have better camouflage and, therefore, are harder for a predator to find. Roll 10 dice; for each time you roll a 6, remove a black moth from the population, and for each time you roll any other number, remove a white moth from the population.
3. Using these 40 survivors, build the population back to 50 moths. You can do this by once again use the Hardy-Weinberg equation. Using the proportion of white moths (bb), you can find the frequency of each allele and then predict how many of each genotype (and phenotype) you should see. If you obtain a fraction in your answer, you should round to the nearest integer and ensure that you have 50 moths total. Write this total in the starting population rows in column 2 of Table 2.
4. Repeat the preceding steps again for generations 2, 3, and 4, simulating several rounds of natural selection.

TABLE 2

Generation	1	2	3	4
Starting White	25			
Starting Black	25			
(B) Allele Frequency				
(b) Allele Frequency				
White Removed (Remaining)				
Black Removed (Remaining)				
(B) Remaining Allele Frequency				
(b) Remaining Allele Frequency				

Answer the following questions:

- According to the Hardy-Weinberg equation, did evolution occur across any of the generations?
- Did the frequency of alleles in the population change in a particular direction each generation, or did it drift randomly?
- In the context of the theory of evolution by natural selection, does your result make sense?

Part 3: Comparison

As a way of contrasting the random nature of genetic drift with the nonrandom evolution of an adaptation by natural selection, you should compare your previous results with a friend that also completed both exercises. Alternatively, you can repeat the exercise from scratch.

- Did your results match that of your friend's (or your repeat attempt) for Table 1? In what ways were they different, if at all?
- Did your results match that of your friend's (or your repeat attempt) for Table 2? In what ways were they different, if at all?
- Why might your answers for the previous two questions differ? Why might you expect similar results when comparing to a friend for the natural selection exercise but not the genetic drift exercise?

Project Materials

- 2 tables for recording data
- Pen or pencil
- 10 physical dice, rerolling of a smaller number of physical dice, or a dice-rolling simulator (hawkes.biz/diceroller)

Student Checklist

- ☐ Complete the exercise for Genetic Drift (Table 1)
- ☐ Answer the questions about Genetic Drift
- ☐ Complete the exercise for Natural Selection (Table 2)
- ☐ Answer the questions about Natural Selection
- ☐ Compare your result with friend's or classmate's
- ☐ Answer the Comparison questions