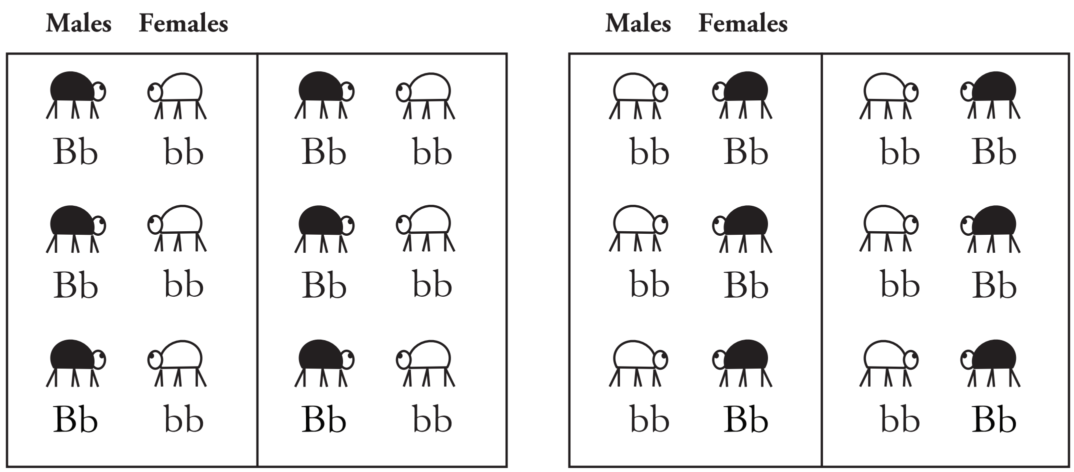
The Hardy-Weinberg Equation

How can we make predictions about the characteristics of a population?

Why?

Punnett squares provide an easy way to predict the possible genotypes for an offspring, but it is not practical to perform a Punnett square analysis on all possible combinations of all members of a population to predict what the population might look like in the future. For that we must turn to statistics. The Hardy-Weinberg equation is a tool biologists use to make predictions about a population and to show whether or not evolution is occurring in that population.

Model 1 – Controlled (Selective) Mating



1. How many mating pairs are illustrated in Model 1?

2. Describe the parents in each mating pair in Model 1. Use terms such as homozygous, heterozygous, dominant, and recessive.

3. Use two Punnett squares to determine the possible genotypes for offspring from the pairs.

4. If each mating pair has one offspring, predict how many of the first generation offspring will have the following genotypes.

   BB Bb bb

5. Imagine the 24 beetles in Model 1 as a population in an aquarium tank.
   a. How likely is the pairing scenario in Model 1 to take place during the natural course of things within that tank?

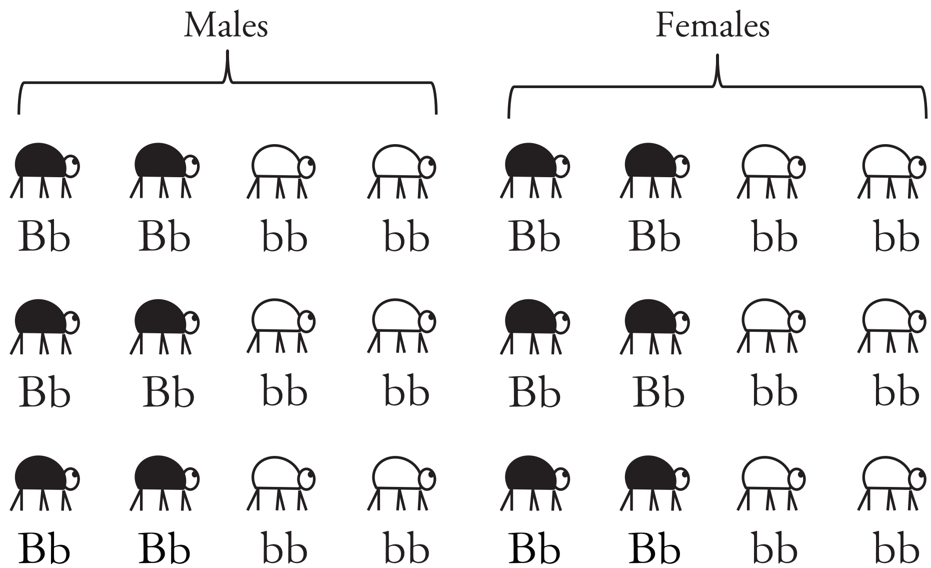
   b. Why is Model 1 labeled "Selective Mating"?

6. List two other pairings that might occur in the population in Model 1 if the beetles were allowed to mate naturally.

7. If the population of beetles in Model 1 mated naturally would your prediction for the offspring in Question 4 still be valid? Explain.

8. Discuss in your group the limitations of Punnett square predictions when it comes to large populations. Summarize the key points of your discussion here.

Model 2 – Population Genetics



9. Compare the organisms in the population in Model 1 with the organisms in the population in Model 2.

10. Individually match up twelve mating pairs from the population in Model 2 that might occur in a natural, random mating situation.

11. Compare your set of mating pairs with other members of your group. Did your mating scheme match anyone else's in the group?

Read This!

When it comes to mating in natural populations with hundreds or even millions of individuals, it is difficult, maybe even impossible, to think of all the mating scenarios. After several generations of leaving things up to nature, the alleles that are present in the population will become more and more randomized. Statistics can help biologists predict the outcome of the population when this randomization has occurred. If the population is particularly nonrandom to start, this randomization may take several generations.

12. How many total alleles are in the population in Model 2?

13. What is the probability of an offspring from the Model 2 population getting a dominant allele?

14. What is the probability of an offspring from the Model 2 population getting a recessive allele?

15. If p is used to represent the frequency of the dominant allele and q is used to represent the frequency of the recessive allele, then what will p + q equal?

16. Use your knowledge of statistics to calculate the probability of an offspring from the Model 2 population having each of these genotypes. Support your answers with mathematical equations.

    (Don't forget there are two ways to get a heterozygous offspring—Bb or bB.)

    BB Bb bb

17. Check your answers in Question 16 by adding the three values together. Your sum should be equal to one. Explain why the sum of the three answers in Question 16 should be equal to one.

18. Using p and q as variables, write formulas for calculating the probability of an offspring from a population having each of the following genotypes.

    BB Bb bb

19. Complete the equation:

    $p^2 + 2pq + q^2 =$

STOP

Read This!

The equations you have just developed, $p + q = 1$ and $p^2 + 2pq + q^2 = 1$, were first developed by G. H. Hardy and Wilhelm Weinberg. They represent the distribution of alleles in a population when

- The population is large.
- Mating is random.
- All genotypes are equally likely to reproduce (there is no natural selection).
- No organisms enter or leave the population (there is no immigration or emigration).
- No mutations occur.

In other words, the group of alleles available in the population must be very stable from generation to generation. If the distribution of genotypes in a population matches that predicted by the Hardy-Weinberg equation, then the population is said to be in **Hardy-Weinberg equilibrium**. If the distribution of genotypes in a population does not match that predicted by the Hardy-Weinberg equation, then the population is said to be evolving.

20. Consider the requirements for a population to be in Hardy-Weinberg equilibrium. In the natural world, are populations likely to be in Hardy-Weinberg equilibrium? Justify your reasoning.

21. Sickle-cell anemia is a genetic disease. The Sickle-cell allele is recessive, but individuals with the homozygous recessive genotype (ss) often die prematurely due to the disease. This affects approximately 9% of the population in Africa. Use the Hardy-Weinberg equations to calculate the following:

    a. The frequency of the recessive allele in the population (q).

    b. The frequency of the dominant allele in the population (p).

    c. The frequency of homozygous dominant individuals in the African population.

    d. The frequency of heterozygous individuals in the African population.

    e. Based on this analysis, is the African population in Hardy-Weinberg equilibrium? Justify your answer.

22. Individuals with the heterozygous genotype (Ss) for Sickle-cell exhibit resistance to Malaria, a serious disease spread by mosquitoes in Africa and other tropical regions.

    a. Discuss with your group how this might affect the frequency of the recessive allele in the African population. Summarize your group's conclusions here.

    b. How might this trait affect the values calculated in Question 21 and the population's tendency toward Hardy-Weinberg equilibrium?

STOP

23. Consider the beetle population in Model 2. Imagine a change occurred in the beetle's ecosystem that made it easier for predators to spot the white beetles and six of the white beetles were lost. Predict the genotype frequency in the population after this event.

24. Compare your answers to Question 22 with those of Question 16. How do your answers support the conclusion that the population is not in Hardy-Weinberg equilibrium?

Extension Questions

25. The ability to taste PTC is due to a single dominant allele "T." You sampled 215 individuals and determined that 150 could detect the bitter taste of PTC and 65 could not. Calculate the following frequencies.

    a. The frequency of the recessive allele.

    b. The frequency of the dominant allele.

    c. The frequency of the heterozygous individuals.

26. Sixty flowering plants are planted in a flowerbed. Forty of the plants are red-flowering homozygous dominant. Twenty of the plants are white-flowering homozygous recessive. The plants naturally pollinate and reseed themselves for several years. In a subsequent year, 178 red-flowered plants, 190 pink-flowered plants, and 52 white-flowered plants are found in the flowerbed. Use a chi-square analysis to determine if the population is in Hardy-Weinberg equilibrium.