Hardy-Weinberg Lab

Objectives:

- To calculate frequencies of alleles and genotypes in the gene pool of a population using the Hardy-Weinberg formula.
- Discuss natural selection and other causes of microevolution as deviations from the conditions required to maintain Hardy-Weinberg equilibrium.

Case 1: A Test of an Ideal Hardy-Weinberg Population

In this activity, your entire class will simulate a population of randomly mating individuals. Choose another student at random (for this simulation, assume that sex and genotype are irrelevant to mate selection.) The population begins with a frequency of 0.5 (50%) for the dominant allele A and also 0.5 (50%) for the recessive allele a. Your initial genotype is Aa. Record this on the Data Sheet. Each member of the class have four cards: each represents a chromosome. Two cards (chromosomes) will have allele A and two cards will have allele a. The four cards represent the products of meiosis. Each "parent" will contribute a haploid set of chromosomes to the next generation.

Procedure:

1. Turn the four cards over so that the letters do not show, shuffle them, and take the card on top to contribute to the production of the first offspring. Your partner should do the same. Put the two cards together. The two cards represent the alleles of the first offspring. One of you should record the genotype of this offspring in the case I question on the data page. Each student pair must produce two offspring, so all four cards must be reshuffled and the processed repeated to produce a second offspring.
2. The other partner should then record the genotype of the second offspring on the data page. The very short reproductive career of this generation is over. You and your partner now become the next generation by assuming the genotypes of the two offspring. That is, student 1 assumes the genotype of the first offspring and student 2 assumes the genotype of the second offspring.
3. Each student should obtain, if necessary, new cards representing the alleles in his or her respective gametes after the process of meiosis. For example, student 1 becomes genotype Aa and obtains cards A, A, a, a; Student 2 becomes aa and obtains cards a, a, a, a. Each participant should randomly seek out another person with whom to mate in order to produce the offspring of the next generation. Remember, the sex of your mate does not matter, nor does the genotype. You should follow the same mating procedures as you did for the first generation, being sure to record your new genotype after each generation. Class Data should be collected after each generation for five generations. At the end of each generation, remember to record the genotype that you have assumed. Your teacher will collect class data after each generation by asking you to raise your hand to report your genotype.
4. **Allele Frequency:** The allele frequencies, *p* and *q*, should be calculated for the population after the five generations of stimulated random mating.

Number of A alleles present at the fifth generation

Number of offspring with genotype AA _____x 2 = _____ A alleles
Number of offspring with genotype Aa _____x 1 =_____ A alleles
Total=_____ A alleles

$$p = \frac{\text{TOTAL number of A alleles}}{\text{Total number of alleles in the population (number of students x 2)}}$$

In this case, the total number of alleles in the population is equal to the number of students in the class x 2.

Number of a alleles present at the fifth generation

Number of offspring with genotype aa _____x 2 = _____ a alleles
Number of offspring with genotype Aa _____x 1 =_____ a alleles
Total=_____ a alleles

$$q = \frac{\text{TOTAL number of a alleles}}{\text{Total number of alleles in the population (number of students x 2)}}$$

Questions:

1. What does the Hardy-Weinberg Equation predict for the new p and q?
2. Do the results you obtained in this stimulation agree? If not, why?
3. What major assumption(s) were not strictly followed in this stimulation?

Case 2: Selection

In this Case you will modify the stimulation to make it more realistic. In the natural environment, not all the genotypes have the same rate of survival; that is, the environment might favor some genotype while selecting against others. An example is the human condition sickle-cell anemia. This is a disease caused by a mutation on one allele, and individuals who are homozygous recessive often do not survive to reach reproductive maturity. For this stimulation you will assume that the homozygous recessive individuals never survive (100% selection against), and that heterozygous and homozygous dominant individuals survive 100% of the time.

Procedure

The procedure is similar to that for Case 1.

1. Start again with your initial genotype and produce your "offspring" as you did for Case 1. This time, however, there is one important difference. Every time your "offspring" is aa, it does not reproduce. Since we want to maintain a constant population size, the same two parents must try again until they produce two surviving offspring. You may need to get new "allele" cards from the gene pool, allowing each individual to complete the activity.
2. Proceed through five generations, selecting against the homozygous recessive offspring 100% of the time. Then add up the genotype frequencies that exist in the population and calculate the new p and q frequencies in the same way you did for case 1.

Questions:

1. How do the new frequencies of p and q compare to the initial frequencies in case 1?
2. What major assumption(s) were not strictly followed in this situation?
3. Predict what would happen to the frequencies of p and q if you simulated another five generations.
4. In a large population would it be possible to completely eliminate a deleterious recessive allele? Explain.

Case 3: Heterozygous Advantage

From Case 2, it is easy to see that the lethal recessive allele rapidly decreases in the population. However, studies show an unexpectedly high frequency of the sickle-cell allele in some human populations. These populations exist in areas where malaria is (or until recently was) killing many people. It seems that individuals who are heterozygous for sickle-cell anemia are slightly more resistant to a deadly form of malaria than are homozygous dominant individuals. In malaria-ridden areas, there is a slight selection against homozygous dominant individuals as compared to heterozygotes. This fact is easily incorporated into our simulations.

Procedure:

1. In this round keep everything the same as it was in Case 2, except that is your offspring is AA, flip a coin. If the coin lands heads up, the individual does not survive; if tails, the individual does survive.
2. Simulate ten generations, starting again with the initial genotype from Case 1. The genotype aa never survives, and homozygous dominant individuals only survive if the coin toss comes up tails. Since we want to maintain a constant population size, the same two parents must try again until they produce two surviving offspring. You may need to get new "allele" cards from the gene pool, allowing each individual to complete the activity. Total the class genotypes and calculate the p and q ratios.

Questions:

1. Explain how the changes in p and q frequencies in Case 2 compare with Case 1 and Case 3.
2. Do you think the recessive all will be completely eliminated in either Case 2 or Case 3?
3. What is the importance of heterozygotes (the heterozygous advantage) in maintaining genetic variation in populations?

Case 4: Genetic Drift

Procedure:

1. It is possible to use our simulation to look at the phenomenon of genetic drift in detail. Divide the lab into several smaller, isolated populations. For example, a class of 30 could be divided into 3 separate populations of 10 individuals each. Individuals from one population do not interact with individuals from other populations.
2. Follow the procedure in Case 1 through five generations. Record the new genotypic frequencies and then calculate the new frequencies of p and q for each population.

Questions:

1. Explain how the initial genotypic frequencies of the populations compare.
2. What do your results indicate about the importance of population size as an evolutionary force?

Data Tables:

Case 1: Hardy-Weinberg Equilibrium

Initial Class Frequencies: AA _____ Aa _____ aa _____	
Generation	Genotype
Initial	
1	
2	
3	
4	
5	
Final Class Frequencies: AA _____ Aa _____ aa _____	
	p _____ q _____

Case 2: Selection

Initial Class Frequencies: AA _____ Aa _____ aa _____	
Generation	Genotype
Initial	
1	
2	
3	
4	
5	
Final Class Frequencies: AA _____ Aa _____ aa _____	
	p _____ q _____

Case 3: Heterozygote Advantage

Initial Class Frequencies: AA _____ Aa _____ aa _____	
Generation	Genotype
Initial	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Final Class Frequencies: AA _____ Aa _____ aa _____	
	p _____ q _____

Case 4: Genetic Drift

Initial Class Frequencies: AA _____ Aa _____ aa _____	
Generation	Genotype
Initial	
1	
2	
3	
4	
5	
Final Class Frequencies: AA _____ Aa _____ aa _____	
	p _____ q _____