AP Lab 8 - Population Genetics and Evolution

Introduction:

In 1908, G.H. Hardy and W. Weinberg suggested a scheme whereby evolution could be viewed as changes in frequency of alleles in a population of organisms. In this scheme, if **A** and **a** are alleles for a particular gene locus and each diploid individual has two such loci, then **p** can be designated as the frequency of the A allele and **q** as the frequency of the a allele. For example, in a population of 100 individuals in which 40% of the alleles are **A**, **p** would be 0.40. The rest of the alleles (60%) would be **a** and **q** would be equal to 0.60. **p + q = 1.** These are referred to as **allele frequencies**. The frequency of the possible diploid combinations of these alleles (AA, Aa, aa) is expressed as $\mathbf{p^2 + 2pq + q^2 = 1.0}$. Hardy and Weinberg also argued that if 5 conditions are met, the population's alleles and genotype frequencies will remain **constant** from generation to generation. These conditions are as follows:

- **The breeding population is extremely large.** (Reduces the problem of genetic drift.)
- **Mating is random.** (Individuals show no preference for a particular mating type.)
- **There is no mutation of the alleles.**
- **No differential migration occurs.** (No immigration or emigration.)
- **There is no selection**. (All genotypes have an equal chance of surviving and reproducing.)

The Hardy-Weinberg equation describes an existing situation. Of what value is such a rule? It provides a yardstick by which changes in allelic frequencies can be measured. If a population's allelic frequencies change, it is undergoing evolution.

The Hardy-Weinberg equations are often applied incorrectly to situations in which they don't apply. As a rule of thumb, remember that these equations are ONLY applicable when a population is **already assumed to be in Hardy-Weinberg equilibrium**—if the population satisfies all 5 of the conditions above. That being said, the Hardy-Weinberg equations are most often used in the following two situations: 1) to predict genotype frequencies for a population assumed to be in Hardy-Weinberg equilibrium given known allele frequencies and 2) to predict allele frequencies based on known phenotype distributions (that's where the q^2 comes in handy).

CASE STUDIES

Case 1 (Test of an Ideal Hardy-Weinberg Community)

The entire class will simulate a population of randomly mating heterozygous individuals with an initial gene frequency of 0.5 for the dominant allele **A** and the recessive allele **a**. Record this on the **Data page**. Each "parent" will contribute a haploid set of chromosomes to the next generation. In order to ensure random mating, choose another student at random. In this simulation, we will assume that gender and genotype are irrelevant to mate selection.

Procedure:

1. Since each member of the class is starting out as a heterozygote, obtain two cards – one with **A** one with **a**. These two cards represent your alleles and the gametes you can produce as a product of meiosis.
2. HOW TO MATE:
   - **Randomly** seek out a person to mate with.
   - Both you and your partner should turn the two cards over so the letters are not showing, shuffle them, and take the card on top to contribute to the production of your 1^{st} offspring.
   - Put the 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 1** section at the end of the lab.
   - Reshuffle your cards and repeat the mating procedure to produce your 2^{nd} offspring. The other partner should then **record** the genotype of the second offspring in the **Case 1** section at the end of the lab.
3. In order to mate in the following generation, you and your partner will each assume the genotype of one of your two offspring. Obtain, if necessary, new cards representing the alleles of your genotype.
4. Follow the same mating procedure in each of the subsequent generations. Make sure to record the new genotype that you assume after each generation on the **Data page**.
5. Class data will be collected at the end of five generations for most scenarios.

Case 2 (Selection)

In this case, the simulation will be modified to make it more realistic. In the natural environment, some genotypes are favored and others are selected against. In the human condition sickle-cell anemia, a homozygous recessive individual usually does not survive to reproduce. For this simulation you will assume that the **homozygous recessive** individuals **never survive**. **Heterozygous and homozygous dominant individuals always survive.**

Procedure:

1. Start again with each class member as a heterozygote (**Aa**).
2. Follow the same mating procedure as in **Case 1**. This time, however, every time your offspring is **aa** it **does NOT survive**. Since we want to maintain a constant population size, the same two parents must try again until they produce two surviving offspring. If necessary, obtain new allele cards from the gene pool.
3. Follow the same mating and selection procedure in each of the subsequent generations. Make sure to carefully record your data on the **Data page**. **Remember, aa NEVER SURVIVES!**
4. Class data will be collected at the end of five generations.

Case 3 (Heterozygote Advantage)

From Case 2 it is easy to see what happens to the lethal recessive allele in the population. However, data from many human populations show an unexpectedly high frequency of the sickle-cell allele in some populations. It turns out that in reality, individuals who are **heterozygous** are slightly more resistant to a deadly form of malaria than homozygous dominant individuals. In other words, there is a **slight selection against homozygous dominant individuals** as compared to heterozygotes.

Procedure:

1. Start again with each class member as a heterozygote (Aa).
2. Follow the same mating procedure as in Case 2. This time, however, if your offspring is **AA**, flip a coin. If heads, the individual does NOT survive; if tails, the individual does survive. Since we want to maintain a constant population size, the same two parents must try again until they produce two surviving offspring. If necessary, obtain new allele cards from the gene pool.
3. Follow the same mating and selection procedure in each of the subsequent generations. Make sure to carefully record your data on the **Data page. Remember, aa NEVER SURVIVES; AA only survives if the coin toss comes up tails.**
4. Class data will be collected at the end of generation five and ten.

How to calculate allele frequencies:

Number of A alleles present

Number of offspring with genotype **AA** _____ X 2= _____ **A** alleles

Number of offspring with genotype **Aa** _____ X 1= _____**A** alleles

Total = _____ **A** alleles

p =	**Total** number of A alleles **Total** number of alleles in the population (number of students X 2)	**=** (in decimal form)

***Follow the same procedure to determine the number of a alleles present**

1. For EACH of the cases, calculate the INITIAL and FINAL (last generation) genotype and allele frequencies.
2. For Case 3, calculate the genotype and allele frequencies after the F5, F10, and F15 generation.

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Name:

Date: **Per:** 2

Purpose: The purpose of this activity is to simulate a breeding population and examine how allele and genotype frequencies change under different selective conditions.

Data:

Case 1 (Hardy-Weinberg Equilibrium)

Initial Class Frequencies:

AA 0 Aa 0 aa 0

A 0.5 a 0.5

My initial genotype: Aa Total # of Students: 29

	My genotype
F_1	
F_2	
F_3	
F_4	
F_5	

F_5 Class Genotypes		
# of AA	# of Aa	# of aa
12	**12**	**5**

Final Class Frequencies:

AA 12/29 Aa 12/29 aa 5/29

A 0.62 a _____

Case 2 (Selection)

Initial Class Frequencies:

AA _____ Aa _____ aa _____

A 0.5 a 0.5

My initial genotype: Aa Total # of Students: 30

	My genotype
F_1	
F_2	
F_3	
F_4	
F_5	

F_5 Class Genotypes		
# of AA	# of Aa	# of aa
20	**10**	**0**

Final Class Frequencies:

AA _____ Aa _____ aa _____

A _____ a _____

Case 3 (Heterozygote Advantage)

Initial Class Frequencies:

AA _____ Aa _____ aa _____

A 0.5 a 0.5

My initial genotype: Aa Total # of Students: 30

	My genotype
F_1	
F_2	
F_3	
F_4	
F_5	

	My genotype
F_6	
F_7	
F_8	
F_9	
F_{10}	

F_5 Class Genotypes			F_{10} Class Genotypes		
# of AA	# of Aa	# of aa	# of AA	# Aa	# aa
13	**17**	**0**	**9**	**21**	**0**

Final Class Frequencies: (after 5 generations)

AA _____ Aa _____ aa _____

A _____ a _____

Final Class Frequencies: (after 10 generations)

AA _____ Aa _____ aa _____

A _____ a _____

Case 4 (Genetic Drift) We'll do this on Thursday!

Initial Class Frequencies

AA_____ Aa_____ aa_____

A _____ a _____

My initial genotype: _____ Total # of Students: _____

	My genotype
F_1	
F_2	
F_3	
F_4	
F_5	

F_5 **GROUP** Genotypes		
# of AA	# of Aa	# of aa

Final GROUP Frequencies

AA _____ Aa _____ aa _____

A _____ a _____

Post-Lab Analysis Questions:
Make sure to refer to SPECIFIC numerical data to support your answers to the following questions.

1. Describe and explain any trends you notice as you compare initial and final allele (p and q) and genotype frequencies: (i.e. How did the allelic or genotypic frequencies of the population change? Why?)
   - In Case 1 (H-W equilibrium) –

   - In Case 2 (Selection) –

   - In Case 3 (Heterozygote advantage)–

   - In Case 4 (Genetic Drift)-

2. In our simulations, which of the 5 H-W conditions were followed? Which of these conditions were violated?

3. In Case 2, what do you predict would happen to the A and a frequencies if you simulated another 5 generations? Explain.

4. If Case 2 were to occur in a large population, would it be likely to COMPLETELY eliminate the lethal recessive allele? Why or why not?

5. Is the recessive allele MORE or LESS LIKELY to decline in frequency in Case 3 as compared to Case 2? Why?

6. Heterozygotes help to maintain genetic variation in a population. Explain WHY it is important for a species to maintain genetic variation.