

POPULATION GENETICS AND EVOLUTION

INTRODUCTION

In 1908 G. H. Hardy and W. Weinberg independently suggest a scheme whereby evolution could be viewed as changes in the 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. Thus, in a population of 100 individuals (each with two loci) 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 equal 0.60 (i.e. $p + q = 1$.) These are referred to as **allele frequencies**. The frequency of the possible diploid combinations of these alleles (AA, Aa, and aa) is expressed as $p^2 + 2pq + q^2 = 1$. Hardy and Weinberg also argued that if five conditions are met, the population's allele and genotype frequencies will remain constant from generation to generation. These conditions are as follows:

1. **The breeding population is large.** (The effect of chance on changes in allele frequencies is thereby greatly reduced.)
2. **Mating is random.** (Individuals show no mating preference for a particular phenotype.)
3. **There is no mutation of the alleles.**
4. **No differential migration occurs.** (No immigration or emigration.)
5. **There is no selection.** (All genotypes have an equal chance of surviving and reproducing.)

The Hardy-Weinberg equation describes an existing situation. If the five conditions are met, then no change will occur in either allele or genotype frequencies in the population. Of what value is such a rule? It provides a yardstick by which changes in allele frequency, and therefore evolution, can be measured. One can look at a population and ask: Is evolution occurring with respect to a particular gene locus? Since evolution is difficult (if not impossible) to observe in most natural populations, we will model the evolutionary process using a simulated population of Pepperidge Farm Goldfish® crackers.



PART I: DETERMINING ALLELE FREQUENCY IN A POPULATION OF GOLDFISH® CRACKERS

In this simulation predators (you) selectively prey upon (eat) individuals (Goldfish® crackers) in a small population. Prey are replaced with individuals randomly selected from an ocean (mixing bowl of Goldfish® crackers) to create the next generation. The Hardy-Weinberg rule will be used to calculate genotype and allele frequencies for each generation.

PROCEDURE:

1. Wash your hands.
2. Take your paper cup to the ocean (mixing bowl of Goldfish® crackers) and randomly select 10 fish. To randomly select the fish, close your eyes, reach into the bowl and pick out 10 fish.
3. Take your 10 fish back to your desk and record in the My Results Data Table on the Generation 1 line the number of white fish, gold fish and brown fish in your population. White fish (original-flavor Goldfish®) have the ff genotype. Gold fish (cheese-flavored Goldfish®) have the Ff genotype and brown fish (pretzel-flavored Goldfish®) have the FF genotype.
4. Choose 3 white fish from the first generation and eat them. If you do not have 3 white fish, fill in the missing number by eating gold fish.
5. Choose at random 3 fish from the ocean and add them to your population. Remember.....don't look while you're selecting the fish from the ocean.
6. Record in the My Results Data Table on the Generation 2 line the number of white, gold and brown fish in your population.
7. Choose 3 white fish from the second generation and eat them. If you do not have 3 white fish, fill in the missing number by eating gold fish.
8. Choose at random 3 fish from the ocean and add them to your population.
9. Record in the My Results Data Table on the Generation 3 line the number of white, gold and brown fish in your population.
10. Choose 3 white fish from the third generation and eat them. If you do not have 3 white fish, fill in the missing number by eating gold fish.
11. Choose at random 3 fish from the ocean and add them to your population.
12. Record in the My Results Data Table on the Generation 4 line the number of white, gold and brown fish in your population.

13. Choose 3 white fish from the fourth generation and eat them. If you do not have 3 white fish, fill in the missing number by eating gold fish.
14. Choose at random 3 fish from the ocean and add them to your population.
15. Record in the My Results Data Table on the Generation 5 line the number of white, gold and brown fish in your population.
16. Complete the My Results Data Table by calculating the genotype frequencies.

MY RESULTS DATA TABLE

Generation	White (ff = q ²)		Gold (Ff = 2pq)		Brown (FF = p ²)	
	Number	Frequency	Number	Frequency	Number	Frequency
1						
2						
3						
4						
5						

17. Calculate the frequency for each allele (F and f) for each generation

Generation	Total Alleles (2 * 10)	F (p)		f (q)	
		# of F alleles 2(FF) + 1(Ff)	Freq. of F allele #/total	# of f alleles 2(ff) + 1(Ff)	Freq. of f allele #/total
1					
2					
3					
4					
5					

18. Go to one of the computers in the room and access the biology87.org web site. Navigate through the web site to the AP Biology Evolution Unit and locate the link under Activity #4 for data entry. Enter the number of white, gold and brown fish for each generation from your results.
19. After everyone has entered their data, record the total the number of gold and brown fish counts of each generation for all lab groups in the Class Results Data table. Calculate the genotype and allele frequencies using the results from the class.

CLASS RESULTS DATA TABLE

Generation	White (ff = q ²)		Gold (Ff = 2pq)		Brown (FF = p ²)	
	Number	Frequency	Number	Frequency	Number	Frequency
1						
2						
3						
4						
5						

20. Calculate the frequency for each allele (F and f).

Generation	Total Alleles (2 * 10)	F (p)		f (q)	
		# of F alleles 2(FF) + 1(Ff)	Freq. of F allele #/total	# of f alleles 2(ff) + 1(Ff)	Freq. of f allele #/total
1					
2					
3					
4					
5					

21. How do the genotype and allele frequencies you calculated using your results compare to those calculated using the class results?

22. What happened to the frequency of the f allele over the 5 generations?

23. What would you predict would happen to the f allele frequency over the next several generations?

24. Is the population of Goldfish® in Hardy-Weinberg equilibrium?

How do you know?_____

25. Is the population of Goldfish® evolving?_____

How do you know?_____

PART III: HARDY-WEINBERG PROBLEMS

26. In *Drosophila*, the allele for normal length wings is dominant over the allele for vestigial wings (vestigial wings are stubby little curls that cannot be used for flight.) In a population of 1,000 individuals, 360 show the recessive phenotype. How many individuals would you expect to be homozygous dominant and heterozygous for this trait?

27. The allele for the ability to roll one's tongue is dominant over the allele for the lack of this ability. In a population of 500 individuals, 25 percent show the recessive phenotype. How many individuals would you expect to be homozygous dominant and heterozygous for this trait?
28. The allele for the hair pattern called "widow's peak" is dominant over the allele for no "widow's peak". In a population of 1,000 individuals, 510 show the dominant phenotype. How many individuals would you expect of each of the possible three genotypes for this trait?
29. In the United States, about 16 percent of the population is Rh-negative. The allele for Rh-negative is recessive to the allele for Rh-positive. If the student population of a high school in the U.S. is 2,000, how many students would you expect for each of the three possible genotypes?

30. In certain African countries, 4 percent of the newborn babies have sickle-cell anemia, which is a recessive trait. Out of a random population of 1,000 newborn babies, how many would you expect for each of the three possible genotypes?
31. In a certain population, the dominant phenotype of a certain trait occurs 91 percent of the time. What is the frequency of the dominant allele?