



Exercise 1: Modeling Genetic Drift

Table 1: Preliminary Analysis of the Population

Diploid allele number	2
Diploid individuals in population	50
Allelic frequency of p in the gene pool	0.5
Allelic frequency of q in the gene pool	0.5

Table 2: Descriptions of Genotype and Phenotype of Individuals

Description	Genotype	Color of Each of 2 Beans	Phenotype
Homozygous dominant	BB	Brown, Brown	Brown fur
Heterozygous	Bb	Brown, White	Brown fur
Homozygous recessive	bb	White, White	White fur

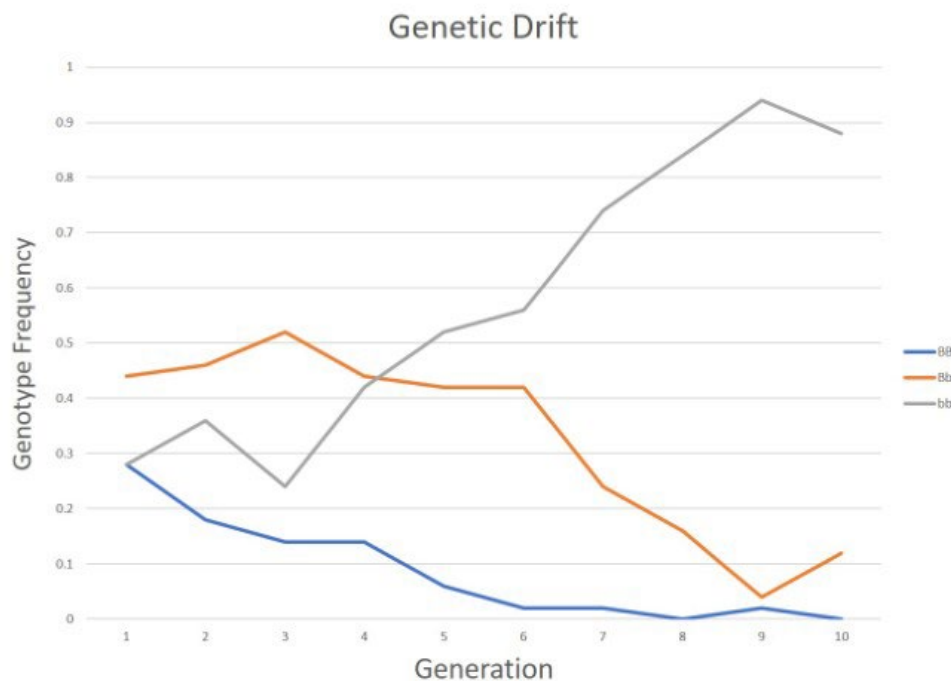
Table 3: Expected Genotypic Frequency and Number

Expected Data	Genotype		
	BB (p^2)	Bb ($2pq$)	bb (q^2)
Expected Frequency	0.25	0.50	0.25
Expected Number	12.5	25	12.5

Table 4: Modeling Genetic Drift

Generation	Starting Allelic #		Genotypic Number			Allelic Number		Genotypic Frequency			Allelic Frequency	
	B	b	BB	Bb	bb	B	b	p^2	$2pq$	q^2	p	q
1	50	50	14	22	14	50	50	0.28	0.44	0.28	0.5	0.5
2	50	50	9	23	18	41	59	0.18	0.46	0.36	0.41	0.59
3	41	59	7	26	17	40	60	0.14	0.52	0.34	0.4	0.6
4	40	60	7	22	21	36	64	0.14	0.44	0.42	0.36	0.64
5	36	64	3	21	26	27	73	0.06	0.42	0.52	0.27	0.73
6	27	73	1	21	28	23	77	0.02	0.42	0.56	0.23	0.77
7	23	77	1	12	37	14	86	0.02	0.24	0.74	0.14	0.86
8	14	86	0	8	42	8	92	0	0.16	0.84	0.08	0.92
9	8	92	1	2	47	4	96	0.02	0.04	0.94	0.04	0.96
10	4	96	0	6	44	6	94	0	0.12	0.88	0.06	0.94

Graph 1: Genotypic Frequencies by Generation



Question 1

What is genetic drift? How did the model population size and sampling techniques relate to this process?

Genetic drift is a change in allele frequencies in a population over time resulting from chance. Small populations are more prone to genetic drift than larger populations. The model population consisted of only 50 individuals. Genetic drift results from random subsets of individuals are sampled to produce the next generation. Random individuals were sampled from the model population to determine allelic frequencies for future generations.

Question 2

How do the predicted allelic frequencies recorded in Data Table 3 compare to the frequencies after 10 generations of sampling recorded in Data Table 4? Does the comparison indicate the model population was at equilibrium?

All students should compare the predicted 0.25:0.5:0.25 genotypic ratios to those recorded in the final row of Data Table 4. Internal testing resulted in a ratio of 0:0.12:0.88 for generation 10,

which is significantly different than the predicted frequencies, meaning the population was not experiencing equilibrium. Student conclusions should reflect their data.

Question 3

List the five assumptions of the Hardy-Weinberg Equilibrium Principle. Describe why the principle was or was not supported by the model population.

1 - The population is very large.

2 - Mating is random.

3 - No genes transfer in to or out of the population (no migration of individuals into or out of the population occurs).

4 - There are no changes in the gene pool due to mutation.

5 - Natural selection does not take place: all genotypes are equal in reproductive success.

The principle was not supported by the model population because of the small population size of only 50 individuals.

Question 4

What is evolution? Was evolution observed in your model population? Reference Graph 1 in your explanation.

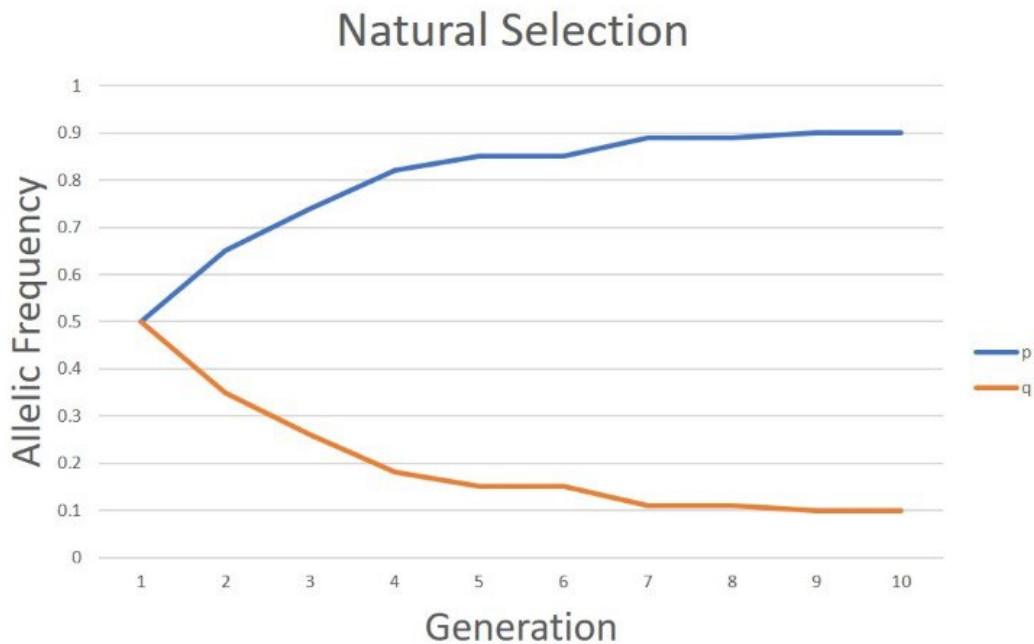
Evolution is the change in gene frequencies over time in a population. Student answers may vary regarding their results, but their explanations should relate to Graph 1. Internal testing demonstrated evolution by the elimination of the homozygous dominant genotype and the proliferation of the homozygous recessive genotype.

Exercise 2: Modeling Natural Selection

Table 4: Modeling Genetic Drift

Generation	Starting Allelic Frequency		Starting Allelic Number		Genotypic Number			Final Genotypic Frequency			Final Allelic Number	
	p	q	B	b	BB	Bb	Deaths (bb)	p ²	2pq	q ²	B	b
1	0.50	0.50	50	50	12	26	12	0.32	0.68	0	50	26
2	0.65	0.35	65	35	21	22	7	0.49	0.51	0	66	22
3	0.74	0.26	74	26	29	16	5	0.64	0.36	0	74	16
4	0.82	0.18	82	18	34	14	2	0.71	0.29	0	82	14
5	0.85	0.15	85	15	35	15	0	0.70	0.30	0	85	15
6	0.85	0.15	85	15	37	11	2	0.77	0.23	0	85	11
7	0.89	0.11	89	11	39	11	0	0.78	0.22	0	89	11
8	0.89	0.11	89	11	39	10	1	0.80	0.20	0	88	10
9	0.90	0.10	90	10	40	10	0	0.80	0.20	0	90	10
10	0.90	0.10	90	10	41	8	1	0.84	0.16	0	90	8

Graph 2: Allelic Frequencies



Question 1

What is natural selection? How did the sampling techniques used on the model population relate to this process?

Natural selection is the process where alleles beneficial to survival of individuals in a particular environment are passed to the next generation at a higher frequency than other alleles, resulting in populations that are better adapted to the environment over time. Natural selection was modeled in the sampling process by removing all homozygous recessive individuals (bb) from each generation so that only individuals expressing the dominant allele contributed to the gene pool of future generations.

Question 2

How did the allelic frequencies change over the 10 generations modeled in response to natural selection? Do you think the white allele could be eliminated from the population if the model had continued for 10 more generations? Reference Graph 2 in your explanation.

The frequency of the B allele increased from 0.5 in Generation 1 to 0.9 in Generation 10, whereas the frequency of the b allele decreased from .05 to 0.1. It is unlikely the b allele would be eliminated by Generation 20 as the frequencies of both alleles stabilized after Generation 7 as shown in Graph 2.

Question 3

A mutation occurs in a population of rabbits affecting ear length. After multiple generations, 30% of the population exhibit the new recessive phenotype for short ears. Use the Hardy-Weinberg equation to determine the genotypic frequencies of the rabbit population. Show all work in your answer.

1. *List the possible genotypes for each of the phenotypes.*

LL – Long ear rabbit

Ll – Long ear rabbit

ll – Short ear rabbit

2. *Determine the phenotypic frequencies in the population.*

The long ear phenotype occurs in 70% of the population for a frequency of 0.7. The short ear phenotype occurs in 30% for a frequency of 0.3.

3. Determine the allelic frequencies of the long allele (L) and the short allele (l) in the population.

Short ear rabbits have a phenotypic frequency of 0.3. All white cats have the genotype ll. Thus, white cats must also have the genotypic frequency of 0.3.

$$\text{Genotypic frequency of ll} = q^2 = 0.3$$

If $q^2 = 0.3$, then $q = 0.55$. Since $p + q = 1$, solve for p : $p = 0.45$. Therefore, frequency of the l allele in the population is $q = 0.55$ and the frequency of the L allele in the population is $p = 0.45$.

4. Determine the genotypic frequencies of LL, Ll, and ll in the population.

Genotypic frequency can be determined from the Hardy-Weinberg Equation: $p^2 + 2pq + q^2 = 1$, where p^2 = frequency of LL, pq = frequency Ll, and q^2 = frequency of ll. The values of p and q have already been determined ($p = 0.45$ and $q = 0.55$): $0.45^2 + 2(0.45)(0.55) + 0.55^2 = 0.2 + 0.5 + 0.3 = 1$

$$\text{Frequency of LL} = p^2 = 0.2$$

$$\text{Frequency of Ll} = 2pq = 0.5$$

$$\text{Frequency of ll} = q^2 = 0.3$$

Question 4

How would the allelic frequencies and resulting graph differ from the results in Data Table 5 and Graph 2 for a population at Hardy-Weinberg equilibrium for 10 generations?

A population at equilibrium for 10 generations would have allelic frequencies that did not change between generation 1 and generation 10. In the model used in this experiment, each generation would have p and q values of 0.5 and the resulting graph would be a horizontal straight line, compared to the results here which varied from frequencies of 0.5 to 0.9 and 0.1 and curved lines when graphed.

Extension Question

Consider a certain species of grasshopper with a body that exhibits two phenotypes for pattern: 1) light green spots and 2) solid color with no spots.

The solid allele is dominant, and the green-spotted allele is recessive. For a total of 487 grasshoppers, 445 are solid and 42 have green spots.

- List and describe all possible genotypes and phenotypes.
- What is the phenotypic frequency of the grasshoppers that have no spots? (Round answer to two decimal places.)
- What is the phenotypic frequency of the green-spotted grasshoppers? (Round answer to two decimal places.)
- Calculate the frequency of the recessive allele in this population. (Round answer to two decimal places.)
- Calculate the frequency of the dominant allele in this population.
- Explain why the phenotypic frequency and genotypic frequency of the green spotted grasshoppers is the same value.
- Explain why the phenotypic frequency and genotypic frequency of the solid grasshoppers IS NOT the same value.

*a. RR = homozygous for solid
Rr = heterozygous for solid
rr = homozygous for green spotting*

*b. Phenotypic frequency = 0.91
(445 / 487 = 0.91)*

*c. Phenotypic frequency = 0.09
(42 / 487 = 0.09)*

*d. Frequency of the recessive allele = 0.30
 $p^2 + 2pq + q^2 = 1$ and $p + q = 1$
If $q^2 = 0.09$, then $q = 0.30$.*

*e. Frequency of the dominant allele = 0.70
 $p + q = 1$
 $p + 0.3 = 1$
 $p = 0.7$*

f. Because this trait follows complete dominance, meaning that the dominant allele (solid coloring) completely masks the recessive allele (green spotting). Only when two recessive alleles are present and the dominant is absent, will the recessive trait of green spotting be visible in the population. In the population, each individual with the recessive trait (green spotting) must have two recessive alleles. When the number of individuals with the recessive phenotype is determined, the number of individuals with the homozygous recessive genotype is also determined.

g. The trait follows complete dominance, meaning that the dominant allele (solid coloring) completely masks the recessive allele (green spotting). Only one dominant allele is needed to produce a solid red color, the second allele has no influence.

For this reason, the homozygous dominant and the heterozygous individual appear the same (solid coloring) but are genetically different. The number of solid grasshoppers in the population includes both the homozygous dominant and heterozygous individuals. Their coloration is indistinguishable from each other.

There are TWO frequencies of solid grasshoppers: the homozygous dominant (p^2) and heterozygotes ($2pq$).