Question 3

3. Evolution is one of the unifying themes of biology. Evolution involves change in the frequencies of alleles in a population. For a particular genetic locus in a population, the frequency of the recessive allele (*a*) is 0.4 and the frequency of the dominant allele (*A*) is 0.6.

(a) What is the frequency of each genotype (*AA*, *Aa*, *aa*) in this population? What is the frequency of the dominant phenotype?

Calculations **(4 points maximum)**

- Frequency *AA* = .36
- Frequency *Aa* = .48
- Frequency *aa* = .16
- Frequency dominant phenotype = .84

(Correct equation needed for credit if one of calculated numbers is wrong.)

(b) How can the Hardy-Weinberg principle of genetic equilibrium be used to determine whether this population is evolving?

Evolving population **(2 points maximum)**

- Allelic frequency changes or five conditions that do not change if population is not evolving
- Means of measurement/detection

(c) Identify a particular environmental change and describe how it might alter allelic frequencies in this population.

Explain which condition of the Hardy-Weinberg principle would not be met. **(4 points maximum)**

- Environmental change identified **(1 point)** (first one scored)
- Explanation of how allelic frequency changed **(1–2 points)**
- Which Hardy-Weinberg condition not met **(1 point)**

3A

3. Evolution is one of the unifying themes of biology. Evolution involves change in the frequencies of alleles in a population. For a particular genetic locus in a population, the frequency of the recessive allele (a) is 0.4 and the frequency of the dominant allele (A) is 0.6.

   (a) What is the frequency of each genotype (AA, Aa, aa) in this population? What is the frequency of the dominant phenotype?

   (b) How can the Hardy-Weinberg principle of genetic equilibrium be used to determine whether this population is evolving?

   (c) Identify a particular environmental change and describe how it might alter allelic frequencies in this population. Explain which condition of the Hardy-Weinberg principle would not be met.

(a) The frequency of the genotype AA, or the homozygous dominant genotype, is expressed as p^2 in the Hardy-Weinberg equation. The frequency of AA is 36%. The frequency of genotype Aa, or heterozygous, is expressed as 2pq, and is 48%. The frequency of genotype aa, or homozygous recessive, is expressed as q^2, and is 16%. The frequency of the dominant phenotype is found by adding p^2 (homozygous dominant) with 2pq (heterozygous). The frequency of this phenotype is 84%.

(b) The frequency results found above of both genotypic and phenotypic frequencies are of a certain population under given conditions. This same population can be tested with the Hardy-Weinberg equilibrium equation at a different time or under different conditions. Then, the results (both genotypic and phenotypic frequencies) can be compared and observed to see if there is a change, or indication, that the population is evolving.

(c) If the land where a population of cows lived was experiencing a severe drought, a good portion of the population might migrate to find more fertile land, and therefore more food. This migration could result in the loss or sudden decrease of a specific allele, alterating the allelic frequencies in the remaining population. The Hardy-Weinberg principle of 'no migration' would not be met in this example.

GO ON TO THE NEXT PAGE.

3B1

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   (a) What is the frequency of each genotype (*AA*, *Aa*, *aa*) in this population? What is the frequency of the <u>dominant</u> <u>phenotype</u>?

   (b) How can the Hardy-Weinberg principle of genetic equilibrium be used to determine whether this population is evolving?

   (c) Identify a particular environmental change and describe how it might alter allelic frequencies in this population. Explain which condition of the Hardy-Weinberg principle would not be met.

The frequency for the genotype AA is .36. The frequency for the genotype aa is .16. The frequency for the genotype Aa is .48. The frequency for the dominant phenotype is $(p^2 + 2pq)$ .84. The genotype AA makes up 36% of the population while the genotype aa makes up 16% of the population and the genotype Aa makes up 48% of the population. The percentage of the population showing the dominant phenotype is 84%. The Hardy-Weinberg principle can be used to determine if the population is evolving by ratios - if the ratio of the dominant genotype to the recessive genotype is 3:1. There are many environmental changes that could alter allelic frequencies in this population, thus causing certain conditions of the Hardy-Weinberg condition not to be met. An example of an environmental change would be the population greatly decreasing in size due to a natural disaster. This would disrupt the Hardy-Weinberg condition of a population being large. Environmental changes can also cause mutation which would disrupt the Hardy-Weinberg conditions. If the population changed due to bottleneck or founder's effect, then the

GO ON TO THE NEXT PAGE.

 3B2

population would become small and allele frequencies would change. For a population to meet Hardy-Weinberg conditions it must also be isolated. If new alleles are entering + leaving the population by immigration or emigration than the Hardy-Weinberg conditions would not be met. The environment must stay constant for Hardy-Weinberg conditions so that natural selection does not occur and so that mating always remains random. For Hardy-Weinberg conditions to be met, the population must be: large, be isolated (no immigration/emigration), have random mating, have no mutations and have no natural selection. This keeps the frequency of alleles in the population from changing. There is no gene flow, no genetic drift and no selective mating.

$p = .6 \quad p^2 = .36 \quad AA = .36$

$q = .4 \quad q^2 = .16 \quad aa = .16 \quad p^2 + 2pq + q^2 = 1$

$2pq = .48 \quad Aa = .48$

GO ON TO THE NEXT PAGE.

3C1

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   (a) What is the frequency of each genotype (AA, Aa, aa) in this population? What is the frequency of the dominant phenotype?

   (b) How can the Hardy-Weinberg principle of genetic equilibrium be used to determine whether this population is evolving?

   (c) Identify a particular environmental change and describe how it might alter allelic frequencies in this population. Explain which condition of the Hardy-Weinberg principle would not be met.

~~The frequency of the recessive genotype is $\sqrt{.4}$ and the frequency of the dominant genotype is~~

— According to Hardy-Weinberg, $\overset{aa}{q}=\sqrt{.4}$ and $\overset{Aa}{2pq}=\sqrt{.6}$. So 60% percent of the population displays the dominant phenotype.

— Hardy-Weinberg was created to demonstrate the typical static population, so if the results do not match Hardy-Weinberg numbers, the population is evolving.

— If there was a flood that, by random, drowned 80% of the population, it would most likely lead to an alteration in allelic frequencies. This is also known as the bottleneck effect. According to Hardy-Weinberg this is a problem because it is not a large population anymore. In smaller populations, variations in genes are more likely to be spread and adopted by offspring.

GO ON TO THE NEXT PAGE.

Question 3

Sample: 3A
Score: 9

The student earned the full 4 points for part (a) because the calculations of genotypic frequencies and of the frequency of dominant phenotypes are all correct. In part (b) the student explains that evolution can be demonstrated by a change in these frequencies over time, thus earning another point. In part (c) the student earned a point for the use of the drought as an environmental change, a second point for a description of the effect of the drought in causing the cows to migrate, and a third point for relating this migration to a possible loss of a specific allele. The final point was earned for identifying migration as a reason why the Hardy-Weinberg equilibrium no longer holds.

Sample: 3B
Score: 6

In part (a) the student earned the full 4 points for the correct calculations of genotype frequencies from allelic frequencies, as well as for the calculation of the frequency of dominant phenotypes. The student earned no points for part (b), since no relevant information is provided. The student earned 1 point in part (c) for identifying a natural disaster as an environmental change, and another point for relating this to the departure from the Hardy-Weinberg equilibrium because there is no longer a large population.

Sample: 3C
Score: 3

The student does not provide correct calculations for part (a) and so earned no points. However, in part (b) the response demonstrates understanding that a change in allelic and genomic frequencies is found when "the population is evolving." In part (c) the student earned a point for using the example of a flood as an environmental change, and another for recognizing that the flood would have led to a small population that no longer meets the expectations of the principle.