

Activity: Hardy Weinberg Problems - Answer Key

AP Biology

- You have sampled a population in which you know that the percentage of the homozygous recessive genotype (aa) is 36%. Using that 36%, calculate the following:
 - The frequency of the "aa" genotype (q^2). **$q^2 = 0.36$ or 36%**
 - The frequency of the "a" allele (q). **$q = 0.6$ or 60 %**
 - The frequency of the "A" allele (p). **$p = 0.4$ or 40%**
 - The frequencies of the genotypes "AA" (p^2) and "Aa" ($2pq$) **$p^2 = AA = 0.16$ or 16% $2pq = Aa = .48$ or 48%**
- Sickle-cell anemia is an interesting genetic disease. Normal homozygous individuals (H^bH^b) have normal blood cells that are easily infected with the malaria parasite. Thus, many of these individuals become very ill from the parasite and many die. Individuals homozygous for the sickle-cell trait (H^sH^s) have red blood cells that readily collapse when deoxygenated. Although malaria cannot grow in these red blood cells, individuals often die because of the genetic defect. However, individuals with the heterozygous condition (H^bH^s) have some sickling of red blood cells, but generally not enough to cause mortality. In addition, malaria cannot survive well within these "partially defective" red blood cells. Thus, heterozygotes tend to survive better than either of the homozygous conditions. If 9% of an African population is born with a severe form of sickle-cell anemia (H^sH^s), what percentage of the population will be more resistant to malaria because they are heterozygous (H^bH^s) for the sickle-cell gene?
 $H^bH^s = 2pq = 0.42$ or 42%
- There are 100 students in a class. Ninety-six did well in the course whereas four blew it totally and received a grade of F. Sorry. In the highly unlikely event that these traits are genetic rather than environmental, if these traits involve dominant and recessive alleles, and if the four (4%) represent the frequency of the homozygous recessive condition, please calculate the following:
 - The frequency of the recessive allele (q). **$q = 0.2$ or 20%**
 - The frequency of the dominant allele (p). **$p = 0.8$ or 80%**
 - The frequency of heterozygous individuals ($2pq$). **$2pq = 0.32$ or 32%**
- Within a population of butterflies, the color brown (B) is dominant over the color white (b). And, 40% of all butterflies are white. Given this simple information, which is something that is very likely to be on an exam, calculate the following:
 - The percentage of butterflies in the population that is heterozygous. **$2pq = 0.47$ or 47%**
 - The frequency of homozygous dominant individuals. **$p^2 = 0.137$ or 13.7%**

5. A rather large population of Biology teachers has 396 individuals with poor vision and 557 with good vision individuals. Assume that poor vision is totally recessive. Please calculate the following:
- The allele frequencies of each allele. **$p = 0.35$ or **35%** **$q = 0.65$ or **65%******
 - The expected genotype frequencies. **$p^2 = 0.12$ or **12%** **$2pq = .46$ or **46%** **$q^2 = 0.42$ or **42%********
 - The number of heterozygous individuals that you would predict to be in this population.
 $0.46(953) = 438$
 - Conditions happen to be really good this year for breeding and next year there are 1,245 young "potential" Biology instructors. Assuming that all of the Hardy-Weinberg conditions are met, how many of these would you expect to have poor vision and how many with good vision?
 $0.58(1245) = 722$ good vision and $0.42(1245) = 523$ poor vision
6. A very large population of randomly-mating laboratory mice contains 35% white mice. White coloring is caused by the recessive genotype, "aa". Calculate allelic and genotypic frequencies for this population.
- $q = 0.592$ or **59.2%** frequency of "a" allele**
 $p = 0.408$ or **40.8% frequency of "A" allele**
 $p^2 = AA = 0.166$ or **16.6%**
 $2pq = Aa = 0.483$ or **48.3%**
 $q^2 = aa = 0.35$ or **35%**
7. The ability to taste PTC is due to a single dominate allele "T". You sampled 215 individuals in biology, and determined that 150 could detect the bitter taste of PTC and 65 could not. Calculate allelic and genotypic frequencies for this population.
- $65/215 = q^2$**
 $q = 0.55$ or **55%**
 $p = 0.45$ or **45%**
 $q^2 = tt = 0.30$ or **30%**
 $2pq = Tt = .495$ or **49.5%**
 $p^2 = TT = 0.20$ or **20%**

Using the Hardy-Weinberg Equation to Interpret Data and Make Predictions

Is Evolution Occurring in a Soybean Population? One way to test whether evolution is occurring in a population is to compare the observed genotype frequencies at a locus with those expected for a non-evolving population based on the Hardy-Weinberg equation. In this exercise, you'll test whether a soybean population is evolving at a locus with two alleles, C^G and C^Y , that affect chlorophyll production and hence leaf color.

How the Experiment Was Done Students planted soybean seeds and then counted the number of seedlings of each genotype at Day 7 and again at Day 21. Seedlings of each genotype could be distinguished visually because the C^G and C^Y show incomplete dominance: $C^G C^G$ seedlings have green leaves, $C^G C^Y$ seedlings have green-yellow leaves, and $C^Y C^Y$ seedlings have yellow leaves.

Data From the Experiment

| Number of Seedlings | | | | |
|---------------------|--------------------|---------------------------|---------------------|-------|
| Time (Days) | Green $C^G C^G$ | Green-Yellow $C^G C^Y$ | Yellow $C^Y C^Y$ | Total |
| 7 | 49 | 111 | 56 | 216 |
| 21 | 47 | 106 | 20 | 173 |

Interpret the Data

1. Use the observed genotype frequencies from Day 7 data to calculate the frequencies of the C^G allele (p) and the C^Y allele (q). (Remember that the frequency of an allele in a gene pool is the number of copies of that allele divided by the total number of copies of all alleles at that locus.)

$$q^2 = 56/216 \quad q = 0.51 \quad p = 0.49$$

2. Next, use the Hardy-Weinberg equation ($p^2 + 2pq + q^2 = 1$) to calculate the expected frequencies of genotypes $C^G C^G$, $C^G C^Y$, and $C^Y C^Y$ for a population in Hardy-Weinberg equilibrium.

$$p^2 = (0.49)^2 = 0.24 \quad 2pq = 2(0.49)(0.51) = 0.50 \quad q^2 = (0.51)^2 = 0.26$$

$C^G C^G$ $C^G C^Y$ $C^Y C^Y$

3. Calculate the observed frequencies of genotypes $C^G C^G$, $C^G C^Y$, and $C^Y C^Y$ at Day 7. (The observed frequency of a genotype in a gene pool is the number of individuals with that genotype divided by the total number of individuals. Compare these frequencies to the expected frequencies calculated in Step 2. Is the seedling population in Hardy-Weinberg equilibrium at Day 7, or is evolution occurring? Explain your reasoning and identify which genotypes, if any, appear to be selected for or against.

$$p^2 = 49/216 = 0.23 \quad 2pq = 111/216 = 0.49 \quad q^2 = 56/216 = 0.26$$

$$C^G C^G \quad C^G C^Y \quad C^Y C^Y$$

The seedling population is in equilibrium at Day 7. The expected and observed genotypic frequencies for each seedling are similar. At Day 7, there is no particular allele that is being selected for or against.

4. Calculate the observed frequencies of genotypes $C^G C^G$, $C^G C^Y$, and $C^Y C^Y$ at Day 21. Compare these frequencies to the expected frequencies calculated in Step 2 and the observed frequencies at day 7. Is the seedling population in Hardy-Weinberg equilibrium at Day 21, or is evolution occurring? Explain your reasoning and identify which genotypes, if any, appear to be selected for or against.

$$p^2 = 47/173 = 0.27 \quad 2pq = 106/173 = 0.61 \quad q^2 = 20/173 = 0.12$$

$$C^G C^G \quad C^G C^Y \quad C^Y C^Y$$

The data suggests that the seedling population is evolving at Day 21. The allele frequencies have changed from Day 7 to Day 21. The $C^Y C^Y$ genotype is being selected against and the $C^G C^Y$ is being selected for.

5. Homozygous $C^Y C^Y$ individuals cannot produce chlorophyll. The ability to photosynthesize becomes more critical as seedlings age and begin to exhaust the supply of food that was stored in the seed from which they emerged. Develop a hypothesis that explains the data for Days 7 and 21. Based on this hypothesis, predict how the frequencies of the C^G and C^Y alleles will change beyond Day 21.

The $C^Y C^Y$ soybean plants do not produce chlorophyll. As the plant begins to grow and develop, it cannot photosynthesize due to the lack of chlorophyll pigment. The plant is therefore unable to produce glucose for energy. Initially the plant is relying on stored sugar for growth and develop, but between Day 7 and Day 21 the plant begins to suffer from a lack of energy and as a result, the number of surviving plants each day decreases over time.

Beyond Day 21, one would expect to see further increase of the C^G allele (selected for), and a decrease in the C^Y allele (selected against)