Date: ________________________________

Calculating Allele Frequency

Definitions:

- **Allele frequency** is a measure of the relative frequency of an allele in a population.
- **Microevolution** is defined as the change in the frequency of alleles that occurs over generations.

For a particular allele N, its frequency in a population is calculated using the formula:

$$\text{allele frequency of N} = \frac{\text{\# of N alleles}}{\text{Total \# of alleles at that locus}}$$

Example 1: Two alleles (brown, B and white, b) exist for mouse coat colour. In a population of mice whose gene pool consists of 500 alleles, 301 of these alleles are brown. Calculate the allele frequencies for:

a. the brown allele ____________ b. the white allele ____________ [Ans: B = 0.60, b=0.40]

Calculating allele frequencies from genotypes

Example 2: In a different population of mice, 290 mice are homozygous BB, 425 are hybrid Bb, and 270 are homozygous bb. Calculate the allele frequencies:

B = ____________ b = ____________

Solution:

Genotypes 290 BB 425 Bb 270 bb

Alleles (2 × 290) B + 425 B = 1005 B 425 b + (2 × 270) b = 965 b

Total alleles = B + b = 1005 + 965 = 1970

$$\text{allele frequency of B} = \frac{1005}{1970} \qquad \text{allele frequency of b} = \frac{965}{1970}$$

B = 0.51 b = 0.49

Example 3: In centaurs, the allele for curly tails (T) is incompletely dominant to the allele for straight tails (t). The hybrid genotype results in wavy tails. In a population of 1500 centaurs, 315 have curly tails, 820 have wavy tails, and the remainder has straight tails.

a. How many total alleles are in this gene pool? ____________________________

b. Determine the allele frequencies of: T = ____________ t = ____________ [Ans: T = 0.48, t=0.52]

The Hardy-Weinberg Model

The Hardy-Weinberg model describes, for a population, the relations hip between the occurrence of genotypes and the frequency of alleles. Hardy and Weinberg independently concluded that allele frequencies are inherently stable in populations, if certain assumptions are met. *(See box)*

Assumptions:

1. Population size is infinitely large
2. No mutation occurs
3. No migration occurs
4. All members of the population breed, and mating is random
5. Natural selection does not occur

A population that meets these assumptions is said to be in **Hardy-Weinberg equilibrium,** because allele frequencies do not change from generation to generation.

The Hardy-Weinberg model was an important step to defining the mechanisms for evolution. Through recognizing that no population can ever meet these five assumptions, it identified situations that would lead to changes in allele frequency. Recall that these changes are the definition of macroevolution.

Description: For a character that has only two alleles (R and r), the frequency of all the dominant R and recessive r alleles adds up to 1.0.

The equation: $$(p + q)^2 = p^2 + 2pq + q^2 = 1$$

Frequency of alleles
p = frequency of dominant allele A
q = frequency of recessive allele a

Frequency of allele combinations (genotypes)
p^2 = frequency of AA (homozygous dominant)
q^2 = frequency of aa (homozygous recessive)
2pq = frequency of Aa (heterozygous)

To solve Hardy-Weinberg Problems follow these steps:

1. Examine the information to determine what piece of information you have been given about the population.
2. Find out the value of p or q. If this is achieved, then every other value in the equation can be determined by simple calculation.
3. Take the square root of q^2 to find q.
4. Determine p by subtracting q from 1 (i.e. p= 1-q).
5. Determine p^2 by multiplying p by itself (i.e. $p^2 = p \times p$)
6. Determine 2 pq by multiplying p times q times 2.
7. Check that your calculations are correct by adding up the values for $p^2 + q^2 + 2pq = 1$.

Practice Problem: In the American Caucasian population approximately 70% of people can taste the chemical phenylthiocarbamide (PTC) (the dominant phenotype), while 30% are non-tasters (the recessive phenotype). Determine the expected frequency of:

a) homozygous recessive phenotype (q^2) ______________
b) the recessive allele (q) ______________
c) the dominant allele (p) ______________
d) homozygous tasters (p^2) ______________
e) heterozygous tasters (2pq) ______________

If a population's genotype distribution does not match those predicted by the H-W model, then at least one of the assumptions of H-W equilibrium is being violated.

Answer:

a) The recessive phenotype q^2 = 30% or 0.30
b) Therefore: q = 0.5477 (square root of 0.30)
c) Therefore: p = 0.4522 (1 – q = p so 1- 0.5477 = 0.4523)
d) Then use p and q in the Hardy-Weinberg equation to solve:
e) Homozygous dominant: p^2 = 0.2046 (p x p = 0.4523 x 0.4523)
f) Heterozygous: 2pq = 0.4953

Population Genetics Worksheet Name ___________________________

1. In humans, attached ear lobes are caused by the inheritance of two recessive alleles. Free ear lobes are the result of inheriting at least one dominant allele for free ear lobes. The frequency of the recessive allele is 70% (0.7). What would the frequencies of the following be, assuming H-W equilibrium?
   Alleles: R ________ r ___________
   Genotypes: RR _______ rr ___________ Rr _________

Answer for #1:
R = 30%, r = 70% (you are given this), RR = 9%, rr = 49%, Rr = 42% ,

Solution: *Let p = R and q = r*

q^2 = rr
(0.7)(0.7) = 0.49

p^2 = RR
(0.3)(0.3) = 0.09

2pq = Rr
(2)(0.7)(0.3) = 0.42

p + q = 1
p = 1-q
p = 1 - 0.7 = 0.3

2. From question 1, how many people in a population of 7000 would carry the <u>allele</u> for free ear lobes? _______________.
   [Ans – 3570]

3. Suppose the allele frequencies for the autosomal gene for eye colour in females are B = 0.4 and b = 0.6, where B is brown and b is blue. Assuming H-W conditions, what would be the frequencies for:
   [Ans –(a) BB – 0.16, Bb – 0.48, bb – 0.36; (b) same as (a); (c) brown – 0.64, blue – 0.36]
   a) the genotypes of the population? BB = _____ Bb = _____ bb = _____
   b) the genotypes of the fifth generation? BB = _____ Bb = _____ bb = _____
   c) the phenotypes of the population? Brown = _____ Blue = _____

4. On an isolated Pacific Ocean Island, there exists a recessive allele for psychic ability which enabled the lucky natives to complete witch doctor school. This recessive allele was found in the population of 2000 natives at a frequency of 10%.
   a. How many witch doctors are there on the island? ___________
   b. What <u>proportion</u> of the population would be hybrid? ___________
   [Ans –(a)20; (b) 0.18 or 18%]

5. If 18 out of 50 lizards sampled has the recessive phenotype for short tails (tt),
   a. What would be the proportion of t alleles in the lizard population? ____________
   b. What would be the allele frequency for the dominant allele? ____________
   c. What percent of the population would be heterozygous? _____________

[Ans –(a)0.6; (b) 0.4; (c) 0.48]

6. Assume that in sheep, white wool colour is dominant to black wool colour. If 25% of the sheep in a large population have black wool, calculate:
   a. the allele frequencies of the two types of wool colour. _________________________
   b. the expected proportion of homozygous white sheep. ____________
   c. the expected proportion of hybrid sheep. ____________
   d. the expected number of white sheep in a population of 750? ____________

[Ans –(a)p=q=0.5; (b)0.25; (c) 0.5; (d) 562.5]

7. A population of 64 individuals is tested for their genotype at a particular locus, R. The observed frequencies are as follows:

   RR = 37 Rr = 20 rr = 7

   a. Determine the allele frequencies for R and r. R _________ r _________
   b. Use the Hardy-Weinberg equation to determine the expected genotypic proportions.

      RR _________ Rr _________ rr _________
   c. Use the proportions above to determine the expected frequencies in the population of 64.

      RR _________ Rr _________ rr _________
   d. Use a chi square test to determine whether the population is in Hardy-Weinberg equilibrium (if the genotypes occur in the expected frequencies). Use a significance level of 0.05.

[Ans –(a) R =p=0.73, r=q=0.27; (b)RR – 0.533, Rr – 0.394, rr – 0.073; (c) RR – 34.1, Rr – 25.2, rr – 4.7; (d)X^2 *= 2.443; yes it is]*

Hardy-Weinberg Calculations

1. 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:
   A. The frequency of the "aa" genotype.
   B. The frequency of the "a" allele.
   C. The frequency of the "A" allele.
   D. The frequencies of the genotypes "AA" and "Aa."
   E. The frequencies of the two possible phenotypes if "A" is completely dominant over "a."

2. If 9% of an African population is born with a severe form of sickle-cell anemia (ss), what percentage of the population will be more resistant to malaria because they are heterozygous (Ss) for the sickle-cell gene? Assume Hardy-Weinberg conditions.

3. Within a population of butterflies, the colour brown (B) is dominant over the colour white (b). If 81% of all butterflies are white, calculate the following:
   A. The percentage of butterflies in the population that are heterozygous.
   B. The frequency of homozygous dominant individuals.

4. A rather large population of squirrels have 250 red-sided individuals and 750 tan-sided individuals. Assume that red is totally recessive. Please calculate the following:
   A. The allele frequencies of each allele.
   B. The expected genotype frequencies.
   C. Conditions happen to be really good this year for breeding and next year there are 1,400 young squirrels. Assuming that all of the Hardy-Weinberg conditions are met, how many of these would you expect to be red-sided and how many tan-sided?

5. A very large population of randomly-mating laboratory mice contains 49% white mice. White colouring is caused by the double recessive genotype, "aa". Calculate allelic and genotypic frequencies for this population.

6. After graduation, you and 19 of your closest friends (total 10 males and 10 females) charter a plane to go on a round-the-world tour. Unfortunately, you all crash land (safely) on a deserted island. No one finds you and you start a new population totally isolated from the rest of the world. Two of your friends are heterozygous for the Huntington allele. Assuming that the frequency of this allele does not change as the population grows to 100,000, how many individuals will be likely to have Huntington's Disease on your island?

7. The ability to taste PTC is due to a single dominant allele "T". You sampled 215 individuals and determined that 138 could detect the bitter taste of PTC and 77 could not. Calculate the following for this population:
   A. The allele frequencies of each allele. (round to the nearest tenth)
   B. The expected genotype frequencies.

8. In a population of fish, the colour red is incompletely dominant to white. Heterozygotes are pink. A sample of 375 fish is observed and the following frequencies are noted: 39 red fish, 154 pink, and 182 white.
   A. Calculate the allele frequencies of the red (R) and white (r) alleles.
   B. Use a chi square test to determine whether the population of fish is in Hardy-Weinberg equilibrium.

9. In cats, friendliness is determined by a dominant gene F. The recessive genotype produces an unfriendly cat. The genotypes of several cats are determined to be: 40 FF, 34 Ff, and 1 ff. Is this population in Hardy-Weinberg equilibrium?