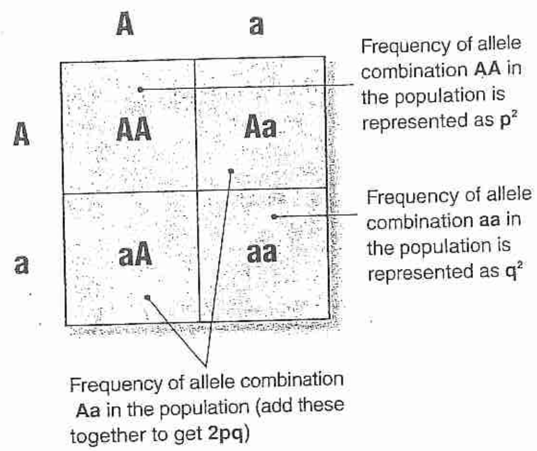
Calculating Allele Frequencies in Populations

Answer Key

The **Hardy-Weinberg equation** provides a simple mathematical model of genetic equilibrium in a gene pool, but its main application in population genetics is in calculating allele and genotype frequencies in populations, particularly as a means of studying changes and measuring their rate. The use of the Hardy-Weinberg equation is described below.

Punnett square



$$(p + q)^2 = p^2 + 2pq + q^2 = 1$$

Frequency of allele types	Frequency of allele combinations
p = Frequency of allele A	p^2 = Frequency of AA (homozygous dominant)
q = Frequency of allele a	2pq = Frequency of Aa (heterozygous)
	q^2 = Frequency of aa (homozygous recessive)

The Hardy-Weinberg equation is applied to populations with a simple genetic situation: dominant and recessive alleles controlling a single trait. The frequency of all of the dominant (A) and recessive alleles (a) equals the total genetic complement, and adds up to 1 or 100% of the alleles present.

How To Solve Hardy-Weinberg Problems

In most populations, the frequency of two alleles of interest is calculated from the proportion of homozygous recessives (q^2), as this is the only genotype identifiable directly from its phenotype. If only the dominant phenotype is known, q^2 may be calculated (1 – the frequency of the dominant phenotype). The following steps outline the procedure for solving a Hardy-Weinberg problem:

Remember that all calculations must be carried out using proportions, **NOT PERCENTAGES!**

1. Examine the question to determine what piece of information you have been given about the population. In most cases, this is the percentage or frequency of the homozygous recessive phenotype q^2, or the dominant phenotype $p^2 + 2pq$ (see note above).
2. The first objective is to 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 2pq by multiplying p times q times 2.
7. Check that your calculations are correct by adding up the values for $p^2 + q^2 + 2pq$ (the sum should equal 1 or 100%).

Worked example

Among Caucasians in the USA, approximately 70% of people can taste the chemical phenylthiocarbamide (PTC) (the dominant phenotype), while 30% are non-tasters (the recessive phenotype).

Determine the frequency of:	***Answers***
(a) Homozygous recessive phenotype(**q^2**).	30% - provided
(b) The dominant allele (**p**).	45.2%
(c) Homozygous tasters (**p^2**).	20.5%
(d) Heterozygous tasters (**2pq**).	49.5%

Data: The frequency of the dominant phenotype (70% tasters) and recessive phenotype (30% non-tasters) are provided.

Working:

Recessive phenotype:	q^2	= 30% *use 0.30 for calculation*
therefore:	q	= 0.5477 *square root of 0.30*
therefore:	p	= 0.4523 *1 – q = p* *1 – 0.5477 = 0.4523*

Use p and q in the equation (top) to solve any unknown:

Homozygous dominant	p^2	= 0.2046 *(p x p = 0.4523 x 0.4523)*
Heterozygous:	2pq	= 0.4953

1. A population of hamsters has a gene consisting of 90% M alleles (black) and 10% m alleles (gray). Mating is random.
Data: Frequency of recessive allele (10% m) and dominant allele (90% M).

Determine the proportion of offspring that will be black and the proportion that will be gray (show your working):

99% black ; 1% gray

Recessive allele:	q	= .1
Dominant allele:	p	= .9
Recessive phenotype:	q^2	= .01
Homozygous dominant:	p^2	= .81
Heterozygous:	2pq	= .18

2. You are working with pea plants and found 36 plants out of 400 were dwarf.
Data: Frequency of recessive phenotype (36 out of 400 = 9%)

(a) Calculate the frequency of the tall gene: .7

(b) Determine the number of heterozygous pea plants:

.42 × 400 = 168

Recessive allele: q = .3
Dominant allele: p = .7
Recessive phenotype: q^2 = .09
Homozygous dominant: p^2 = .49
Heterozygous: 2pq = .42

3. In humans, the ability to taste the chemical phenylthiocarbamide (PTC) is inherited as a simple dominant characteristic. Suppose you found out that 360 out of 1000 college students could not taste the chemical.
Data: Frequency of recessive phenotype (360 out of 1000).

(a) State the frequency of the gene for tasting PTC:

.4

(b) Determine the number of heterozygous students in this population:

.48 × 1000 = 480

Recessive allele: q = .6
Dominant allele: p = .4
Recessive phenotype: q^2 = .36
Homozygous dominant: p^2 = .16
Heterozygous: 2pq = .48

4. A type of deformity appears in 4% of a large herd of cattle. Assume the deformity was caused by a recessive gene.
Data: Frequency of recessive phenotype (4% deformity).

(a) Calculate the percentage of the herd that are carriers of the gene:

.32

(b) Determine the frequency of the dominant gene in this case:

.8

Recessive allele: q = .2
Dominant allele: p = .8
Recessive phenotype: q^2 = .04
Homozygous dominant: p^2 = .64
Heterozygous: 2pq = .32

5. Assume you placed 50 pure bred black guinea pigs (dominant allele) with 50 albino guinea pigs (recessive allele) and allowed the population to attain genetic equilibrium (several generations have passed).
Data: Frequency of recessive allele (50%) and dominant allele (50%).

Determine the proportion (%) of the population that becomes white:

.25 or 25%

Recessive allele: q = .5
Dominant allele: p = .5
Recessive phenotype: q^2 = .25
Homozygous dominant: p^2 = .25
Heterozygous: 2pq = .50

6. It is known that 64% of a large population exhibit the recessive trait of a characteristic controlled by two alleles (one is dominant over the other).
Data: Frequency of recessive phenotype (64%). Determine the following:

(a) The frequency of the recessive allele: $\sqrt{.64}$ = .8 q = .8 p = .2

(b) The percentage that are heterozygous for this trait: 2 × .8 × .2 = .32

(c) The percentage that exhibit the dominant trait: AA + Aa = .04 + .32 = .36

(d) The percentage that are homozygous for the dominant trait: .04

(e) The percentage that has one or more recessive alleles: Aa + aa = .32 + .64 = .96

7. Albinism is recessive to normal pigmentation in humans. The frequency of the albino allele was 10% in a population.
Data: Frequency of recessive allele (10% albino allele).

Determine the proportion of people that you would expect to be albino:

.01 or 1%

Recessive allele: q = .1
Dominant allele: p = .9
Recessive phenotype: q^2 = .01
Homozygous dominant: p^2 = .81
Heterozygous: 2pq = .18