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EDVO-Kit #

Population Genetics and Evolution

Storage:
Store entire experiment in the refrigerator.

Experiment Objective:

The objective of this experiment module is to use the Hardy-Weinberg theorem to calculate allele and genotype frequencies. Students will predict the effect of selection processes on allelic frequencies, and discuss the effect of changes in allelic frequencies on evolution.

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Major Section Headings

Experiment Components

Storage:
Store entire experiment in the refrigerator.

All components of this experiment are intended for educational research only. They are not to be used for diagnostic or drug purposes, nor administered to or consumed by humans or animals.

This experiment is designed for 10 lab groups.

Contents:

- PTC taste paper
- Control taste paper

Requirements

- Calculator with square root function
- 100 index cards

BACKGROUND INFORMATION

Population Genetics and Evolution

Population genetics deals with analysis of gene frequencies in a population over many generations. The concept of describing frequencies of inherited traits owes its origin to scientific works published at the beginning of the 20th century. A 1908 paper, "Mendelian Proportions in a Mixed Population" published in Science 28 (49-50) by British mathematician G.H. Hardy, and a separate independent study also published in 1908 by the German physician W. Weinberg, both suggested that gene frequencies were not dependent upon dominance or recessiveness but may remain unchanged from one generation to the next under a set of "idealized conditions". These classic papers describe an equation which has come to be called the Hardy-Weinberg theorem of genetic equilibrium. This theorem has become the basis for population genetics.

The Hardy-Weinberg theorem is used to determine the frequencies of individual alleles of a pair of genes, and the frequency of heterozygotes and homozygotes in the population. The theorem states that in the absence of outside forces such as mutation, selection, random genetic drift, and migration, gene frequencies remain constant over many generations in a large population. It is important to remember that in natural populations, events such as gene mutation, selection of genotypes which confer enhanced viability, presence of lethal homozygous recessive genes, nonrandom mate selection, and immigration and emigration of individuals of a population, are events that do occur. Nevertheless, the Hardy-Weinberg theorem is useful since unexpected deviations can point to the occurrence of evolutionary significant events such as speciation.

Distribution frequencies of two alleles for a given gene at a single locus, one being dominant, the other recessive, will follow a binomial distribution in the population. Consider the case of two alleles for a gene, one dominant and the other recessive.

Let p = the frequency of one allele and q = the frequency of the other. If gene frequencies are expressed as decimals, the following must be true,

Equation #1: $p + q = 1$

and,

Equation #1a: $p = 1 - q$

therefore,

Equation #2: $(p + q)^2 = 1$.

BACKGROUND INFORMATION

Background Information, continued

Expanding equation #2 generates,

Equation #3: $p^2 + 2pq + q^2 = 1$.

When equation 3 is applied to an ideal population, it follows that the frequency of homozygous dominant individuals is p^2, the frequency of the heterozygotes is 2pq, and the frequency of homozygous recessives is q^2.

As an example, consider the following hypothetical situation. The famous European genetics instructor, Professor Ed V. Otek, tested his rather large genetics class for the ability to taste the chemical phenylthiocarbamide, PTC. He knew that the gene for this ability to taste PTC had two alleles, the dominant allele for tasting called T, and the recessive allele called t. He found that out of 1000 students, there were 700 students with the ability to taste PTC and 300 who lacked the ability to taste PTC. He used the Hardy-Weinberg equation to determine the gene frequencies for the T and t alleles of the gene for the ability to taste PTC. His notes show the following analysis:

A. Converted raw data to decimals.

- Frequency of two possible genotypes for tasting, TT and Tt, was 700/1000 = 0.7.
- Frequency of unique genotype for inability to taste PTC, tt, was 300/1000 = 0.3.

B. Determined gene frequency of the unique allele.

- From the Hardy-Weinberg equation #3, ($p^2 + 2pq + q^2 = 1$), the frequency of non-tasters, tt $= 0.3 = q^2$.
- Taking the square root of 0.3, q = 0.5477, and 0.5477 is the frequency of the t allele in Dr. Otek's student population.

C. Determined gene frequency of other allele, p: From equation #1a, (p = 1-q), the frequency of p is .4523.

D. Determined frequency of homozygous TT and heterozygous Tt individuals in the population. Using equation 3:

$$p^2 + 2pq + q^2 = 1,$$

$$0.4523^2 + 2(0.4523 \times 0.5477) + 0.5477^2 = 1$$

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BACKGROUND INFORMATION

Background Information, continued

- The frequency of homozygous tasters is,
  $TT = p^2 = 0.4523^2 = 0.2046$.

- The frequency of heterozygous tasters is
  $Tt = 2pq = 2\ (0.4523 \times 0.5477) = 0.4954$.

During this laboratory experiment, the class will utilize the Hardy-Weinberg equation to analyze population data from the class.

