**ALLELE AND PHENOTYPE FREQUENCIES**

**IN ROCK POCKET MOUSE POPULATIONS**

**INTRODUCTION:**

The tiny rock pocket mouse weighs just 15 grams, about as much as a handful of paper clips. A typical rock pocket mouse is 172 millimeters long from nose to rump, which is shorter than an average pencil. Its impact on science, however, has been enormous. What’s so special about this little mouse?

Populations of rock pocket mice are found all over the Sonoran Desert in the southwestern United States. Two varieties occur widely in the area—a light-colored variety and a dark-colored variety. Similarly, there are two major colors of substrate, or surface material, that make up the rocky desert floor. Most of the desert landscape consists of light-colored sand and granite. Here and there, however, separated by several kilometers of light-colored substrate, are patches of dark volcanic rocks that formed from cooling lava. These areas of dark volcanic rock range in age from 1,000 to more than 1 million years old.

Dr. Michael Nachman of the University of Arizona and his colleagues have spent many years researching the genetics of fur color in rock pocket mice. In particular, they were interested in understanding the forces that shape genetic variation in natural populations.

Investigating the adaptive value of different coat colors in rock pocket mice is an example of how scientists are attempting to connect genotype with phenotype for fitness-related traits. In this type of research, investigators try to find the underlying gene or genes for a given adaptation. Examples of other fitness-related traits that researchers are currently investigating are resistance to the pesticide warfarin in rats, tolerance to heavy metals in plants, and antibiotic resistance in bacteria.

**Following the Film…**

**a.** What specific trait did researchers study in this investigation?

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**b.** How does this trait affect the survival of the mice in different environments?

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**c.** What is the genetic basis of the trait?

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**PART 1:**

**REVIEWING THE PRINCIPLES OF THE HARDY-WEINBERG THEOREM**

The genetic definition of “evolution” is “a change to a population’s gene pool.” “Gene pool” is defined as “the total number of alleles present in a population at any given point in time.” According to the Hardy-Weinberg theorem, a population is in equilibrium (and is **therefore *not* evolving**) when **all** of the following conditions are true:

**1. The population is very large and well mixed.**

**2. There is no migration.**

**3. There are no mutations.**

**4. Mating is random.**

**5. There is no natural selection.**

To determine whether a population’s gene pool is changing, we need to be able to calculate allelic frequencies. Suppose, for example, a gene has two alleles, *A* and *a.* Each individual has one of three genotypes: *AA*, *Aa*, or *aa*. If the population is in equilibrium, the overall number of *A* alleles and *a* alleles in the gene pool will remain constant, as will the proportion of the population with each genotype. If allele frequencies or genotype frequencies change over time, then evolution is occurring.

**Two equations** are used to calculate the frequency of alleles in a population, where ***p*** represents the frequency of the dominant allele and ***q*** represents the frequency of the recessive allele:

***p* + *q* = 1.0** and ***p*2 + 2*pq* + *q*2 = 1.0**

|  |  |  |
| --- | --- | --- |
| **Equation** | **What does it say?** | **When do I use it?** |
| ***p* + *q* = 1.0** | if there are only two alleles for a gene, one dominant and one recessive, then 100% of the alleles are either dominant (*p*) or recessive (*q*) | to find the frequency of the dominant or recessive allele |
| ***p*2 + 2*pq* + *q*2 = 1.0** | 100% of individuals in the population will have one of these genotypes: *AA*, *Aa*, and *aa*. | to find the % of individuals in the population |

• If *p* represents the frequency of the *A* allele, then the frequency of the genotype *AA* will be *p* × *p*, or *p*2.

• If *q* represents the frequency of the *a* allele, then the frequency of the genotype *aa* will be *q* × *q*, or *q*2.

• For heterozygotes, we must allow for either the mother or the father to contribute the dominant and recessive alleles. You can think of it as allowing for both genotypes *Aa* and *aA*. So, we calculate the frequency of the heterozygous genotype as 2*pq*.

In terms of alleles, p = \_\_\_\_\_ and q = \_\_\_\_\_. In terms of genotypes, p2= \_\_\_\_\_, 2pq = \_\_\_\_\_, q2= \_\_\_\_\_

**Rock Pocket Mice Genotypes and Phenotypes**

In rock pocket mice, several genes code for fur color. Each gene has several possible alleles. That’s why there is a range of fur color from very dark to light. For simplicity, we will work with two alleles at one gene. The allele for dark-colored fur (*D*) is dominant to the allele for light-colored fur (*d*). In this scenario, individual rock pocket mice can have one of three genotypes and one of two phenotypes, as summarized in the table below.



So, applying Hardy-Weinberg, we have the following:

***p*** = the frequency of the dominant allele (*D*)

***q*** = the frequency of the recessive allele (*d*)

***p*2** = the frequency of *DD*

**2*pq*** = the frequency of *Dd*

***q*2** = the frequency of *dd*

**SAMPLE PROBLEM**

In a hypothetical population consisting of 100 rock pocket mice, 81 individuals have light, sandy-colored fur. Their genotype is *dd*. The other 19 individuals are dark colored and have either genotype *DD* or genotype *Dd*.

* Find *p* and *q* for this population and calculate the frequency of heterozygotes in the population.

🡪It is easy to calculate *q*2.

1. *Calculate q using q*2 **q2** = 81/100 = 0.81, or 81%. ***q***= √0.81 = 0.9
2. *Now, calculate p using the equation p + q = 1.*

*p* + 0.9 = 1 *p* = 0.1

1. *Now, to calculate the frequency of heterozygous genotypes, we need to calculate 2pq.*

*2pq = 2(0.1)(0.9) = 2(0.09)* 2*pq* = 0.18

QUESTIONS

**1.** If there are 12 rock pocket mice with dark-colored fur and 4 with light-colored fur in a population, what is

the value of *q*? Remember that light-colored fur is recessive.

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**2.** If the frequency of *p* in a population is 60% (0.6), what is the frequency of *q*?

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**3.** In a population of 1,000 rock pocket mice, 360 have dark-colored fur. The others have light-colored fur. If the population is at Hardy-Weinberg equilibrium, what percentage of mice in the population are homozygous dominant, dark-colored mice?

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**PART 2: APPLYING HARDY-WEINBERG TO ROCK MOUSE FIELD DATA**

Dr. Nachman and his colleagues collected rock pocket mice across 35 kilometers of the Arizona Sonoran Desert, which included both dark, rocky lava outcrops and light, rocky, granite areas. They recorded substrate color and coat-color frequencies for each location. Each site was separated from any of the others by at least eight kilometers. The researchers trapped a total of 225 mice. Their data are summarized below.

**Field Data Summary**

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**QUESTIONS**

**1.** Calculate the overall frequencies of light-colored mice and dark-colored mice caught on light-colored substrates. (frequency = number of mice of one color/total number of mice)

Frequency of light-colored mice \_\_\_\_\_\_\_\_ Frequency of dark-colored mice \_\_\_\_\_\_\_\_

**2.** Calculate the overall frequencies of light-colored mice and dark-colored mice caught on dark-colored substrates. (frequency = number of mice of one color/total number of mice)

Frequency of light-colored mice \_\_\_\_\_\_\_\_ Frequency of dark-colored mice \_\_\_\_\_\_\_\_

**3.** Using the Hardy-Weinberg equation and data from the table above, determine the number of mice with the *DD* and *Dd* genotypes on the light, rocky, granite substrate.

Frequency of mice with the *dd* genotype on light-colored substrate \_\_\_\_\_\_\_\_

Frequency of mice with the *DD* genotype on light-colored substrate \_\_\_\_\_\_\_\_

Frequency of mice with the *Dd* genotype on light-colored substrate \_\_\_\_\_\_\_\_

**4.** Using the Hardy-Weinberg equation and data from the table above, determine the number of mice with the *DD* and *Dd* genotypes on the dark, rocky lava substrate.

Frequency of mice with the *dd* genotype on dark-colored substrate \_\_\_\_\_\_\_\_

Frequency of mice with the *DD* genotype on dark-colored substrate \_\_\_\_\_\_\_\_

Frequency of mice with the *Dd* genotype on dark-colored substrate \_\_\_\_\_\_\_\_

**5.** Which fur color seems to have the greatest overall selective advantage? Use data collected from both dark-colored and light-colored substrates to support your answer.

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6. To determine if the rock pocket mouse population is evolving, explain why it is necessary to collect fur color frequency data over a period of many years.

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