Chapter 11 The Evolution of Populations

Section 11.4 Hardy-Weinberg Principle

- *Large* populations
- Random *mating*

Hardy-Weinberg principle

- *dominant* alleles DO NOT REPLACE *recessive* ones
- frequency of alleles *remains constant*
- proportions of *homo*zygotes & *hetero*zygotes remains constant

I. Hardy-Weinberg equilibrium describes populations that are *not evolving.*

-**Real populations** rarely meet all ***five conditions.***

-**Real population** ***data*** is compared to a model.

-***Models*** are used to studying how populations evolve.

- **frequency** =***proportion of a group that is one type***
- **<u>equation</u>**

  $p^2 + 2pq + q^2 = 1$ (population) ***genotype frequency***

  p and q are ***allele*** **frequencies** ***(single allele)***

  $p + q =$ ***1 (allele frequency)***

The final three possible genotypic frequencies in the offspring become:

$f(AA) = p^2$

$f(Aa) = 2pq$

$f(aa) = q^2$

II. The Hardy - Weinberg equation is used to predict genotype frequencies in a population.

A. ***Predicted*** genotype frequencies are compared with actual frequencies.

-used for traits in ***simple dominant-recessive*** systems

-must know frequency of ***recessive*** homozygotes

- **Genotype frequencies stay the same if five conditions are met.**

*very large population: ***no genetic drift***

*no emigration or immigration: ***no gene flow***

*no mutations: ***no new alleles*** added to gene pool

*random mating: ***no sexual selection***

*no natural selection: ***all traits aid equally*** in survival

	p	q
p	p^2	pq
q	pq	q^2

"The Hardy-Weinberg equation is based on Mendelian genetics. It is derived from a simple Punnett square in which p is the frequency of the dominant allele and q is the frequency of the recessive allele."

The Hardy-Weinberg formulas allow us to detect some allele frequencies that change from generation to generation, thus allowing a simplified method of determining that evolution is occurring. There are two formulas that must be memorized:

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

$$\textit{and } p + q = 1$$

p = frequency of the ***dominant*** **allele** in the population

q = frequency of the ***recessive*** **allele** in the population

p^2 = *frequency* of **homozygous dominant** individuals

q^2 = *frequency* of **homozygous recessive** individuals

$2pq$ = *frequency* of **heterozygous** individuals

Section 11.5 Speciation through Isolation

New species can arise when populations are isolated.

A. The isolation of populations can lead to speciation.

1. Populations become isolated when there is ***no gene flow.***

   -Isolated populations ***adapt*** to their own environments.

   -Genetic differences can add up over generations.

2. ***Reproductive*** isolation can occur between isolated populations.

   -members of different populations ***cannot mate*** successfully, ***possibly from a mutation passed on over time***

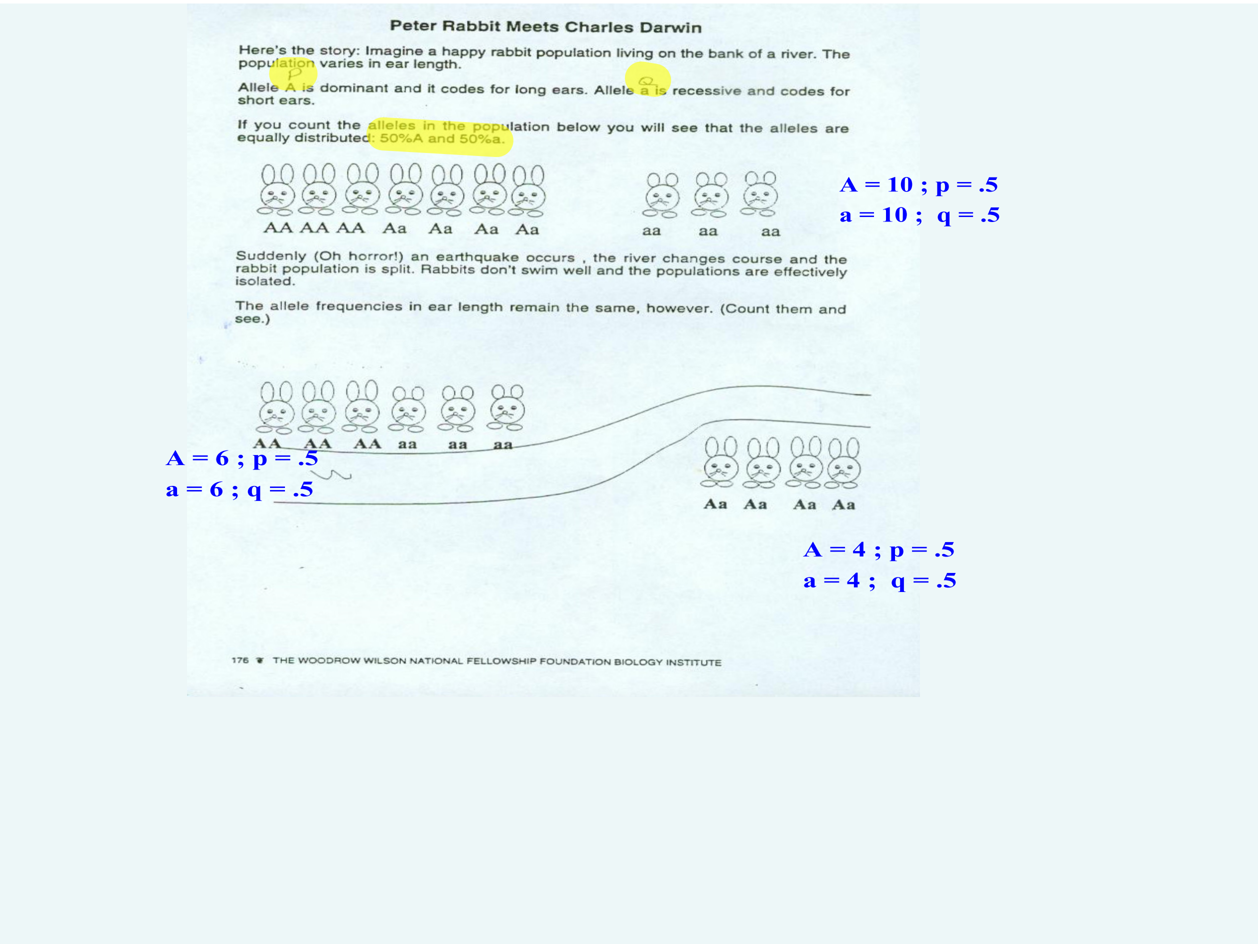
   -final step to becoming ***separate species (speciation)***

B. Populations can become isolated in several ways.

1. ***Behavioral*** barriers can cause isolation.
   -called behavioral ***isolation***
   -includes differences in ***courtship or mating*** behaviors

2. ***Geographic*** barriers can cause isolation.
   -called geographic ***isolation***
   -physical barriers divide population
   i.e. rivers, mountains, lake beds

3. ***Temporal*** barriers can cause isolation.
   -called temporal ***isolation***
   -timing of reproductive periods prevents mating
   (such as time of day or time of year)



Peter Rabbit Meets Charles Darwin

Here's the story: Imagine a happy rabbit population living on the bank of a river. The population varies in ear length.

Allele A is dominant and it codes for long ears. Allele a is recessive and codes for short ears.

If you count the alleles in the population below you will see that the alleles are equally distributed: 50%A and 50%a.

AA AA AA Aa Aa Aa Aa aa aa aa

A = 10 ; p = .5
a = 10 ; q = .5

Suddenly (Oh horror!) an earthquake occurs , the river changes course and the rabbit population is split. Rabbits don't swim well and the populations are effectively isolated.

The allele frequencies in ear length remain the same, however. (Count them and see.)

AA AA AA aa aa aa

A = 6 ; p = .5
a = 6 ; q = .5

Aa Aa Aa Aa

A = 4 ; p = .5
a = 4 ; q = .5

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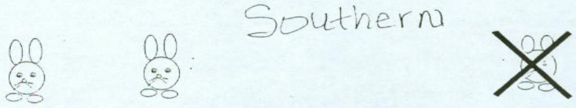
The earthquake has disrupted things and the southern population migrates south in search of food and the northern population migrates north in search of food. The rabbits reproduce (that's what rabbits do best) and many generations pass. Things have changed, however. Now allele A (long ears) gives the southern rabbits a selective advantage: long ears mean more heat loss, less energy expended, more time for fun and greater reproductive success.

Southern



AA Aa aa

A = 3 or 3/4 p = .75

a = 1 or 1/4 q = .25

Dies pre-reproduction
A=75% a=25%

Now lets look at the northern rabbits:

Some climatic change has occurred and in the northern rabbits allele a is favored.

Short ears mean less heat loss, more energy conserved, more time for fun, greater reproductive success.

AA AA Aa aa aa aa

Dies. Pre-reproduction.

New gene frequencies A= 1 or 1/8 p = .125

a= 7 or 7/8 q = .875

The gene frequencies have changed. Has evolution occurred?

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Hardy-Weinberg Equilibrium

It is at the population level that evolution occurs. A population is a group of individuals of the same species in a given area whose members can interbreed. Because the individuals of a population can interbreed, they share a common group of genes known as the gene pool. Each gene pool contains all the alleles for all the traits of all the population. For evolution to occur in real populations, some of the gene frequencies must change with time. The gene frequency of an allele is the number of times an allele for a particular trait occurs compared to the total number of alleles for that trait.

$$\text{Gene frequency} = \frac{\text{the number of a specific type of allele}}{\text{the total number of alleles in the gene pool}}$$

Consider a population whose gene pool contains the alleles *A* and *a*.. Hardy and Weinberg assigned the letter p to the frequency of the dominant allele *A* and the letter q to the frequency of the recessive allele *a*.. Since the sum of all the alleles must equal 100%, then p+q=1. They then reasoned that all the random possible combinations of the members of a population equal $(p+q)^2$ or $p^2 + 2pq + q^2$. The frequencies of *A* and *a* will remain unchanged generation after generation if the following conditions are met:

1. **Large population. The population must be large to minimize random sampling errors.**
2. **Random mating. There is no mating preference. For example an *AA* male does not prefer an *aa* female.**
3. **No mutation. The alleles must not change.**
4. **No migration. Exchange of genes between the population and another population must not occur.**
5. **No natural selection. Natural selection must not favor any particular individual.**

Hardy-Weinberg Equilibrium

Let's look at an analogy that may help understand Hardy-Weinberg Equilibrium. Imagine a "swimming" pool of genes as shown in Figure 1.

Find: Frequencies of *A* and *a*. and the genotypic frequencies of AA, Aa and *aa*.

Solution:

$f(A) = \frac{12}{30} = 0.4 = 40\%$

$f(a) = \frac{18}{30} = 0.6 = 60\%$

Then, $p + q = 0.4 + 0.6 = 1$

and $p^2 + 2pq + q^2 = AA + Aa + aa$

$= .16 + .48 + .36 = 1$

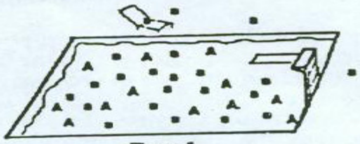

Figure 1

As long as the conditions of Hardy-Weinberg are met, the population can increase in size and the gene frequencies of *A* and *a* will remain the same. Thus, the gene pool does not change.

Now, suppose more "swimmers" dive in as shown in Figure 2. What will the gene and genotypic frequencies be?

Solution:

$f(A) = \frac{12}{34} = .35 = 35\%$

$f(a) = \frac{22}{34} = .65 = 65\%$

$f(AA) = .12$, $f(Aa) = .46$ and $f(aa) = .42$

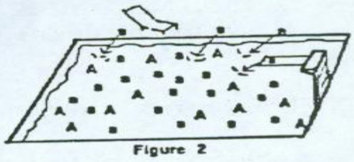

Figure 2

The results show that Hardy-Weinberg Equilibrium was not maintained. The migration of swimmers (genes) into the pool (population) resulted in a change in the population's gene frequencies. If the migration were to stop and the other agents of evolution (i.e., mutation, natural selection and non-random mating) did not occur, then the population would maintain the new gene frequencies generation after generation. It is important to note that a fifth factor affecting gene frequencies is population size. The larger a population is, the number of changes that occur by chance alone becomes insignificant. In the analogy above, a small population was deliberately used to simplify the explanation.

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

and $p + q = 1$

p = **frequency** of the **dominant allele** in the population

q = **frequency** of the **recessive allele** in the population

p^2 = **frequency** of **homozygous dominant** individuals

q^2 = **frequency** of **homozygous recessive** individuals

2pq = **frequency** of **heterozygous** individuals