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.**

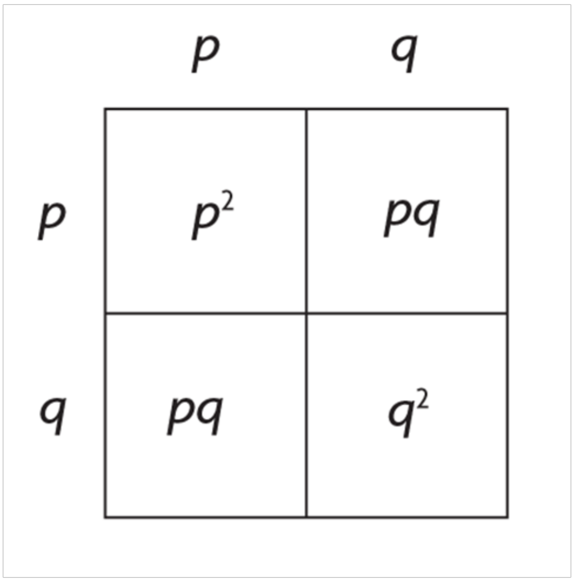
*very large population: ***no genetic drift***

*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***

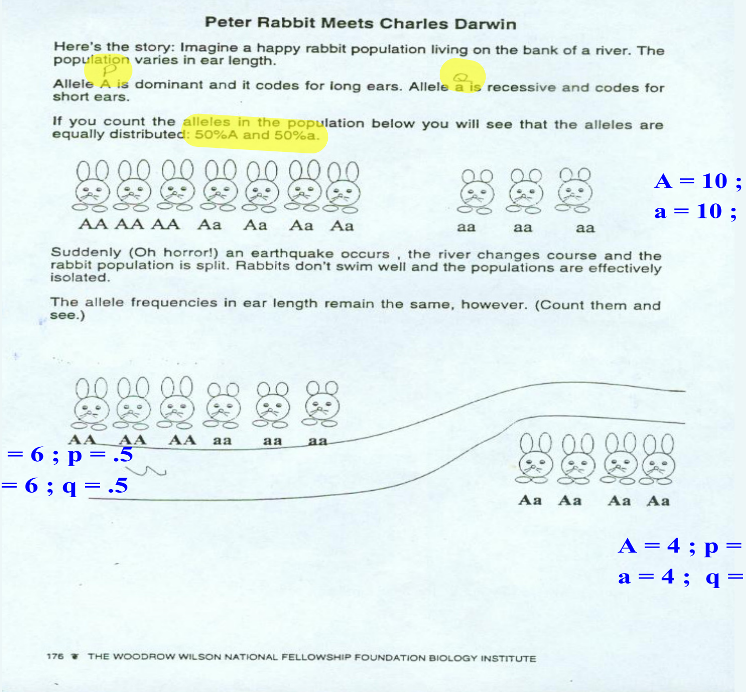
   -final step to becoming ***separate species (speciation)***

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.

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.)

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

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

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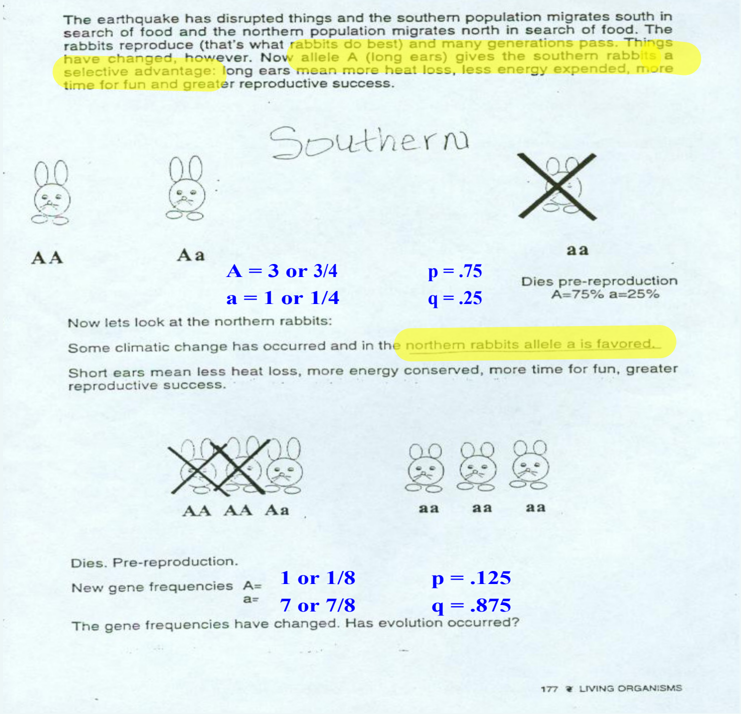

The earthquake has disrupted things and the southern population migrates south in search of food and the northern population migrates north in search of food. The rabbits reproduce (that's what rabbits do best) and many generations pass. Things have changed, however. Now allele A (long ears) gives the 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

a = 1 or 1/4

$p = .75$

$q = .25$

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

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

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

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 "a" allele.

B. The frequency of the "A" allele.

C. The frequencies of the genotypes "AA" and "Aa."

A. q^2 (aa) = .36

q (a) = $\sqrt{.36}$ = .6

B. $1 - q = p$

p (A) = .4

C. p^2 (AA) = $.4^2$ = .16

$2pq$ (Aa) = 2(.4)(.6) = .48

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

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?

q^2 (ss) = .09

q(s) = $\sqrt{.09}$ = .3

$1-q = p$

p (S) = .7

$2pq$ (Ss) = 2(.7)(.3) = .42

or 42% are heterozygous

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

3. **Within a population of butterflies, the color brown (B) is dominant over the color white (b). And, 40% 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.**

A. q^2 (bb) = .4

q (b) = $\sqrt{.4}$ = .632

$1 - q = p$

p (B) = .368

$2pq$ (Bb) = 2(.368)(.632) = .465 or 46.5%

B. p^2 (BB) = $(.368)^2$ = .135424 or .135

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

4. **Tay Sachs is a recessive condition that affects about 1 in 1,600 babies in the Jewish population of the United States. Please calculate the following.**

A. **The frequency of the recessive allele in the population.**

B. **The frequency of the dominant allele in the population.**

C. **The percentage of heterozygous individuals (carriers) in the population AND number of individuals that are carriers.**

A. q^2 (tt) = 1/1,600 = .000625

q (t) = $\sqrt{.000625}$ = .025

B. $1 - q = p$

p (T) = 1- .025 = .975

C. $2pq$ (Tt)= 2(.975)(.025) = .04875 or 4.8%

or 78 individuals are carriers