

THE HARDY-WEINBERG PRINCIPLE



Is there a way to measure
evolution?

What did Darwin not know?



- Genetics!
- He didn't know how traits passed from generation to generation
- Gregor Mendel's work came AFTER Darwin

Modern Synthesis



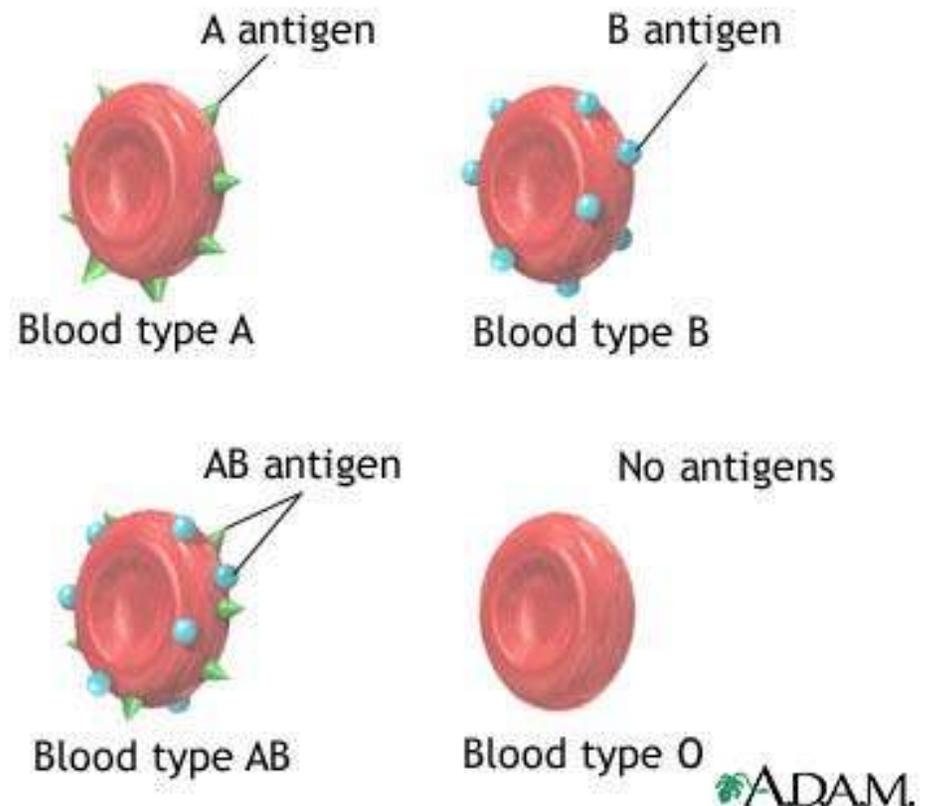
- The Modern Synthesis- evolution integrated into other fields of life science
- Population genetics – study of how genes change in a population over time

Measuring genetic variation and changes

- First we need to know about populations
- Population- Localized group of individuals that are capable of interbreeding and producing fertile offspring
- Populations have gene pools
 - ▣ Gene Pool: All of the alleles found in a population
- Remember, evolution is the change in population NOT in an individual

What the heck is an allele?

- Allele: Alternative version of a gene that produces a distinguishable phenotype effect
- Each person has two alleles for every gene
- Other examples?



Gene pools and allele frequencies

- So what does all of this have to do with measuring evolution?

We measure the allele frequencies because if the allele frequencies change, then the genetic make up of the population is changing

- Allele frequency = how often a gene occurs in a population

Remember, evolution is the change in the genetic makeup of a population over time

Measuring allele frequencies

- So, how can we measure how often a allele occurs in a population?
- We can count (or estimate) how often the allele occurs
- How can we tell if the allele frequency is changing?
- We can compare our results to a population that IS NOT changing or compare our results from one time period to the next.

The Hardy-Weinberg Theorem



- If a population IS NOT evolving, then it is in a state called Hardy-Weinberg Equilibrium
- If it is not evolving, then allele frequencies remain constant from generation to generation

Conditions of Hardy-Weinberg Equilibrium



1. Extremely large population size
 - ▣ Eliminates chance
 2. No gene flow (migration)
 - ▣ No transfer of alleles in or out of the pop.
 3. No mutations
 4. Random mating
 - ▣ No preference
 5. No natural selection
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- ▣ Populations with these characteristics are not evolving

Hardy-Weinberg Equilibrium



- Do these conditions ever exist?
- So, why is this a useful thing for us as scientists?
- The rate of evolution is typically so slow that populations appear to be in equilibrium
- This allows us to estimate changes in allele frequencies, which helps us see how evolution is occurring

Using H-W to determine allele frequency

- Step 1: How many alleles at the locus?
 - ▣ Fixed = only one
 - ▣ When two alleles, one is p , the other is q
 - ▣ p is dominant and q is recessive
- Step 2: How many individuals in population?
- Step 3: How many are homozygous and how many are heterozygous?
 - ▣ Count 'em up!
 - ▣ Don't forget, each individual has 2 copies of each chromosome!
- If we know allele frequency, we can estimate genotype frequency

Lots of tricky vocab here



- Locus?
- Dominant and recessive?
- Homozygous ?
- Heterozygous?

- Lets get this down first.

Example problem

- Lets say we have a population of muskrats. Muskrats have a gene for tail size. Homozygous T^L is for long tailed. Homozygous T^S is for short tailed. The heterozygous condition demonstrates incomplete dominance.



We need to have an equation!!!



- The Hardy-Weinberg Equation

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

- Important hint: p and q will equal 1.

Math time!

- Lets treat p as dominant and q as recessive
- How do we get p^2 ?
 - ▣ Find the frequency and multiply it ($p \times p$)
 - ▣ I believe that it is time to practice!

- What do we want to know?
 - ▣ Identify the frequency of p and q

- If 200 muskrats have a long tail, 125 have a medium tail and 175 have a short tail, what is the frequency of each allele?

$$p^2 =$$

$$p =$$

$$q^2 =$$

$$q =$$

$$2pq =$$



Hardy-Weinberg Equation

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

p^2 = frequency of homozygous dominant individuals

$2pq$ = frequency of heterozygote individuals

q^2 = frequency of homozygous recessive individuals

p = frequency of dominant allele

q = frequency of recessive allele

NOTE: $p + q = 1$

H-W example #1:

In a certain population, 36% have sickle cell anemia. What is the frequency of the *dominant allele*?

What do we know? (p^2 , $2pq$, q^2 , p or q)

$$q^2 = 36\% \text{ or } 0.36$$

What do we want to find?

p

Calculations:

$$\sqrt{q^2} = q \quad \sqrt{0.36} = 0.6 \quad q = 0.6$$

$$p + q = 1 \quad \text{Thus, } p = 1 - 0.6 \text{ or } 0.4$$

H-W example #2:

In a certain population, the frequency of the dominant allele is 0.7. What is the frequency of *heterozygous individuals*?

What do we know? (p^2 , $2pq$, q^2 , p or q)

$$p = 0.7$$

What do we want to find?

$$2pq$$

Calculations:

$$p + q = 1 \quad \text{Thus, } q = 1 - 0.7 \text{ or } 0.3$$

$$2pq = 2 \times 0.7 \times 0.3 \text{ or } 0.42$$

From the previous example we know:

$$p = 0.7 \quad q = 0.3 \quad 2pq = 0.42$$

Calculate the frequency of *homozygous dominant* individuals.

$$0.49$$

Calculate the frequency of *homozygous recessive* individuals.

$$0.09$$

If there are 1000 individuals in this population, *how many are:*

☞ *heterozygous?* 420

☞ *homozygous dominant?* 490

☞ *homozygous recessive?* 90

How is Hardy-Weinberg actually useful?

- You can estimate the frequency of an allele in a population
 - ▣ Great for determining number of carriers of a disorder in a population
 - Cystic fibrosis, PKU,
- Compare allele frequencies over time
- Calculated frequencies can be used to measure observed frequencies. Those frequencies can be used to compare to expected predicted frequencies
 - ▣ If they don't match, then evolution is occurring

Illustrative example

