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TOPIC 7.5

Hardy-Weinberg Equilibrium

EVO-1.K.1

Hardy-Weinberg is a model for describing and predicting allele frequencies in a nonevolving population. Conditions for a population or an allele to be in Hardy-Weinberg equilibrium are—

(1) a large population size

(2) absence of migration

(3) no net mutations

(4) random mating

(5) absence of selection.

These conditions are seldom met, but they provide a valuable null hypothesis.

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Hardy-Weinberg Equilibrium

EVO-1.K.2

Allele frequencies in a population can be calculated from genotype frequencies.

RELEVANT EQUATION

Hardy-Weinberg Equation—

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

$$p + q = 1$$

where:

p = frequency of allele 1 in the population

q = frequency of allele 2 in the population

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Hardy-Weinberg Equilibrium

EVO-1.L.1

Changes in allele frequencies provide evidence for the occurrence of evolution in a population.

EVO-1.L.2

Small populations are more susceptible to random environmental impact than large populations.

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NOTE:

The BEST video to watch to understand the conditions of Hardy-Weinberg is by Paul Anderson

TedEd:

Five Fingers of Evolution

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For Hardy-Weinberg, the population size should be...

A. Small
B. Large

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For Hardy-Weinberg, the population size should be...

B. Large

Hardy-Weinberg states that a population is not evolving if the allele frequencies stay the same. When the population is large, it allows for genetic drift to not affect the population to the same extreme. The five conditions for Hardy-Weinberg are LARGE population size, RANDOM mating, NO mutations, NO gene flow, and NO natural selection.

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Why do you want a large population size?

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Why do you want a large population size?

To inhibit genetic drift situations. Recall, we said yesterday that random situations could impact allele frequency.

If you had a population of 100 vs 100,000 and 50 individuals die from a random event. That decrease of 50 from the random event would be 50% of the first and 5% of the second population.

So, you see how the small population can have a large difference in the allele frequency

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For Hardy-Weinberg, condition for gene flow?

A. No gene flow
B. Yes gene flow

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For Hardy-Weinberg, condition for gene flow?

A. No gene flow

Hardy-Weinberg states that a population is not evolving if the allele frequencies stay the same. When the individuals immigrate or emigrate, alleles are added or removed from the population, which changes the allele frequency. The five conditions for Hardy-Weinberg are LARGE population size, RANDOM mating, NO mutations, NO gene flow, and NO natural selection.

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Why no gene flow for Hardy-Weinberg?

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Why no gene flow for Hardy-Weinberg?

Gene flow can modify the allele frequency due to the movement of alleles (not by evolution) and this can introduce new alleles from another population

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For Hardy-Weinberg, what about mutations?

A. No mutations
B. Yes mutations

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For Hardy-Weinberg, what about mutations?

A. No mutations

Hardy-Weinberg states that a population is not evolving if the allele frequencies stay the same. Mutations add new alleles to a population, which will change the allele frequencies. The five conditions for Hardy-Weinberg are LARGE population size, RANDOM mating, NO mutations, NO gene flow, and NO natural selection.

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Why should there be no mutations for Hardy-Weinberg?

Why should there be no mutations for Hardy-Weinberg?

Mutations add new alleles which is going to definitely change the allele frequency.

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For Hardy-Weinberg, what about mating?

A. Nonrandom mating
B. Random mating

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For Hardy-Weinberg, what about mating?

B. Random mating

Hardy-Weinberg states that a population is not evolving if the allele frequencies stay the same. Random mating allows for no traits to be selected for or against which can affect the allele frequencies. The five conditions for Hardy-Weinberg are LARGE population size, RANDOM mating, NO mutations, NO gene flow, and NO natural selection.

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Why should mating be random for Hardy-Weinberg?

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Why should mating be random for Hardy-Weinberg?

No one allele should be more "favorable" than another because it will modify the allele frequency

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For Hardy-Weinberg, what about natural selection?

A. No natural selection
B. Yes natural selection

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For Hardy-Weinberg, what about natural selection?

A. No natural selection

Hardy-Weinberg states that a population is not evolving if the allele frequencies stay the same. Natural selection allows for traits to be selected for or against which can affect the allele frequencies. The five conditions for Hardy-Weinberg are LARGE population size, RANDOM mating, NO mutations, NO gene flow, and NO natural selection.

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Why should there be no natural selection?

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Why should there be no natural selection?

Natural selection involves one allele being more favorable and thus will lead to allele frequency differences

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So, I always tell my students, its...

LARGE
RANDOM
NO
NO
NO

(large population, random mating, no mutation, no gene flow, and no natural selection)

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If allele frequency stays the same, but genotype frequencies change.

A. Population is still in Hardy-Weinberg

B. Population is NO LONGER in Hardy-Weinberg

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If allele frequency stays the same, but genotype frequencies change.

B. Population is NO LONGER in Hardy-Weinberg

Hardy-Weinberg equilibrium states that genetic variation (genotypic and allelic frequencies) will remain unchanged over multiple generations.

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Dominant allele frequency...

A. p
B. q
C. p^2
D. q^2

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Dominant allele frequency...

A. p

Hardy-Weinberg equilibrium involves
$p + q = 1$ AND $p^2 + 2pq + q^2 = 1$

where...

p = frequency of dominant allele
q = frequency of recessive allele
p^2 = frequency of homozygous dominant
$2pq$ = frequency of heterozygous
q^2 = frequency of homozygous recessive

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Homozygous recessive...

A. p
B. q
C. p^2
D. q^2

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Homozygous recessive...

D. q^2

Hardy-Weinberg equilibrium involves $p + q = 1$ AND $p^2 + 2pq + q^2 = 1$

where...

p = frequency of dominant allele

q = frequency of recessive allele

p^2 = frequency of homozygous dominant

$2pq$ = frequency of heterozygous

q^2 = frequency of homozygous recessive

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If the q value is 0.4, what is the p value?

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If the q value is 0.4, what is the p value?

0.6

Recall:

$p + q = 1$

So, $p + 0.4 = 1$

$p = 1 - 0.4$

$p = 0.6$

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If $p = 0.8$, what is q^2?

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If $p = 0.8$, what is q^2?

$q^2 = 0.04$

Recall:

$p + q = 1$

So, if $p = 0.8$

then $q = 0.2$

So, $q^2 = (0.2)^2$

and (0.04)

Don't forget your multiplication rules with decimals and forget to move your decimal.

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Note:

The math for these problems could get a little tricky! It's important to remember and understand what all the variable stand for. Students sometimes get the singlets versus the squares/doublets confused.

If you are talking about an allele – you are talking about ONE allele (dominant allele, recessive allele) so it's p and q.

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Note:

If talking about a trait, you are talking about TWO alleles (diploid organisms). So, dominant phenotype or homozygous dominant, etc correspond with the p^2, q^2, and 2pq.

Notice the ONE refers to a single variable while the TWO refers to the variables with a 2 for exponent of leading term.

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Which method do you use to calculate the allele frequency?

If you are given **ALL** of the phenotypes, solve for the alleles by **COUNTING** the alleles.

If you are only given **SOME** of the phenotypes, solve for the alleles by the **EQUATION**.

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What does it mean if the population remains in Hardy Weinberg equilibrium?

A. Population is not evolving
B. Population is genetically diverse
C. Population is undergoing gradual equilibrium
D. Population is undergoing punctuated equilibrium

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What does it mean if the population remains in Hardy Weinberg equilibrium?

A. Population is not evolving

Hardy-Weinberg equilibrium states the conditions that must be met so the genetic frequencies remain the same and the population is not evolving.

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What is allele frequency?

A. The number of different alleles possible in a population

B. The number of individuals with each allele

C. The percent of individuals in the population with a trait

D. The percent of the allele in the population

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What is allele frequency?

D. The percent of the allele in the population

Frequencies refer to percents, so the allele frequency is the percent of the allele in the population. It is calculated as p or q in the Hardy-Weinberg equilibrium formula. It can be calculated as number of alleles divided by the total alleles.

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What variable represents the frequency of the recessive allele?

A. p
B. p^2
C. q
D. q^2

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What variable represents the frequency of the recessive allele?

C. q

Hardy-Weinberg equilibrium involves
$p + q = 1$ AND $p^2 + 2pq + q^2 = 1$

where...
p = frequency of dominant allele
q = frequency of recessive allele
p^2 = frequency of homozygous dominant
$2pq$ = frequency of heterozygous
q^2 = frequency of homozygous recessive

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What is genotype frequency?

A. The number of individuals with each genotype in the population
B. The number of individuals with each phenotype in the population
C. The percent of individuals with each genotype
D. The percent of individuals with each phenotype

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What is genotype frequency?

C. The percent of individuals with each genotype

Frequencies refer to percents, so the genotypic frequency is the percent of the genotype in the population. It is calculated as p^2, $2pq$, or q^2 in the Hardy-Weinberg equilibrium formula. It can be calculated as number of genotype divided by the total individuals.

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What variable is used for frequency of homozygous dominant?

A. p
B. p^2
C. q
D. q^2

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What variable is used for frequency of homozygous dominant?

B. p^2

Hardy-Weinberg equilibrium involves
$p + q = 1$ AND $p^2 + 2pq + q^2 = 1$

where...

p = frequency of dominant allele
q = frequency of recessive allele
p^2 = frequency of homozygous dominant
$2pq$ = frequency of heterozygous
q^2 = frequency of homozygous recessive

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What is the variable for frequency of the homozygous recessive?

A. p
B. p^2
C. q
D. q^2

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What is the variable for frequency of the homozygous recessive?

D. q^2

Hardy-Weinberg equilibrium involves
$p + q = 1$ AND $p^2 + 2pq + q^2 = 1$

where...

p = frequency of dominant allele
q = frequency of recessive allele
p^2 = frequency of homozygous dominant
$2pq$ = frequency of heterozygous
q^2 = frequency of homozygous recessive

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What variable is used for frequency of heterozygous?

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What variable is used for frequency of heterozygous?

2pq

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What is the equation used for Hardy-Weinberg?

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What is the equation used for Hardy-Weinberg?

$$p + q = 1$$

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

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Which variable should you always start with for solving these questions?

A. p
B. p^2
C. q
D. q^2

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Which variable should you always start with for solving these questions?

D. q^2

If you are NOT given all of the genotypes, solving for the q^2 is your first step. There's only one option for the recessive phenotype vs dominant phenotype can be either homozygous dominant or heterozygous.

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If 36% of the population has sickle cell disease. Solve for all values.

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If **36%** of the population has sickle cell disease. Solve for all values.

$$q^2 = 0.36$$

$$q = 0.6$$

$$p = 0.4$$

$$p^2 = 0.16$$

$$2pq = 0.48$$

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If the population has 75 with DD, 50 with Dd, and 25 with dd. Solve all values.

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If the population has 75 with DD, 50 with Dd, and 25 with dd. Solve all values.

$\#D = 2(75)+50 = 200$

$p = 200/300 = 0.67$

$\#d = 2(25) + 50 = 100$

$q = 100/300 = 0.33$

$p^2 = 75/150 = 0.5$

$2pq = 50/150 = 0.33$

$q^2 = 25/150 = 0.17$

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How do you know the population is in equilibrium?

A. $p = q$

B. $p^2 = q^2$

C. $p + p^2 = q + q^2$

D. Frequencies remain the same between each generation

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How do you know the population is in equilibrium?

D. Frequencies remain the same between each generation

As the population is in equilibrium, the allelic and genotypic frequencies remain the same. The conditions for Hardy-Weinberg keeps the frequencies constant.

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Extremely large population attempts to avoid

A. Gene flow
B. Genetic drift
C. Mutations

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Extremely large population attempts to avoid

B. Genetic drift

Genetic drift involves the change of allele frequencies due to random chance.

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