

Hardy-Weinberg Equilibrium

Learning objective 7.5.A Describe the conditions under which allele and genotype frequencies will change in populations.

Name:

Date:

Period:

Use the tool **A Population That Is Not Evolving**. Part 1 uses **One generation**, Parts 2 and 3 use **Break one condition**, and Parts 4 and 5 use **Work the equation**. Hardy-Weinberg is the only model in this unit that describes a population where **nothing is happening**. That is what makes it useful: it tells you the frequencies a population would have if no process were acting on it, so a departure from those frequencies is evidence that one is. Keep two claims separate throughout — the **proportions** ($p^2 + 2pq + q^2 = 1$, about one generation) and the **equilibrium** (allele frequencies not changing, about successive generations).

Part 1 • One round of random mating

Four populations, each deliberately built out of proportion, each given a single generation of random mating and nothing else. Record the heterozygote frequency and the allele frequency **separately**.

Starting population	Aa before	Aa after	p before	p after
All heterozygotes				
No heterozygotes at all				
Two separate populations, just merged				
Already in proportion				

1. Explain what p^2 , $2pq$ and q^2 each represent.

2. Explain why the heterozygote term is doubled and the other two are not.

3. In every row the genotype frequencies changed and the allele frequency did not. Explain why random mating can do the first without doing the second.

Part 2 · Break one condition at a time

Go to **Break one condition**. Every run starts at $p = 0.6$ and lasts **40** generations. The first button is the control. Each of the others breaks exactly one condition and changes nothing else.

Run	p at end	Aa observed	Aa predicted by $2pq$	Still in proportion?
All five conditions met				
Population is small				
Selection acts				
Mutation occurs				
Migration occurs				
Mating is non-random				

4. State the five conditions required for Hardy-Weinberg equilibrium.

5. Three of your rows moved the allele frequency and one moved the genotype frequencies instead. Explain why those are two different kinds of failure.

Part 3 · Reading a population's history from its numbers

Open the panels beneath the graph. Each scenario below describes a real measurement; use your Part 2 table to decide which condition is broken, and say which ones your evidence rules out.

What was measured	Which condition is broken?	What does the evidence rule out?
Allele frequencies steady for 20 years; far fewer heterozygotes than $2pq$ predicts		
Genotypes exactly in proportion every generation; allele frequency rose steadily		
A population of 25; allele frequency jumped around with no consistent direction		
Genotypes in proportion; allele frequency moved toward a neighboring population's		

6. Explain how a population can be in Hardy-Weinberg proportions in every generation and still not be at equilibrium.

7. A single small population's allele frequency changed a great deal over 40 generations. Explain why this alone is not evidence of selection, and what would be.

Part 4 · Working the equation

Go to **Work the equation**. Every one of these starts from the recessive phenotype, because it is the only phenotype whose genotype can be read directly. Fill the table from the four buttons.

Scenario	q^2	q	p	p^2	$2pq$	Carriers per affected
Cystic fibrosis						
Attached earlobes						
Bitter tasting						
White moths						

8. Explain why every Hardy-Weinberg calculation starts from the recessive phenotype rather than the dominant one.

9. In a sample of 2,400 people, 1,482 can taste bitterness (the dominant phenotype). Show how to find the number expected to be heterozygous.

Part 5 · Why a rare allele hides

Look at the last column of your Part 4 table, and at the panel headed **Why a rare recessive disorder has so many carriers**. Cystic fibrosis affects about 1 in 377 people in the population studied.

Allele frequency q	Affected, q^2	Carriers, $2pq$	Carriers per affected
0.50			
0.20			
0.10			
0.05			
0.01			

10. Explain why the number of carriers of a rare recessive allele is so much larger than the number of affected individuals.

11. Connect this to Topic 7.2: explain why selection against a recessive disorder is so slow at removing the allele.

12. Explain why a model whose conditions no real population meets is still worth having.

What the model simplifies

One gene with two alleles, complete dominance, and no effect on sex or age of action. Real loci have more alleles, incomplete dominance, and effects that depend on when in life they act — a disorder appearing after reproduction is nearly invisible to selection, which is why the Hardy-Weinberg prediction can hold for it despite an obvious fitness cost.

The control population is 20,000 individuals, which is large but not infinite; the idealised model assumes an infinite one. The control therefore still drifts a little, and that residual movement of 0.0150 is shown rather than hidden. Every broken condition that moves allele frequencies was confirmed to move them by more than twice as much.

Each condition is broken on its own with everything else held at the ideal. Real populations break several at once and the processes interact — selection in a small population, for instance, is far less reliable than selection in a large one.

Non-random mating is modeled as a preference for one's own genotype. Real assortative mating acts on phenotypes, so for a recessive trait the heterozygotes group with one homozygote class; the numbers change and the conclusion does not.

The four worked scenarios use published phenotype frequencies and then assume Hardy-Weinberg proportions, which is what the exam asks. Whether any of those populations really is at equilibrium is a separate question, and for cystic fibrosis it is not — the allele is under selection, which is the subject of Part 5.