AP BIOLOGY · UNIT 7 · TOPIC 7.5

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 get a single generation of random mating and nothing else. Three are built out of Hardy–Weinberg proportions; the fourth is already in proportion. Click each population in turn and record the heterozygote frequency and the allele frequency, before and after.

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

2. Explain why the heterozygote term, 2pq, is doubled but p^2 and q^2 are not.

3. In the first three rows of the Part 1 table, one generation of random mating changed the genotype frequencies but left the allele frequency almost unchanged. Explain how random mating can change genotype frequencies without changing allele frequencies.

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, All five conditions met, 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. Identify the five conditions required for Hardy–Weinberg equilibrium.

5. In the Part 2 table, three of the broken conditions changed the allele frequency, and one changed the genotype frequencies instead.
(a) Identify the broken condition that changed the genotype frequencies but not the allele frequency.

(b) Explain why breaking this condition affects a population differently from breaking the other three.

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

Open the panels beneath the graph. Each row below describes a measurement made on a population. Use the Part 2 table to identify the condition that is not met, and record the processes that the 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. Using the Selection acts row of the Part 2 table, 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.
(a) Explain why this change alone is not evidence of natural selection.

(b) Describe data that would show that natural selection caused the change.

Part 4 · Working the equation

Go to **Work the equation**. Every one of these starts from the recessive phenotype. Click each of the four scenario buttons and fill in the table.

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

8. Explain why Hardy–Weinberg calculations begin with the frequency of the recessive phenotype rather than the frequency of the dominant phenotype.

9. In a sample of 2,400 people, 1,482 can taste a bitter compound, which is the dominant phenotype. Assuming Hardy–Weinberg equilibrium, calculate the number of people in the sample expected to be heterozygous. Show your work.

Part 5 · Why a rare allele hides

Read the panel headed Why a rare recessive disorder has so many carriers. Then, for each allele frequency q in the table, calculate the frequency of affected individuals (q^2), the frequency of carriers ($2pq$, with $p = 1 - q$), and the number of carriers per affected individual ($2pq \div q^2$). The last column of the Part 4 table gives the same ratio for the four scenarios. 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. Using the Part 5 table, explain why the number of carriers of a rare recessive allele is much larger than the number of affected individuals.

11. Topic 7.2 showed that selection against a harmful recessive allele slows as the allele becomes rarer. Using the Part 5 table, explain why selection removes a rare recessive allele so slowly.

12. No real population meets all five Hardy–Weinberg conditions. Explain why the Hardy–Weinberg model is still useful for studying populations.

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 idealized 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.