AP BIOLOGY · UNIT 7 · TOPIC 7.11

Variations in Populations

Learning objective 7.11.A Explain how the genetic diversity of a species or population affects its ability to withstand environmental pressures.

Name: Date: Period:

Use the tool **The Insurance You Cannot Buy Later**. Parts 1 and 2 use **When it matters**, Part 3 uses **One field, one pathogen**, and Parts 4 and 5 use **Spend it once**. Genetic diversity is the standard example of something whose value cannot be measured while things are going well. It costs a population nothing and buys it nothing while the environment stays the same; it is the only thing that lets a population survive when the environment moves; and **a population cannot rebuild it on its own after the move**, because the process that builds it is hundreds of times slower than the one that destroys it. That is why the tool's title calls it insurance.

Part 1 · Two worlds, five populations

Five populations differ in exactly one thing: how much **heritable variation** they carry for a trait (V). Click A stable environment and each value of V in turn. Then click An environment that keeps changing, in which the optimum moves by **0.05** every generation, and click each value of V again. Record the readouts for both environments. Fill in the stable column first, and look at it before you fill in anything else.

Heritable variation	Stable: final population	Moving: lag at the end	Moving: final population
0.05			
0.20			
0.50			
1.00			
2.00			

1. Explain how the genetic diversity of a population affects its ability to withstand an environmental pressure.

2. In the stable environment, the population with the least heritable variation reached the same final population as the population with the most.
(a) Explain why the two populations did equally well in the stable environment.

(b) Describe what this result indicates about the value of genetic diversity.

Part 2 · A prediction that could have failed

In the panel headed “All five, in both worlds,” the last column of the table is the **fastest sustained environmental change** a population with that much variation can survive. It was not measured from the simulation. It was calculated separately from the model’s equations and then used to predict which populations would survive. Copy it into the table, and check the prediction against the Part 1 table. The environment in this tool moves at **0.05** per generation.

Heritable variation	Fastest survivable change	Faster than 0.05?	Did it survive?
0.05			
0.20			
0.50			
1.00			
2.00			

3. Explain why a population with low genetic diversity is at greater risk when the environment changes.

4. A population is large and stable.
(a) Explain why the size of the population does not indicate whether it has enough genetic diversity to survive an environmental change.

(b) Describe how researchers could determine whether the population has enough genetic diversity.

Part 3 · One field, one pathogen

Go to **One field, one pathogen**. A field of **100,000** plants is divided equally among a number of resistance genotypes. A new pathogen strain arrives that overcomes exactly one of them. Click each number of genotypes and record the readouts. In the last column, three strains arrive, each overcoming one genotype chosen at random. For question 6, open “The same principle, pointed at us” at the bottom of the tab.

Resistance genotypes	Plants lost to one strain	Share of the crop lost	Lost after three strains
1			
2			
4			
8			
16			
64			

5. Explain why a crop grown as a single genotype can be destroyed entirely by one pathogen strain, while a field with several resistance genotypes is not.

6. Genetic diversity is usually described as good for a population. Explain how the genetic diversity of a large population of bacteria makes an infection harder to cure.

Part 4 · What a crash costs

Go to **Spend it once**. The tab shows three real populations that went through a bottleneck. **Heterozygosity** is the standard measure of the genetic diversity a population has left: the fraction of loci at which a typical individual carries two different alleles. The tool gives the heterozygosity each population kept as a fraction of what it had before the bottleneck. The tab opens with the California condor selected, so make the prediction before you read any readouts.

Prediction: the population that lost the most heterozygosity was _____.

Then click each population and record its readouts.

Population	Founders	Generations spent small	Heterozygosity kept	Lost
Black-footed ferret				
California condor				
Greater prairie chicken (Illinois)				

7. (a) Describe what a population bottleneck is.

(b) Explain why a bottleneck reduces the genetic diversity of a population.

8. One of the three populations in the Part 4 table started with more founders than the other two but kept less heterozygosity than either.
(a) Identify the population.

(b) Explain how this population lost more heterozygosity than the other two.

Part 5 · Buying it back

The second panel of Spend it once, headed “The asymmetry,” shows what happens after a population recovers in numbers. Copy its table, and notice the direction in which the third column changes: it is the opposite of what most people expect. The second column is the heterozygosity itself, between 0 and 1, so it is not on the same scale as the Part 4 column. For question 11, open “The one fast remedy, and what it requires” below the table.

If the population recovers to	Diversity it can eventually hold	Generations to get there by mutation	Years, at a condor generation
100			
1,000			
5,000			

9. A population recovers from a bottleneck and returns to its former numbers. Explain why its genetic diversity does not return with them.

10. In the Part 5 table, a population that recovers to a larger size takes longer, not less time, to rebuild its genetic diversity by mutation. Explain why.

11. (a) Describe the one process that can restore the genetic diversity of a population quickly.

(b) Identify what this process requires.

What the model simplifies

Part 1 treats a single quantitative trait under selection around a moving optimum, with the population's mean responding in proportion to its heritable variance. This is a standard formulation and it was chosen because it has a known analytic answer for the fastest environmental change a population can survive, so the simulation could be checked against a prediction rather than only against itself, which is what Part 2 asks students to do. Real populations face many pressures at once, on many traits.

The variance is held constant through each run. In reality directional selection erodes the variation it feeds on, so a population tracking a moving optimum gets worse at it over time unless mutation and recombination replenish the variance. The model therefore flatters the low-variance populations rather than exaggerating their problem.

Part 3 assumes the resistance genotypes are equally common and that a new strain defeats exactly one of them. Real resistance is often partial, often controlled by several genes at once, and a strain that defeats one genotype frequently has some effect on others. The direction of the result is robust to all of that; the exact fractions are not.

The heterozygosity calculation uses the standard expectation for a population of a given effective size, which is not the same as its census size: effective size is usually a good deal smaller, because not every individual reproduces and not equally. The founder numbers used are the historical counts, so the real losses were probably somewhat worse than the figures shown.

Recovery is calculated from drift and mutation together, at a mutation rate generous enough to favor recovery. It ignores inbreeding depression, which acts on a much shorter timescale than mutation and makes the practical situation worse than the genetic arithmetic alone suggests.

The 2025 course framework lists corn rust among its illustrative examples for this topic. It is described here by its mechanism (a single resistance gene deployed across a very large area of near-identical plants, defeated by a strain that overcomes it) rather than attached to a specific epidemic with a specific figure, because the mechanism is what the objective asks for and is what generalizes.