

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 put; it is the only thing that lets a population survive when the environment moves; and **it cannot be acquired after the move**, because the process that builds it is thousands of times slower than the one that destroys it. That is what the word insurance in the title is doing.

Part 1 • Two worlds, five populations

Five populations differ in exactly one thing: how much **heritable variation** they carry for a trait. Run each of them in a stable environment, then in one where the optimum moves by **0.05** every generation. Record what happens in both. Fill the stable column in 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. Look at your stable column. Explain why the population with the least variation did exactly as well as the one with the most, and what that tells you about what genetic diversity actually is.

Part 2 · A prediction that could have failed

The last column of the tool's table is the **fastest sustained environmental change** a population with that much variation can survive. It was not measured from the simulation — it was worked out separately from the model's equations and then used to predict which populations would live. Copy it in, and check the prediction yourself against your Part 1 results. 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 doing well. Explain why you cannot tell from that whether it has enough genetic diversity, and what you would have to do to find out.

Part 3 · One field, one pathogen

Go to **One field, one pathogen**. A field of **100,000** plants is divided among some number of resistance genotypes, and a new pathogen strain arrives that gets past exactly one of them. Record what each field loses.

Resistance genotypes	Plants lost to one strain	Share of the crop	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 mixed field is not.

6. Genetic diversity is usually described as good for a population. Explain how the same property makes a bacterial infection harder to cure.

Part 4 · What a crash costs

Go to **Spend it once**. Three real populations that went through a bottleneck. **Heterozygosity** is the standard measure of how much diversity a population has left — the fraction of loci at which a typical individual carries two different alleles. Record what each crash cost. Before you fill in the last column, predict which of the three you expect to come off worst.

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

7. Explain what a population bottleneck is and why it reduces genetic diversity.

8. One of these three started with more founders than the other two and came out with less diversity than either. Identify it and explain how that happened.

Part 5 · Buying it back

The second panel of that tab asks what happens after the population recovers in numbers. Fill it in, and pay attention to the direction the third column runs — it is the opposite of what most people expect.

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 table above, a population that recovers to a larger size takes longer to rebuild its diversity, not shorter. Explain why.

11. Describe the one thing that can restore a population's genetic diversity quickly, and state what it 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 mutation alone, at a 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 generalises.