

Disruptions in Ecosystems

Learning objective 8.7.A Explain the interaction between the environment and random or preexisting variations in populations, 8.7.B explain how invasive species affect ecosystem dynamics, 8.7.C describe human activities that lead to changes in ecosystem structure and dynamics, and 8.7.D explain how geological and meteorological activity leads to changes in ecosystem structure and dynamics.

Name:

Date:

Period:

Use the tool **What Changes, and How Fast**. Parts 1 and 2 use **Already there**, Part 3 uses **Nobody ordered it**, Part 4 uses **Free of what ate it**, Parts 5 and 6 use **What we put in**, and Part 7 uses **How fast**. This is the last topic in the course and it collects the argument the whole of it has been making: an environment changes, and the variation that was already there decides who is left. Four of these parts turn on a detail of **order or timing** rather than on a definition, so read the step numbers as carefully as the values.

Part 1 · Four populations, one destination

Three genotypes: $w(AA) = 1 - s$, $w(Aa) = 1$, $w(aa) = 1 - t$, with $s = 0.2$ and $t = 0.8$. The heterozygote is the fittest genotype. Predict where each population will end up before you record anything, then run all four.

Starting frequency, p	Your prediction	After 200 generations	t / (s + t)
0.02			
0.25			
0.60			
0.95			

1. Define an adaptation, and explain why the phrase “in a particular environment” cannot be dropped from that definition.

2. Define heterozygote advantage.

3. All four populations finished at the same frequency from very different starting points. Explain what that tells you about where the equilibrium comes from.

Part 2 · Why the costly allele is not removed

At equilibrium the allele that is costly when doubled up sits at **20%**, so **4.0%** of every generation is born homozygous recessive and pays the full price. Selection is not failing. Work out why not, then compare the run against one with a plain directional advantage.

Run	Value at generation 200	Still changing?	Where it is heading
Heterozygote advantage			
Plain directional selection			
Balance, then the pressure on AA removed			

4. Explain why heterozygote advantage keeps a costly allele in a population instead of removing it.

5. The directional run has not reached fixation after 200 generations and does not pass 0.99 until generation 352. Explain why removing the last few percent of a disfavored recessive allele is so slow.

6. Explain what happens to the balance when the environment stops penalizing one homozygote, and what that tells you about who the polymorphism belongs to.

Part 3 · Two hypotheses, one measurement

Many identical cultures are grown from single cells, then each is exposed to something that kills all but the resistant. Under one hypothesis the resistance appears **because of** the exposure; under the other it was already there. Both are set to produce the same expected number of survivors — **4.61** per culture — so no average can separate them. Record everything else.

Hypothesis	Expected	Observed mean	Variance ÷ mean	Largest culture	Cultures with none
Mutations arise on demand	4.61				
Mutations arise beforehand	4.61				

7. State what it means to say that mutations are not directed by specific environmental pressures.

8. Both hypotheses predict the same number of survivors on average. Using your table, describe a measurement that does distinguish them, and explain why it works.

9. Your last column is the simplest version of the test and needs no statistics at all. Explain what it shows and why each hypothesis produces the number it does.

Part 4 · An invader that is worse at everything

The introduced species grows more slowly than the native (**0.24** against **0.3**) and tolerates less crowding (**800** against **1,000**). Run it twice. The only difference between the runs is whether the native still has its own predator.

Scenario	Your prediction	Native ends at	Invader ends at	Who wins
Native's predator present				
Nothing eats either species				

10. Explain how the introduction of an invasive species can allow it to take over an ecosystem.

11. The invader in your table is the inferior organism by every measure that does not involve a predator, and it still won one of the runs. Explain what that tells you about what “invasive” means.

Part 5 · Biomagnification

A consumer must eat about ten units of prey to build one unit of itself, so only **10%** of the energy passes up a level. Fill in both middle columns, then multiply them together in the last one and look at what you get.

Level	Share of the original energy	Toxin, ppm	× the water	Share × factor
Producers				
Primary consumers				
Secondary consumers				
Tertiary consumers				
Top consumers				

12. Explain biomagnification, and why the last column of your table comes out the way it does.

13. Explain why this happens to some substances and not to energy, given that both pass through the same food chain.

14. The water in this example holds 0.05 ppm, which would be called clean. Explain why the organism most at risk is the one furthest from the contamination.

Part 6 · Eutrophication

Nutrients arrive for the first twenty steps only, then stop. Record the **step numbers** as carefully as the values — the order in which things happen is the whole point of this part.

Nutrient input	Algae peak at step	Oxygen lowest at step	Lowest oxygen	Fish left
2.0				
8.0				
20.0				
40.0				
60.0				

15. Explain what actually kills the fish in a eutrophicated lake.

16. Your two step-number columns are not the same. Explain why the oxygen minimum comes after the algal peak rather than during it, and what the algae were doing to the oxygen while they were alive.

17. At the lowest nutrient input every fish survived. Explain why a small amount of nutrient enrichment is absorbed, and what that means for how the problem should be described.

Part 7 · How fast

Every disruption the CED names for this topic, ordered by how long it takes. Fill in the order of magnitude — the power of ten — rather than a precise figure, because that is all these numbers support.

Disruption	CED objective	Kind	Order of magnitude, years
Meteor impact on dinosaurs			
El Nino			
Logging			
Potato blight			
Zebra mussels			
Dutch elm disease			
Kudzu			
Urbanization			
Monocropping			
Global climate change			
Continental drift			

18. Your list spans 8 orders of magnitude. Explain why the speed of an environmental change matters as much as its size.

19. State the one mechanism that all nineteen answers in this handout have in common, in a single sentence.

What the model simplifies

The selection recursion assumes an infinite population, random mating, discrete non-overlapping generations, no mutation, no migration and constant fitnesses. Every one of those is false of real populations, and the first matters most: in a small population an allele at 20% can be lost to drift regardless of what selection would prefer.

The heterozygote-advantage example is the shape of the sickle-cell case rather than a model of it. The real system involves several alleles, several malaria parasites, and a fitness landscape that shifts with the local burden of infection.

The mutation experiment uses a deterministic generator seeded to a fixed value, so the numbers are identical on every load and can be verified. Real cultures vary; the qualitative pattern — a few jackpots, many empties, variance far above the mean — is the robust part, and it is what Luria and Delbrück found in 1943.

The two hypotheses are deliberately given the same expected number of resistant cells, so that no average can separate them in principle. Their sample means still differ substantially, which is not a flaw in the simulation: the undirected distribution's weight sits in rare jackpots, so an average of 200 cultures lands well below its own expectation. An average is a poor summary of a distribution shaped like that, which is exactly why the original experiment compared variances.

The invasion model gives the native a predator and the invader none, and holds everything else fixed. Real invasions usually involve several advantages at once — escape from predators, escape from pathogens, disturbance that favors fast colonizers — and what is isolated here is that the first of those is sufficient on its own, not that it is the only one operating.

Biomagnification uses a single transfer efficiency of 10% at every step. Real efficiencies range from about 2% to 40% and vary by ecosystem, and real toxins are excreted at some rate rather than not at all. The structural claim is what is asserted: the share of the original energy multiplied by the concentration factor is exactly 1 at every level.

The eutrophication model is a compartment sketch, not a limnological simulation. An earlier version fed nutrients in continuously and the oxygen minimum then arrived at the same moment as the algal peak — which would have hidden the one thing the section exists to show. The nutrients now arrive as a pulse, as a runoff event actually does, and the oxygen minimum falls 47 steps after the bloom.

The durations in the last part are cited magnitudes drawn from the literature rather than outputs of a model, and they are rounded hard to the nearest order of magnitude. What is computed is the comparison between them.

One oddity is the CED's, not this tool's: logging, urbanization and monocropping are listed in the 2025 Course Framework under 8.7.D, the objective about geological and meteorological activity, rather than under 8.7.C, the objective about human activities. That is where the CED puts them, so that is where they appear here, labeled as human. It is worth telling students, because an exam question could reasonably reference either objective.