

Speciation

Learning objective 7.10.A Describe the conditions under which new species may arise, 7.10.B describe the rate of evolution and speciation under different ecological conditions, and 7.10.C explain the processes and mechanisms that drive speciation.

Name:Date:Period:

Use the tool **When One Becomes Two**. Part 1 uses **Stop the gene flow**, Parts 2 and 3 use **Seven ways to stop it**, and Parts 4 and 5 use **Where, and how fast**. One sentence holds this whole topic together: **speciation is gene flow stopping**. Reproductive isolation is what stops it. Allopatry and sympatry are two circumstances in which it stops. Gradualism and punctuated equilibrium are two tempos at which the divergence that follows can happen. Every part of this handout is a version of that one sentence, so if a part stops making sense, go back to it.

Part 1 · What gene flow decides

Two populations of **300** start identical at **40** loci. Each is pushed by its own local selection, each drifts, and a fraction of each moves into the other every generation. **That fraction is the only thing that differs between the four runs**. Step through them in the tool and record what you find. Genetic distance is the average difference in allele frequency across the loci: 0 means identical, 1 means completely different.

Migration each way	Individuals moving per generation	Genetic distance after 300 generations	Generations to reach 0.25
0%			
0.1%			
1%			
5%			

1. Describe the conditions under which a new species may arise.

2. Every row of that table has the same selection, the same drift and the same starting point. Explain why the fourth row does not diverge.

Part 2 · Seven barriers, one after another

Go to **Seven ways to stop it**. Switch the barriers on one at a time, in order, and record what happens. **Reaching it** is the fraction of the original pairings that gets as far as this barrier; **removes here** is the fraction this barrier takes out. Notice that not one of the seven is complete on its own.

Barrier	Pre- or post-zygotic?	Blocks	Reaching it	Removes here	Isolation so far
Habitat isolation					
Temporal isolation					
Behavioral isolation					
Mechanical isolation					
Gametic isolation					
Reduced hybrid viability					
Reduced hybrid fertility					

3. Distinguish between pre-zygotic and post-zygotic barriers, and give two examples of each.

4. None of these barriers blocks more than 90% on its own, yet together they block 99.90%. Explain how, using the numbers in your table.

Part 3 · Two questions that sound like one

Look at your completed table. **Reduced hybrid fertility** blocks **90%** — the strongest barrier of the seven — and removes **0.0091** of the original pairings. **Habitat isolation** blocks only **60%** and removes **0.6000**, **66 times as much**. That is the first result, and it is real. Now use the second and third panels of that tab to test what it means — because the obvious conclusion from it is wrong.

Put the barriers in this order	Which barrier is first	How much the first one removes	Total isolation at the end
As listed			
Reversed			
Strongest first			
Weakest first			

5. Explain why habitat isolation removes so many more pairings than reduced hybrid fertility, even though it is the weaker barrier.

6. Look at the last column of the table you just filled in. Explain what it shows and why reordering the barriers has that effect on it.

7. If exactly one of the seven barriers stopped working, which one would cost this population the most isolation? Explain why it is not the same barrier as your answer to question 5.

Part 4 · Where the gene flow stops

Go to **Where, and how fast** and use the second panel. Allopatric and sympatric are not two different biological processes — they are two different **circumstances** in which the same process, gene flow stopping, can happen. The words describe geography and nothing else.

	Allopatric	Sympatric
Geographic overlap		
What stops gene flow		
Example		
Which is commoner, and why		

8. Distinguish between allopatric and sympatric speciation, and state what stops gene flow in each.

9. Sympatric speciation is the rarer of the two. Explain why, in terms of gene flow.

Part 5 · How fast, and in which direction

Use the first panel of that tab. Both lineages start at 0 and finish at **10**. Gradualism and punctuated equilibrium are claims about the **shape** of change over time, not about how much of it there is — so the endpoints cannot tell them apart. Fill in the table, then answer the questions.

	Gradualism	Punctuated equilibrium
Total change over the run		
Fraction of the time spent in stasis		
Fastest single interval		
What the fossil record would show		

10. Distinguish between gradualism and punctuated equilibrium, and explain what kind of evidence would be needed to tell them apart.

11. Explain the difference between divergent and convergent evolution, and state what conditions make speciation especially rapid.

What the model simplifies

The forty loci in Part 1 are independent and each is under selection of the same strength, in opposite directions in the two populations. Real genomes are nothing like this: loci are linked, most are under no selection at all, and the ones that matter for reproductive isolation are a small and unevenly distributed

minority. What survives the simplification is the comparison between the rows, which is the only thing Part 1 is used for.

The migration rates were chosen to straddle the selection coefficient, because a locus stays differentiated while selection is stronger than migration and is homogenized once migration is stronger. The transition is a slope, not a cliff: the third row has migration below the selection coefficient and still loses most of its divergence. Read the table as four points on a curve, not as two categories.

The seven barrier strengths are illustrative figures, not measurements of any real species pair. They were chosen so that no single barrier is close to complete, which is the condition under which the multiplicative result is worth showing. Real barrier strengths are measured in the field and vary enormously; the arithmetic that combines them is what is general.

The two tempo curves in Part 5 are drawn, not simulated. They are a diagram of two hypotheses about the shape of change, built to reach the same endpoint so that the endpoint cannot be what distinguishes them. Gradualism and punctuated equilibrium are also not exclusive alternatives in the way an exam question implies — the same lineage can do both at different times, and the modern position is closer to “how often each” than to “which one”.

Speciation is treated throughout as a two-population event with a clean before and after. It is usually neither: it is a process with a long ambiguous middle, in which populations exchange some genes and not others, and there is often no moment at which one could say it had finished. The biological species concept is a definition that works well at the ends and badly in the middle, which is where most real cases sit.