AP BIOLOGY · UNIT 7 · TOPIC 7.10

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.** Click each migration rate (0%, 0.1%, 1% and 5% each way) and record the four readouts. 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 the Part 1 table has the same selection, the same drift and the same starting point. Explain why the populations in the 5% row do not diverge.

Part 2 · Seven barriers, one after another

Go to **Seven ways to stop it**. The table in the panel headed “All seven, in the order they act” gives each barrier’s type, the percentage it blocks, the fraction it removes and the isolation so far. Copy those values. **Reaching it** is the fraction of the original pairings that gets as far as a barrier: 1.0000 for the first barrier, and 1 minus the isolation so far of the barrier above it for each later one; **removes here** is the fraction that the barrier takes out. No single barrier 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. (a) Describe the difference between pre-zygotic and post-zygotic barriers.

(b) Identify two pre-zygotic barriers.

(c) Identify two post-zygotic barriers.

4. No barrier blocks more than 90% on its own, yet together the seven barriers block 99.90% of pairings. Using the numbers in the Part 2 table, explain how the barriers combine to produce this total.

Part 3 · Two questions that sound like one

Look at the completed Part 2 table. **Reduced hybrid fertility** blocks **90%**, the most of any of the seven barriers, and removes **0.0091** of the original pairings. **Habitat isolation** blocks only **60%** and removes **0.6000**, **66 times as much**. That result is real, but the obvious conclusion from it is wrong. Scroll down to the panel headed “And the correction to it, which matters more,” and copy its first table, which runs the same seven barriers in four different orders. For question 7, use the table headed “What each barrier is actually worth” below it.

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. Habitat isolation blocks a smaller percentage of pairings than reduced hybrid fertility does. Explain why habitat isolation removes many more of the original pairings.

6. (a) Using the Part 3 table, describe the effect of changing the order of the barriers on the total isolation.

(b) Explain why the order of the barriers has this effect on the total isolation.

7. Suppose that exactly one of the seven barriers stopped working.
(a) Identify the barrier whose loss would decrease the total isolation the most.

(b) Habitat isolation removes more of the original pairings than any other barrier. Explain why losing habitat isolation would decrease the total isolation less than losing the barrier identified in part (a).

Part 4 · Where the gene flow stops

Go to **Where, and how fast** and use the second panel, Where the gene flow stops. 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 more common, and why		

8. (a) Describe the difference between allopatric and sympatric speciation.

(b) Describe what stops gene flow in each type of speciation.

9. Sympatric speciation is less common than allopatric speciation. Explain why, in terms of gene flow.

Part 5 · How fast, and in which direction

Use the first panel of the same tab, headed “Two tempos, one endpoint.” 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 change there is, so the endpoints cannot tell them apart. Click Gradualism only and Punctuated equilibrium only to see each curve, and read the four readouts. The gradualism column has no readout for the second and third rows: a steady curve spends 0% of its time in stasis, and its fastest interval compared with itself is 1×. Fill in the last row from the shape of each curve.

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

10. (a) Describe the difference between gradualism and punctuated equilibrium.

(b) Explain why the total change over the run cannot distinguish gradualism from punctuated equilibrium.

(c) Identify the kind of evidence that could distinguish them.

11. In the tool, the panel headed “Apart, and together again” compares divergent and convergent evolution.
(a) Describe the difference between divergent evolution and convergent evolution.

(b) Describe the conditions that 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.