

Signal Transduction Pathways

Learning objective 4.3.A Explain how signal transduction pathways amplify cellular responses.

Name: _____

Date: _____

Period: _____

Use the tool **One Signal, Many Copies**. Parts 1 and 2 use **The cascade**, Part 3 uses **What a phosphate does** and Part 4 uses **Break it two ways**. This is the one topic in the unit with real arithmetic in it, so show your working every time you are asked for a number.

Part 1 · Count the cascade

Set the sliders to each combination below and record the number of molecules activated at the end. Write the calculation in the third column, not just the answer.

Each step activates	Steps	Calculation	Molecules at the end
10	2		
10	4		
10	6		
20	4		
100	4		

1. Write a general equation for the number of molecules activated at the end of a cascade.

2. Look at the top two rows of the diagram. Explain why nothing is amplified at the receptor.

Part 2 · Which slider matters more?

Reset the tool, then press **Double what each step activates** and record the result. Reset again, press **Add two steps instead**, and record that. Predict which will be larger before you press anything.

Change	Each step activates	Steps	Molecules at the end	How many times the starting value
Starting point	10	4		1×
Double the gain				
Add two steps				

3. State which change produced the bigger response, and explain why in terms of where each number sits in the calculation.

4. Explain why amplification is useful to a cell, given that hormones circulate at very low concentrations.

Part 3 · What a phosphate does

Switch to **What a phosphate does** and step through the four stages, recording all four readouts each time.

Step	Phosphate attached?	Protein active?	Protein molecules	Back where it started?
Inactive protein				
A kinase adds a phosphate				
The active protein does its job				
A phosphatase removes the phosphate				

5. One column is the same on all four rows. Name it, and explain what its being constant tells you about how a cell amplifies a signal.

6. Describe what a kinase does to a protein, and explain how that changes the protein's activity.

7. Explain why a cell also needs phosphatases.

Part 4 · Two ways to break a pathway

Switch to **Break it two ways**. For each of the three cells, record the response with the signal present and with it absent.

Cell	Response with the signal	Response with no signal	Behaving correctly?
Working normally			
A relay enzyme cannot be activated			
A relay enzyme is stuck in its active shape			

8. Two of these cells are faulty in opposite directions. Describe each fault and its effect.

9. A patient produces a normal amount of a hormone and their cells do not respond to it. Explain why giving them more of the hormone might not help.

10. A mutation locks a relay protein permanently in its active form. Predict what the cell does, and explain how this could contribute to a tumour.

What the model simplifies

Every step is given the same gain. In a real cascade the gain differs from step to step, and some steps have a gain close to one and exist to regulate rather than to amplify.

The horizontal axis of the cascade diagram is logarithmic, because a linear axis cannot show one molecule and a hundred million on the same picture. Each equal step along it is a ten-fold increase, so the bars are shorter than the numbers feel.

The course framework does not require the individual enzymes or intermediates of any named pathway, so this tool counts molecules and tests dependencies rather than naming them. Phosphorylation is the mechanism the framework does expect you to be able to describe.

Activation is drawn as instantaneous and complete. Real cascades take seconds, do not activate every available molecule, and are being switched off by phosphatases the whole time they are switching on — so the final number is a ceiling rather than a measurement.