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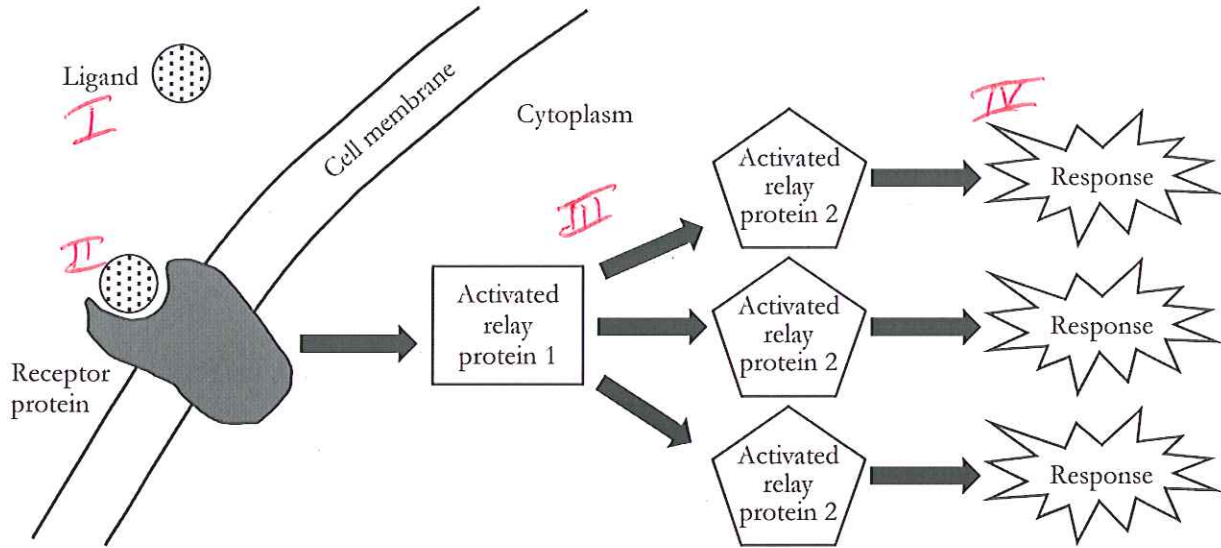
# Signal Transduction Pathways

What happens inside of a cell when a signal has been received?

## Why?

When cells release signal molecules (ligands) to send a message, and the message is received, a whole host of events take place inside the cell. The ultimate goal is a response—a gene is turned on, a protein is manufactured, an enzyme is activated, the cell divides or dies, etc. There are many responses that could occur, but the pathways to those responses are very similar.

## Model 1 – Basic Signal Transduction Pathway



1. According to Model 1, does the signal transduction pathway occur inside or outside of a cell?

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2. Compare the shape of the ligand in Model 1 to the shape of the receptor protein.

They fit together exactly



3. The four steps in the signal transduction pathway are listed below. Label the diagram above with the Roman numerals to indicate where on the diagram each step is taking place.

- I. Signaling
- II. Reception
- III. Transduction
- IV. Response

4. Based on the diagram in Model 1 and your labels, propose a definition for “transduction” in the context of the signal transduction pathway.

*A “translation” of the signal into the response*

5. Amplification often occurs during the transduction step in the signal transduction pathway.  
a. Define “amplification” as it is used in everyday language.

*Making something louder or more powerful.*

- b. Explain how the signal in Model 1 was amplified.

*One ligand leads to a threefold response.*

6. List several possible responses that could occur due to a signal being received by a cell. (*Hint:* There are several listed in the *Why?* box.)

*- growth*                      *- enzyme activation*  
*- death*  
*- gene activation*  
*- protein manufacture*

7. Once the response is achieved in a cell, what would need to occur to stop the response?

*The relay proteins would need to be deactivated  
(at base, the ligand would need to decouple from the  
receptor).*



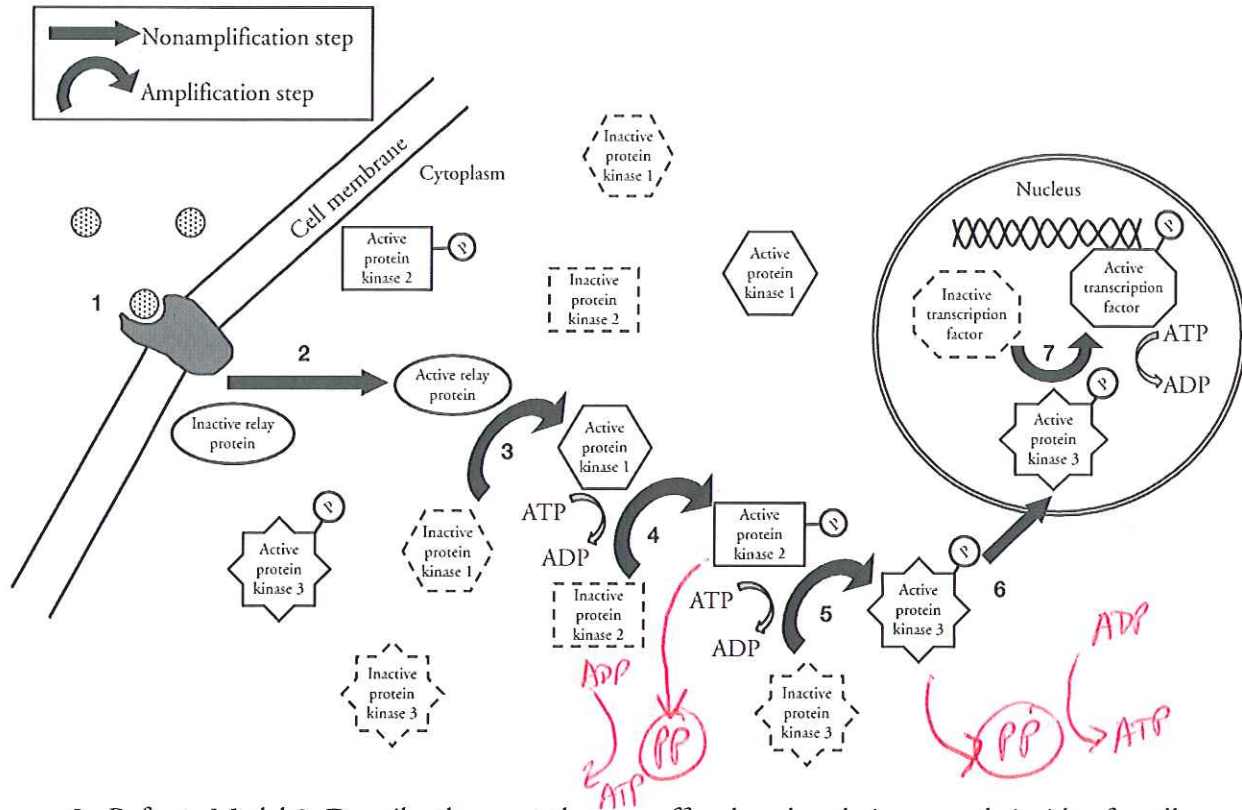
## Read This!

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Signal transduction pathways are as varied as the species on Earth, but each of them follow the same basic steps. Reception may occur by the ligand attaching to a receptor protein or the ligand may travel through the cell membrane by diffusion. Transduction may occur by one protein or by several proteins activating each other in a cascade. Keep this in mind as you continue working through this activity.

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## Model 2 – Phosphorylation Cascade



8. Refer to Model 2. Describe the event that sets off a phosphorylation cascade inside of a cell.

*The ligand causes a receptor protein to activate a relay protein.*



9. **Phosphorylation** is a process that adds a phosphate group onto a protein to “activate” it—that is, to change its shape enough that it can function properly.

a. Which step(s) in the phosphorylation cascade illustrated in Model 2 include phosphorylation?

*4, 5, 7*

b. Where do the phosphate groups come from that are added to the proteins during phosphorylation?

*ATP*

10. According to Model 2, what class of enzymes performs phosphorylation?

*Protein kinases*



11. Identify the steps in Model 2 that represent reception, transduction, and response for the phosphorylation pathway.

Reception

*①*

Transduction

*②-6*

Response

*⑦*

12. What is the cell's response to the signal received in Model 2?

*A transcription factor activates (DNA transcription of a gene begins)*

13. In Model 2, steps 3, 4, and 5 are shown as amplification steps. Describe what that means in terms of this signal transduction pathway example.

*more molecules than the original ligand are becoming involved.*

14. What advantage would there be to an organism if the signal transduction pathway had several amplification steps?

*A single (or low count of) ligand molecule(s) can lead to a magnified response by the cell.*

15. Describe what would occur in the cell if the activated protein kinase enzymes continued to be active for a long period of time.

*ATP molecules would become used up.*

16. What would need to occur in the cell to deactivate the protein kinase enzymes?

*Dephosphorylation and deactivation of the relay protein.*

17. Protein phosphatases are enzymes that remove phosphate groups from proteins. Complete the illustration in Model 2 by adding at least two protein phosphatases (PP) to show how the cell is returned to inactive status.

18. Although signal transduction pathways vary among species, there are several common elements. Explain how a biologist might use details about signal transduction pathways used in different species as evidence for evolutionary relatedness.

*Species with common signal pathways are more closely related than those with dissimilar pathways.*

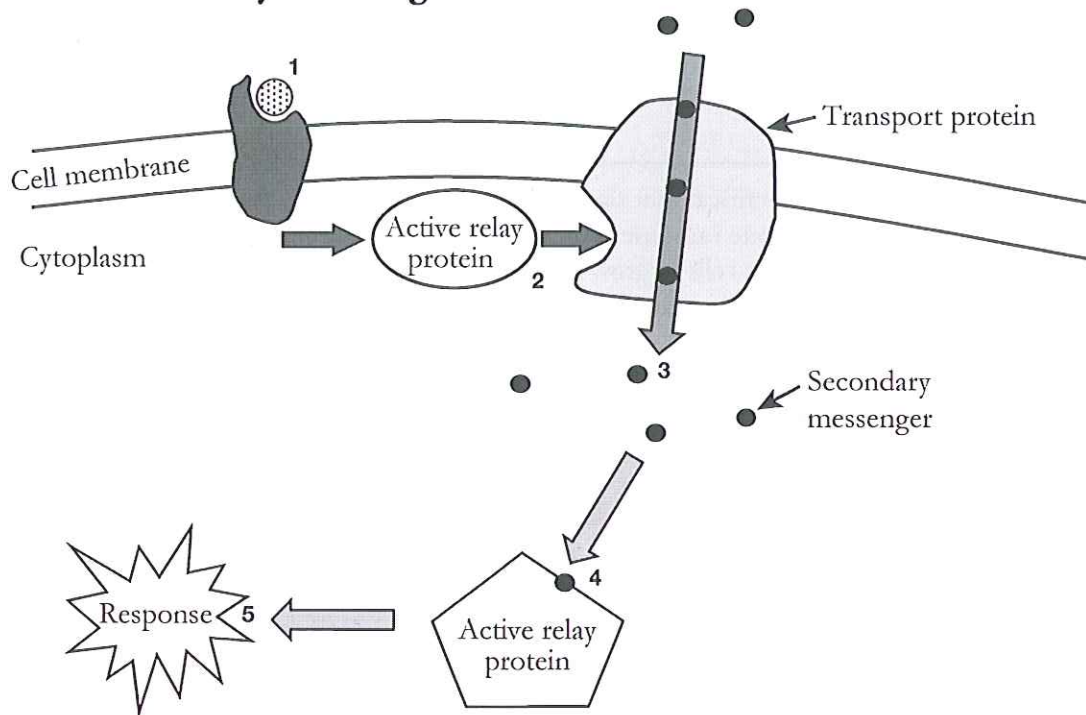
*Signal pathways appear to be ancient.*





## Extension Questions

### Model 3 – Secondary Messengers



19. Consider the signal transduction pathway in Model 3. What event begins the process of producing a cellular response?

*Ligand binds to a receptor protein*

20. Locate the secondary messenger molecules in Model 3.

a. Describe the type of diffusion that is used to get the secondary messengers into the cell.

*Facilitated diffusion*

b. What activates or opens the transport protein channel that allows the secondary messengers to enter the cell?

*An active relay protein*

## Read This!

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Relay molecules and secondary messengers have essentially the same jobs in signal transduction pathways. However, relay molecules are almost always proteins that require activation. They are large and do not diffuse through the cell quickly. Secondary messengers on the other hand are small, water soluble molecules that can diffuse quickly. They may or may not need activation before they are able to move the signal on to the next step in the process. Cyclic AMP (cAMP) and calcium ions ( $\text{Ca}^{2+}$ ) are common secondary messengers in human systems.

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21. Within an organism it is critical that signals between cells are very specific. For example, if ligand A is meant to activate immune system cells to reproduce in response to an infection, it should not also cause other cells to grow as if they had received a growth hormone. When a ligand is released, what prevents all of the cells in the body from being affected?

*A cell needs specific receptor molecules to be affected by a released ligand.*