Chapter 11: Cell Communication

11.1 Describe how external signals are converted to responses within cells.

11.2 Identify different types of signal receptors and explain how they function.

11.3 Explain the roles of phosphorylation, dephosphorylation, and second messengers in signal transduction.

11.4 Describe how cells respond to signaling, including fine-tuning of the response.

11.5 Use apoptosis as an example to illustrate how multiple signaling pathways can be integrated in a cell.

The special challenge in Chapter 11 is not that the material is difficult to understand but that most of the material may be completely new to you. Cell communication is often not covered in introductory high school biology courses, yet perhaps no other section of biology has grown as much as our understanding of cell signaling in the last decade. Take your time with this section, and you will be rewarded with a knowledge base that will be most helpful in this course and courses to come.

Study Tip: Figure 11.1 in your text explains the desperate flight of an impala at the cellular level. It shows how the signal (sensing a cheetah nearby) leads to the release of more glucose to power an escape. Although the specific details are unique to the signal, cell signals show three definite stages. Label and describe the three stages for this example in the boxes below. These three stages of the cell signal response are consistent across all types of cell signals.

Concept 11.1 External signals are converted to responses within the cell

LO 11.1: Describe how external signals are converted to responses within cells.

1. Cell signaling in bacteria provides evidence this is an ancient process that first evolved hundreds of millions of years ago. What is *quorum sensing*, a signaling mechanism seen in bacteria today? How is it related to *biofilms*?

2. Biofilms on your teeth could protect bacteria that cause cavities and gum disease. What is another way quorum sensing can lead to disease?

3. Yeasts find their sexual mates by chemical signals that activate a *signal transduction pathway.* What are the three major steps in this pathway?

4. Study Figure 11.3. The yeast cells are of two mating types, a and α. Like male and female, they must find each other in order to mate. How does each mating type signal which it is? How does each type "know" the other type is near?

5. Your answer to question 3 included a *signal* and its *reception*. When reception occurs in cells of different mating types, what occurs next?

This is the *cellular response.* The response is caused by cellular changes that occur as a result of signal reception and transduction. Logically, the three-stage process is termed a *signal transduction pathway.*

6. Chemical signals may pass between adjacent animal cells through _____ and between plant cells via _____ .

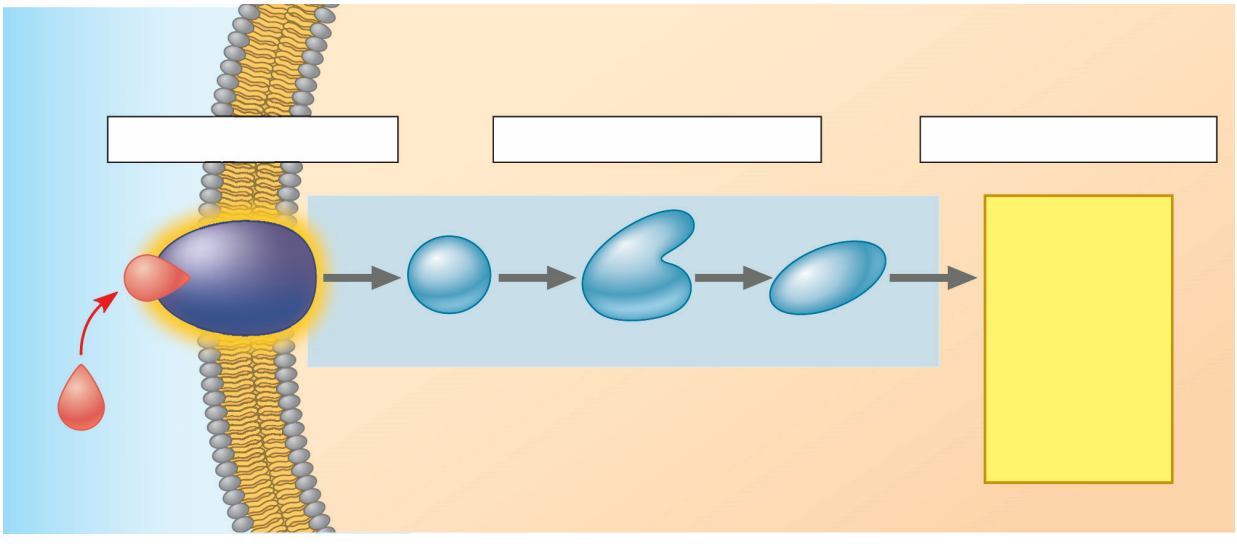
7. What are two additional ways chemical signals may pass between animal cells?

8. What are three examples of animal signaling molecules? A study of Figure 11.5 in your text may help you answer this.

9. Chemical signals are received by specific *target cells*. What is required for reception by a target cell

10. How does a hormone qualify as a *long-distance signaling* example?

11. A signal transduction pathway has three stages. Use Figure 11.6 in your text to label the missing parts of the following figure.



12. If this were the pathway studied by Earl Sutherland, label *epinephrine*.

13. Describe each step in the signal transduction pathway.

signal reception

signal transduction

cellular response

Concept 11.2 Signal Reception: A signaling molecule binds to a receptor, causing it to change shape

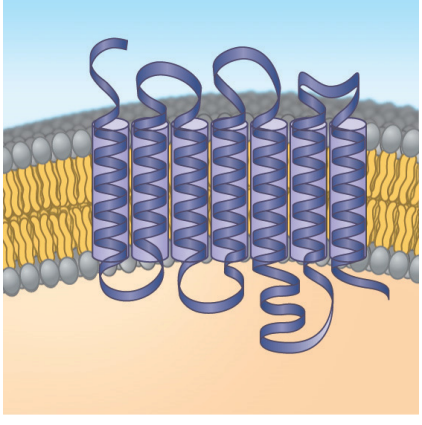
LO 11.2: Identify different types of signal receptors and explain how they function.

14. Explain the term *ligand*. (This term is not restricted to cell signaling. You will see it in other situations during the year.)

15. Cell-surface receptors bind to water-soluble signaling molecules and fall into three general groups. What are these three categories of receptors? (We will look at each in depth.)

16. *G protein-coupled receptors* (*GPCR*) are a large family of receptors. Study the *GPCR* shown in Figure 11.8 in your text and read the accompanying text. How does a G protein receive a signal?

17. Here is a ribbon model of a GPCR imbedded in the plasma membrane. GPCR are composed of seven transmembrane α helices and two specific binding sites. Label these elements.



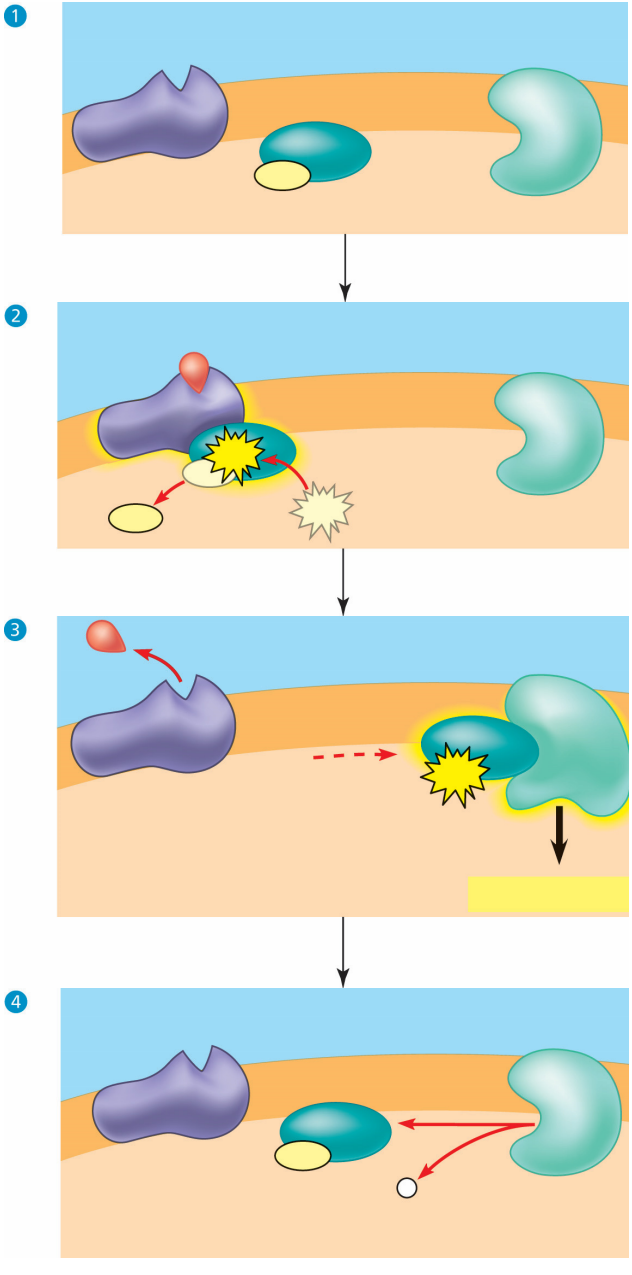
18. What processes in humans depend on GPCRs? What are examples of errors in GPCR signaling?

19. The text explains the three major types of membrane receptors in Figure 11.8. This material is of fundamental importance, so we will work through the specific figures for each type of membrane receptor. The first example is a *G protein-coupled receptor (GPCR)*. In the first figure, label the components and then describe the role of the three components.

G protein-coupled receptor

G protein

GDP



20. Label and then describe what happens in step 2.

21. Label and then describe what happens in step 3. (The yellow box at the bottom right is important!)

22. Equally important to starting a signal is stopping a signal. Step 4 stops the signal. (Failure to do so can lead to serious problems, like cancer.) Label and then describe how the signal is halted.

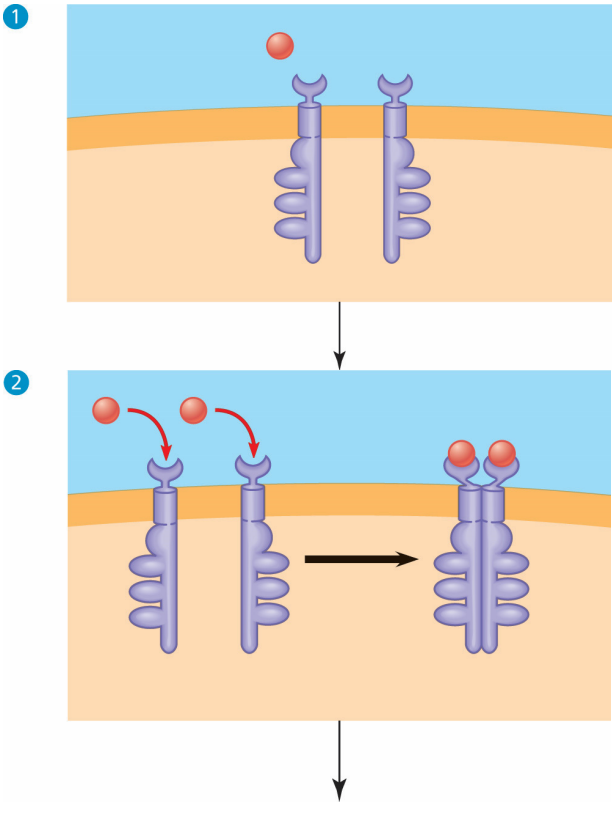
23. A G protein is also a GTPase enzyme. Why is this important?

24. The second type of receptor, described on p. 219, is the *receptor tyrosine kinases (RTKs)*. Explain what a *kinase* enzyme does.

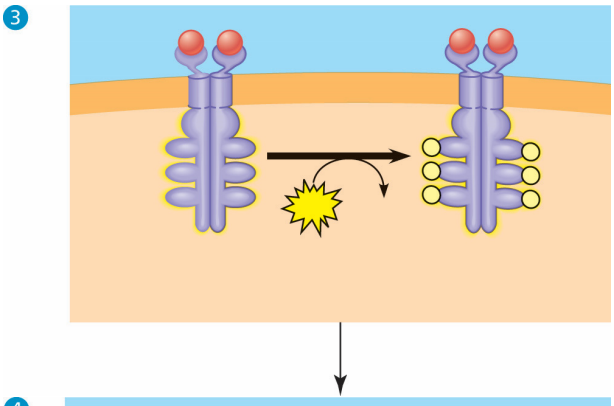
25. What is a key difference between the number of pathways RTKs can initiate and GPCRs can initiate?

26. Use Figure 11.8 in your text to provide all of the missing labels on the diagram below; then explain what happens in step 1.

27. Label step 2 and then describe what happens to receptor tyrosine kinases when signaling molecules have attached.



28. Label and explain how the receptors are activated in step 3.



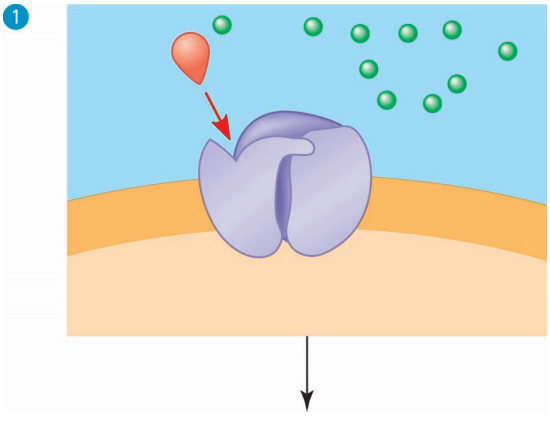
29. Use step 4 to explain how the activated receptor can stimulate multiple cellular response pathways. Each activated protein shown in this step triggers a *different* signal transduction pathway, leading to a *different* cellular response.

30. Look next at *ion channel receptors* (p. 220). This figure shows the flow of ions into the cell. Ion channel receptors can also stop the flow of ions. These comparatively simple membrane receptors are explained in three steps. Label this diagram of the first step and then explain the role of the labeled molecules.

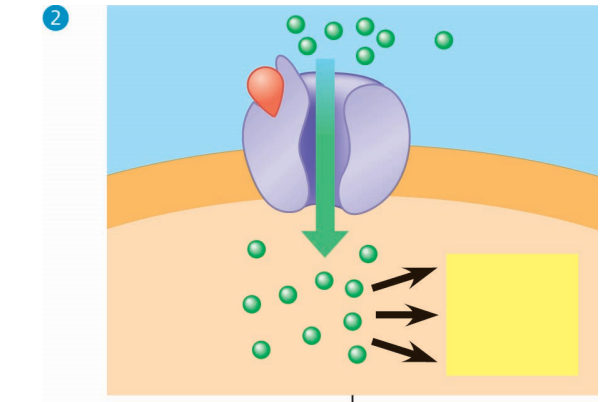
ligand

ligand-gated ion channel receptor

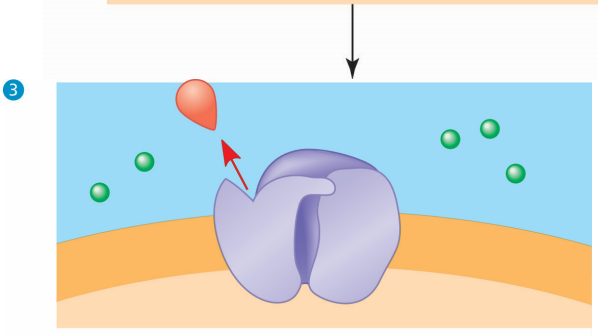
ions



31. Step 2 shows what has happened with the binding of the ligand to the receptor. Label and explain what occurs.



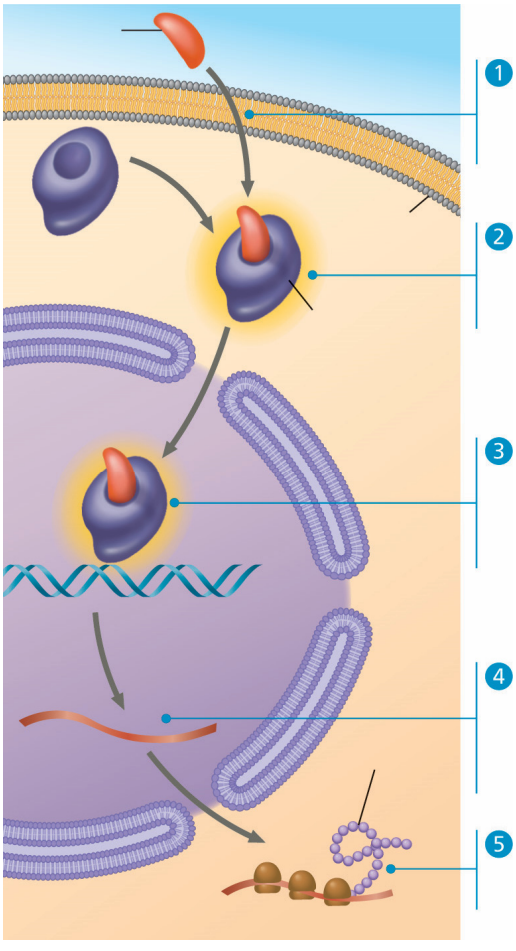
32. The ligand attachment to the receptor is brief. In step 3, the ligand dissociates. Label and explain what occurs.



33. Read the final paragraph below the Ion Channel Receptors figure in your text carefully. In what body system are *ligand-gated ion channels* and *voltage-gated ion channels* of particular importance?

34. To bind intracellular receptors, the signaling molecules must be able to pass through the plasma membrane. What types of molecules can serve as signals? Give three examples.

35. The figure below shows how aldosterone, a hydrophobic steroid hormone, triggers a cell-signaling pathway. It is important as an example of how intracellular receptors work. At each bullet, add an explanation of what is happening in the cell.



36. Why do only kidney cells respond to aldosterone?

37. The important concept of gene regulation by activation of *transcription factors* is introduced in the paragraph below Figure 11.9 of your text. Explain the function of transcription factors in the cell.

Concept 11.3 Signal Transduction: Cascades of molecular interactions transmit signals from receptors to relay molecules in the cell

LO 11.3: Explain the roles of phosphorylation, dephosphorylation, and second messengers in signal transduction.

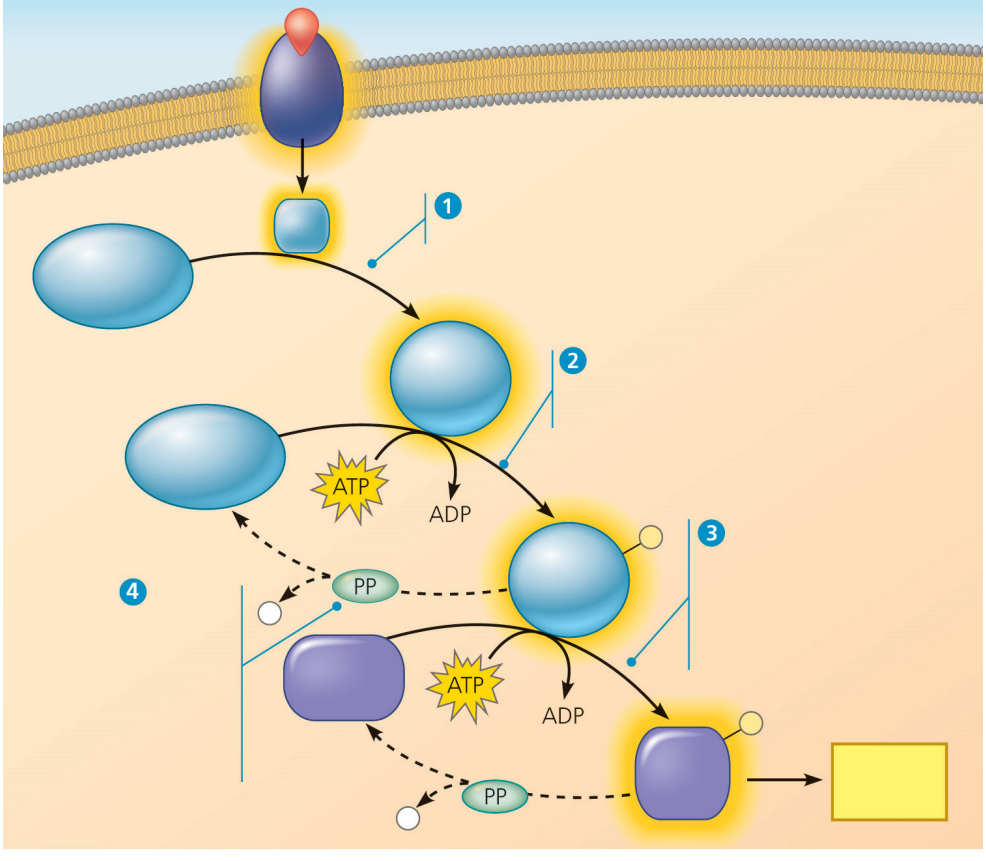
38. What are two benefits of multistep pathways like the one in Figure 11.10 in your text?

39. Explain the role in transduction of these two categories of enzymes:

protein kinases

protein phosphatases

40. Refer to Figure 11.10 to label this image. Explain what is occurring in the cell at each numbered step.



41. A *phosphorylation cascade* can be turned "on" and turned "off," as shown in the figure you just labeled.

    a. How does an inactive protein kinase become activated?

    b. How does an inactive protein become activated?

    c. How does an active protein kinase become deactivated?

42. What is the difference between a first messenger and a second messenger?

43. Two common *second messengers* are *cyclic AMP (cAMP)* and *calcium ions* (Ca^{2+}). Explain the role of the second messenger cAMP in Figure 11.12 in the text.

44. Consider again the discussion of how epinephrine triggers the breakdown of glycogen in the liver, begun in Concept 11.1. For this pathway,

    a. What is the first messenger?

    b. What is the second messenger?

    c. Why could glycogen phosphorylase be activated only when epinephrine was added to *intact* cells?

45. What is the important relationship between the second messenger and *protein kinase A*?

46. Figure 11.12 in the text explains how a cellular response is initiated; how might that response be inhibited?

47. Use your new knowledge of cell signaling to explain the mechanism of disease in cholera.

48. List three types of cellular responses often induced by calcium ions. Be sure to include a plant example!

49. What happens to the cytoplasmic concentration of calcium when it is used as a second messenger?

Concept 11.4 Cellular Response: Cell signaling leads to regulation of transcription or cytoplasmic activities

LO 11.4: Describe how cells respond to signaling, including fine-tuning of the response.

50. The response to a cell signal can occur either in the nucleus or in the cytoplasm. Read the text on p. 226, and study Figure 11.15. What normally happens in a *nuclear response*?

51. Figure 11.16 in your text shows a *cytoplasmic response* to a signal. How is this different from a nuclear response in terms of both the signal molecule and its effect?

52. Figure 11.16 in your text shows how a signal can be amplified in a phosphorylation cascade. A single molecule of epinephrine results in the formation of approximately how many molecules of glucose 1-phosphate?

53. How is it that some cells do not respond to specific signaling molecules, and for the cells that do respond, it is often in different ways?

54. Figure 11.17 in your text shows five different cellular results from a single signaling molecule. Briefly describe each response.

Cell A

Cell B

Cell C

Cell D

55. How do *scaffolding proteins* enhance a cellular response?

56. In cell signaling, termination is an essential aspect of the pathway. Describe two ways the signal may be terminated. What is one way relay molecules are inactivated?

Concept 11.5 Apoptosis requires integration of multiple cell-signaling pathways

LO 11.5: Use apoptosis as an example to illustrate how multiple signaling pathways can be integrated in a cell.

57. What specifically happens to a cell during the process of *apoptosis*?

58. Describe three examples of apoptosis, including normal as well as abnormal functions.

59. The signal for apoptosis can come from outside or inside the cell. Give one example when the signal comes from outside the cell and two examples of cellular occurrences that would prompt an apoptosis signal from inside the cell.

Test Your Understanding, p. 233

Now you should be ready to test your knowledge. Place your answers here:

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____ 7. _____