Chapter 39: Plant Responses to Internal and External Signals

39.1 Trace the steps of a signal transduction pathway in a plant.
39.2 Identify plant hormones and their functions.
39.3 Describe plant responses to light.
39.4 Give examples that show how plants respond to stimuli.
39.5 Describe plant defenses against herbivores and pathogens.

This chapter explores many different ways in which plants respond to signals, and you will see many links to other chapters, including cell signaling, hormones, and immune response. Not surprisingly, plants exhibit a number of behaviors that enhance their biological fitness. These behaviors are the subject of this chapter.

Study Tip: We hope that you have seen a field of sunflowers rotate with the sun as depicted in Figure 39.1 in your text. Light is only one of the factors to which plants respond. What nine stimuli does Figure 39.1 list as factors to which plants respond?

Concept 39.1 Signal transduction pathways link signal reception to response

LO 39.1: Trace the steps of a signal transduction pathway in a plant.

This concept brings together the general ideas on cell communication from Chapter 11 with specific examples of signal transduction in plants. As with animals, plants have receptors that trigger signal transduction pathways when activated. Let's begin with a review of three steps in signal transduction.

Step 1: Reception. Cell signals are detected by receptors that undergo changes in shape in response to a specific stimulus.

Step 2: Transduction. Transduction is a multistep pathway that amplifies the signal. This effect allows a small number of signal molecules to produce a large cellular response.

Step 3: Response. Cellular response is primarily accomplished by two mechanisms:

a. increasing or decreasing mRNA production
b. activating existing enzyme molecules

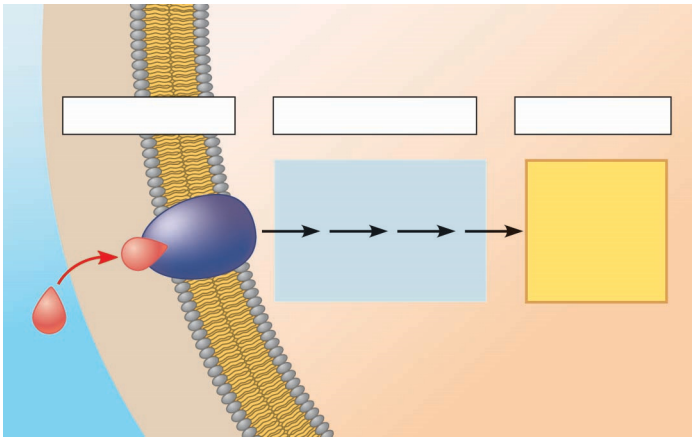
1. Label completely the parts of signal transduction on this figure. For each step, give an example of what a failure at that step might cause to happen within a cell or organism. You may give examples from any type of cell to show that you understand the normal function of a pathway, as well as how it may be disrupted.

Failure at step:

1.

2.

3.

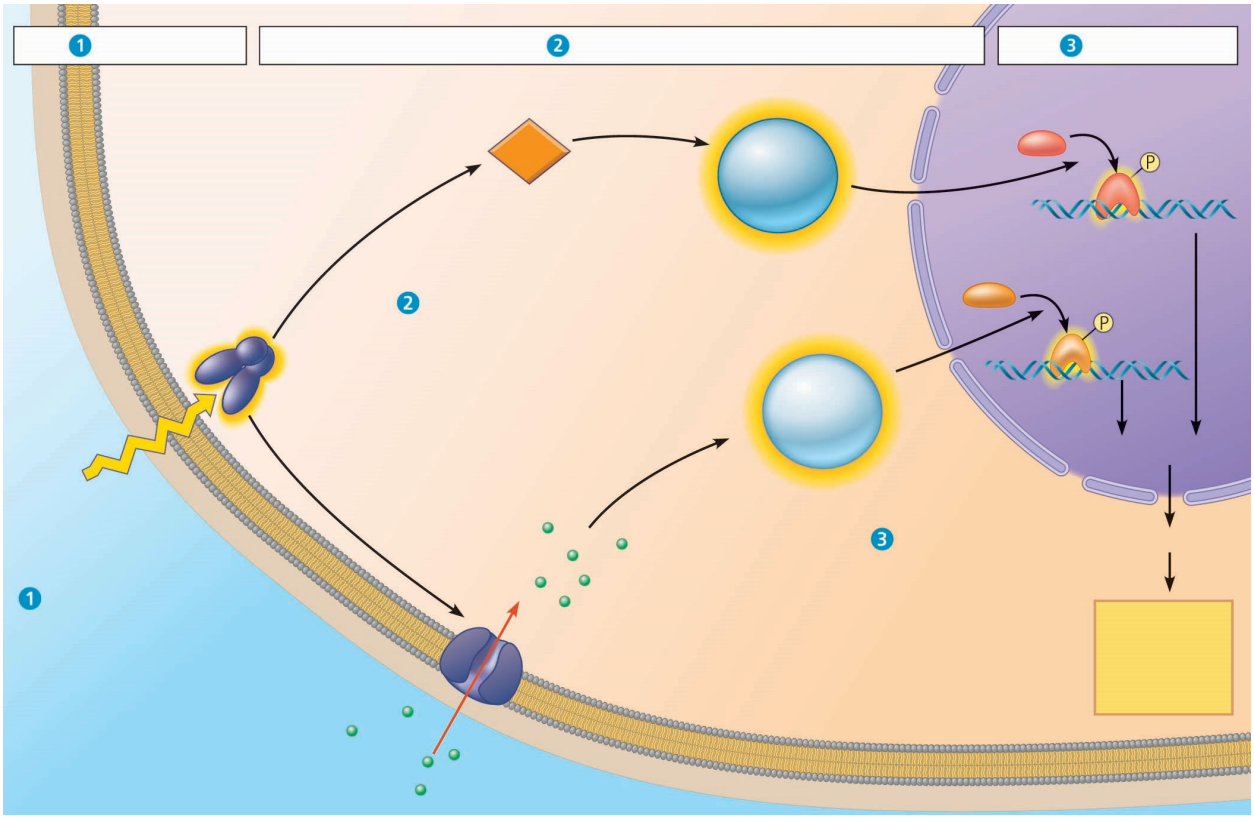


2. Have you ever seen a shriveled potato sending out skinny, pale sprouts? What is this called? What is the stimulus?

3. How do the potato's morphological adaptations for growing in darkness increase its biological fitness?

4. If you move the potato into the light, the sprout will respond by forming short, sturdy stems and broad, green leaves. What is this response to light called?

5. The following figure gives a specific example of a signal transduction in plants for the *greening* or *de-etiolation response* previously described. Label all parts of the figure including: *reception*, *transduction*, *response*, *phytochrome*, *signal*, Ca^{2+} *channel*, *second messenger (cGMP)*, *protein kinase*, *transcription factor*, and *DNA*.



6. Use the figure you just labeled to answer the following questions:

   a. What is the signal?

   b. What occurs in transduction?

   c. What are the two *second messengers* in this pathway?

   d. Explain how the light signal causes the *greening response*. Number the steps, as shown in the figure in your text.

7. Signal transduction pathways must also have a means for turning off when the initial signal is no longer present. What acts an "off switch," and how does it work?

8. Focus on the final section in this concept, De-etiolation Proteins. Give at least three specific ways in which proteins that are either activated or newly transcribed contribute to the process of greening.

Concept 39.2 Plants use chemicals to communicate

LO 39.2: Identify plant hormones and their functions.

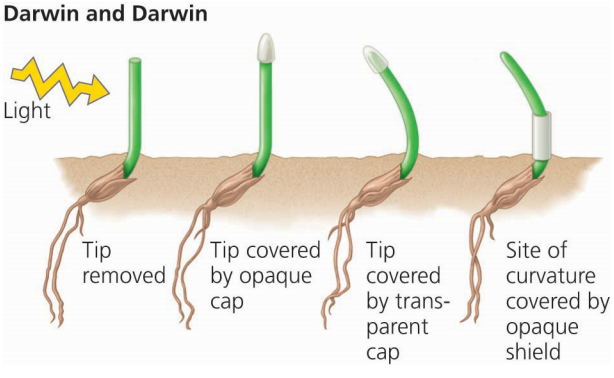
In this concept we will concentrate on the five "classic" hormones: auxins, gibberellins, cytokinins, abscisic acid, and ethylene.

9. Both plants and animals have *hormones*. The original definition of a hormone has three parts. What are they?

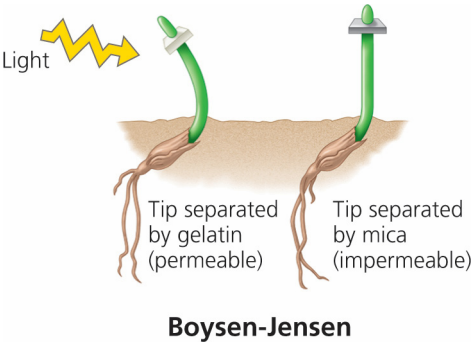
10. Many modern plant biologists think the term *hormone* as previously defined doesn't quite fit plants. What term do they use instead?

11. What is a *tropism*?

12. The following sketch describes early experiments on *phototropism* conducted by Charles and Francis Darwin. What can be concluded from these experiments? Cite evidence that supports this conclusion.



13. This sketch describes the *Boysen-Jensen experiment.* What conclusions can be drawn from it? Cite evidence to support your conclusions.

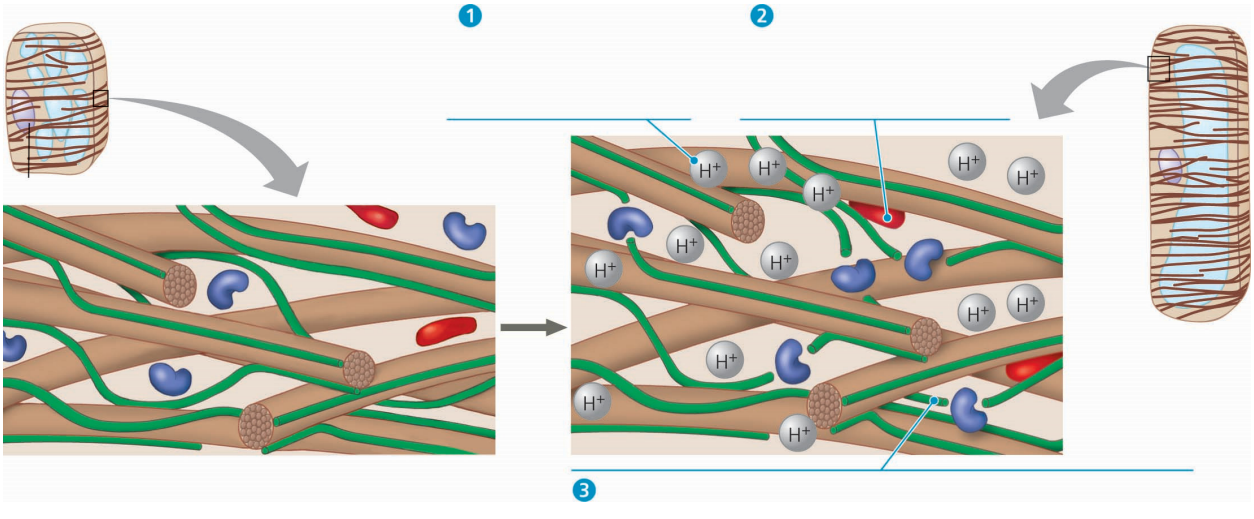


Boysen-Jensen

14. What name was ultimately given to the chemical that diffused through the gelatin layer? What was its specific chemical structure found to be?

15. At first, auxin transport was thought to be a function of gravity, until it was determined that plants regularly transport auxins against gravity. Explain *polar transport*.

16. One critical function of auxins is cell elongation. Use the figure below to explain the *acid growth hypothesis* for cell elongation by labeling the diagram and then explaining the process as indicated by the three numbered sites.



17. a. What is *pattern formation* (you may remember this term from Chapter 18 on gene regulation) in plants?

    b. Give a specific example of the role auxins play in pattern formation.

18. Did you catch the discussion of auxins as herbicides? Perhaps you have used a weed killer to kill dandelions in your lawn. Explain how an herbicide with auxins, such as 2,4-D kills dandelions without killing the grass.

19. Cytokinins influence cell division, cell differentiation, and apical dominance (often in concert with auxins). In the chart below explain the influence of cytokinins on the process indicated.

Cytokinin-Influenced Plant Responses	Description
Cell division and differentiation	
Apical dominance	
Anti-aging effects	

20. A disease Asian farmers called "foolish seedling disease" turned out to be caused by a hormone group that would eventually be called *gibberellins*. As with cytokinins, gibberellins often work in concert with auxins. Explain the different effects attributed to gibberellins in the chart below.

Gibberellin-Influenced Plant Responses	Description
Stem elongation	
Fruit growth	
Germination	

21. Abscisic acid is known as the plant hormone that generally slows growth. Two examples are seed dormancy and drought tolerance. Explain the role of abscisic acid in each.

    a. Seed dormancy

    b. Drought tolerance

    c. Give one example of the evolutionary advantage of seed dormancy.

22. The unusual thing about ethylene is it is a gas hormone. Ethylene has a variety of effects on plants. One important effect is the *triple response* to mechanical stress. Explain the three maneuvers of the triple response system that a plant could use if it came across a large stone during germination.

23 Three more well-studied effects of ethylene are *senescence*, *leaf abscission*, and *fruit ripening*. Explain the role of ethylene in each of these examples in the chart below.

Ethylene-Influenced Plant Responses	Description
Senescence	
Leaf abscission	
Fruit ripening	

24. Explain why it is true that "one rotten apple can spoil the bunch."

Concept 39.3 Responses to light are critical for plant success

LO 39.3: Describe plant responses to light.

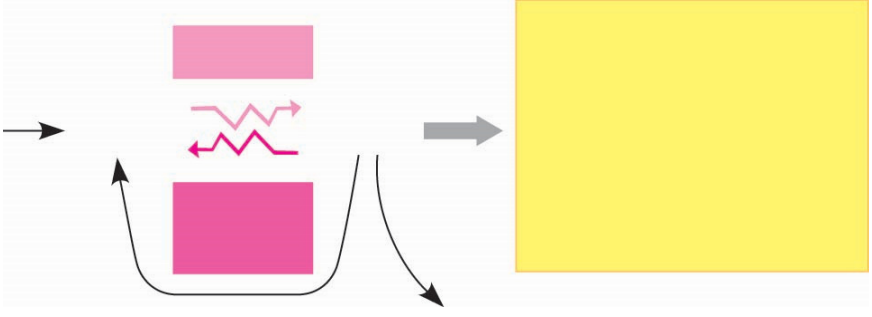
The ideas of action and absorption spectra were introduced in the chapter on photosynthesis. These concepts can be reviewed on pp. 193–194 and Figure 10.9 in your text.

25. Researchers have determined that plants have two major classes of light receptors. List each class.

26. What are three different responses initiated by blue light?

27. What wavelengths of light are absorbed by *phytochromes*?

28. Phytochromes are photoreceptors that have two isomer forms, P_r and P_{fr}. As a result, the two forms of the photoreceptors act as a switching mechanism. Figure 39.17 in your text shows the conversion of P_r to P_{fr} and the reverse. Label all parts of the figure, then list four plant responses to P_{fr}.



29. What conditions maintain phytochromes as P_r?

30. Which is the active form of phytochrome, P_r or P_{fr}? _____

31. Look again at the effect of light exposure on lettuce seed germination shown in Figure 39.16 in your text. What is the role of red and far-red light in determining the seed's response?

32. Read carefully the Phytochromes and Shade Avoidance section. Which type of red light is more common in a shaded area? Why?

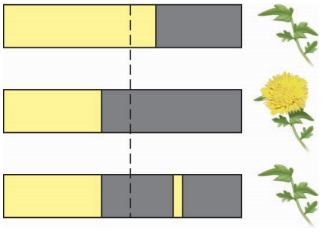
33. What is a *circadian rhythm*? Give one plant example and one human example.

34. How do phytochromes function in plant circadian rhythms?

35. What is *photoperiodism*?

36. Plants detect photoperiod, and in many species it affects their time of flowering. Explain each of the following and give an example of a plant that is in the group. For the short- and long-day plants, label the figures and include them in your explanation.

a. short-day plant



b. long-day plant

c. day-neutral plant

37. The plant in the following figure is a short-day plant. Label *R, FR*, and *critical dark period*. For each line, explain why flowering occurs or does not occur.

Concept 39.4 Plants respond to a wide variety of stimuli other than light

LO 39.4: Give examples that show how plants respond to stimuli.

38. Asking a nonbiology friend how a seed knows to send its shoot up and its roots down will often generate a number of responses. Eventually, many people finally get to the only factor that makes sense, gravity. What is *gravitropism*? How may a plant detect gravity?

39. What is *thigmotropism*? How is it adaptive?

40. The section of Environmental Stresses is especially important today with the interest in trying to predict the impact of climate change on agriculture. Use the *Problem-Solving Exercise* on p. 863 of your text to answer the following.

    a. What are the three climate variables that are most important in predicting crop productivity?

    b. What general trends do you see from the map?

    c. If a friend claims "climate change increases the number of days above freezing and so more crop biomass will be harvested in the future," what data could you cite to refute this claim?

41. Drought can reduce crop yields and even kill plants.

    a. How is a plant triggered to close its stomata when there is a water deficit?

    b. What are two ways a plant can slow transpirational water loss?

    c. Why does drought diminish crop yield?

42. In the following chart give a brief explanation of how plants deal with the listed stresses.

Environmental Stress	Plant Response
Flooding	
Salt stress	
Heat stress	
Cold stress	

43. After reading the closing concept section on Evolution on p. 865, how do you think the antifungal defense proteins became involved in fighting cold stress? (The answer is not in the text but give the idea some thought and develop some ideas.)

Concept 39.5 Plants respond to attacks by pathogens and herbivores

LO 39.5: Describe plant defenses against herbivores and pathogens.

44. Like animals, plants have immune responses. The first line of immune defenses is the physical barrier formed by the epidermis and the bark or periderm. If the barrier is breached, then *PAMP-triggered immunity* (PAMP = pathogen-associated molecular patterns) becomes the plant's next line of defense. How are the plant immune responses similar to vertebrate responses? Different?

45. Similar but even stronger defenses are initiated by the second plant immune response, *effector-triggered immunity*.

    a. What are *effectors*?

    b. Explain the role of the *hypersensitive response* as a component of effector-triggered immunity.

    c. Going beyond the localized hypersensitive response is a warning to the entire plant termed *systemic acquired resistance.* Describe how this works, including the role of *salicylic acid*.

46. Herbivory both reduces the size of the plant and opens the plant to infection by bacteria, viruses, and fungi. Study the **Make Connections** Figure 39.27 in your text that describes how plants can combat herbivory by defenses at several levels of biological organization. For each level, describe the general mode of defense and give an example.

Level of Defense	Mode of Defense	Example
Molecular		
Cellular		
Tissue		
Organ		
Organismal		
Population		
Community		

Test Your Understanding, p. 871

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

7. _____