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Name Leanie Hoeher Period _____

Chapter 39: Plant Responses to Internal and External Signals

Concept 39.1 Signal transduction pathways link signal reception to response

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

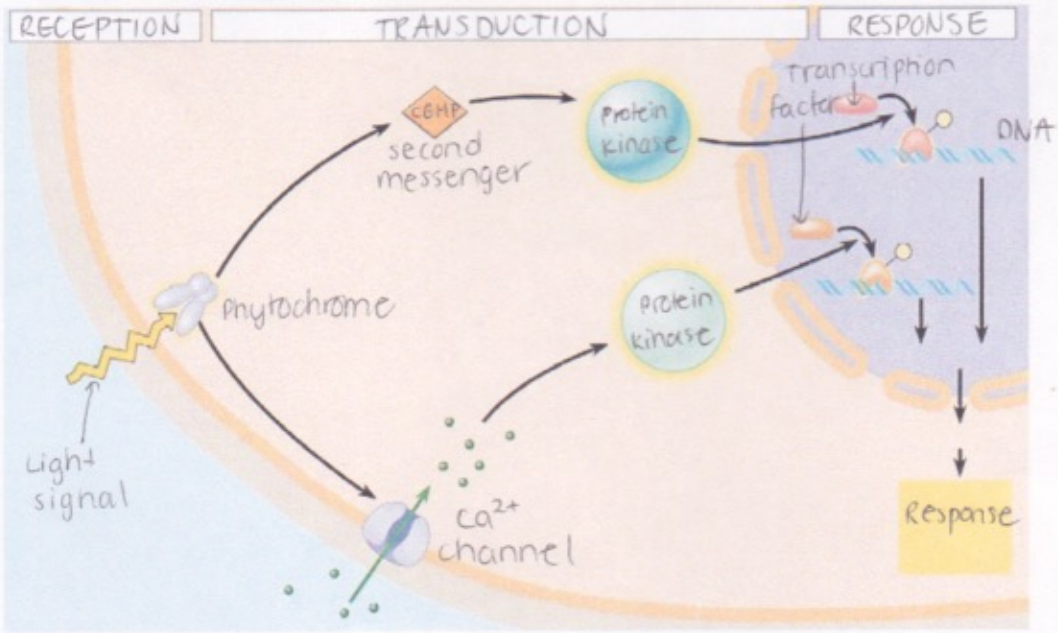
1. Have you ever seen a shriveled potato sending out skinny, pale sprouts? What is this called?

   Etiolation

2. 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?

   De-etiolation

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



4. Return to the figure and explain how the light signal causes the *greening response*. You may choose to number the steps, as shown in the figure in your text.
First, the phytochrome receives the light signal, which can then activate signal transduction pathways. Second messengers like cGMP and increase in cytosolic Ca^{2+} activate protein kinases. The signal is amplified and leads to expression of genes for proteins that function in de-etiolation through transcription factors.

5. What are the two *second messengers in* this pathway?
cGMP and Ca^{2+}

Concept 39.2 Plant hormones help coordinate growth, development, and responses to stimuli

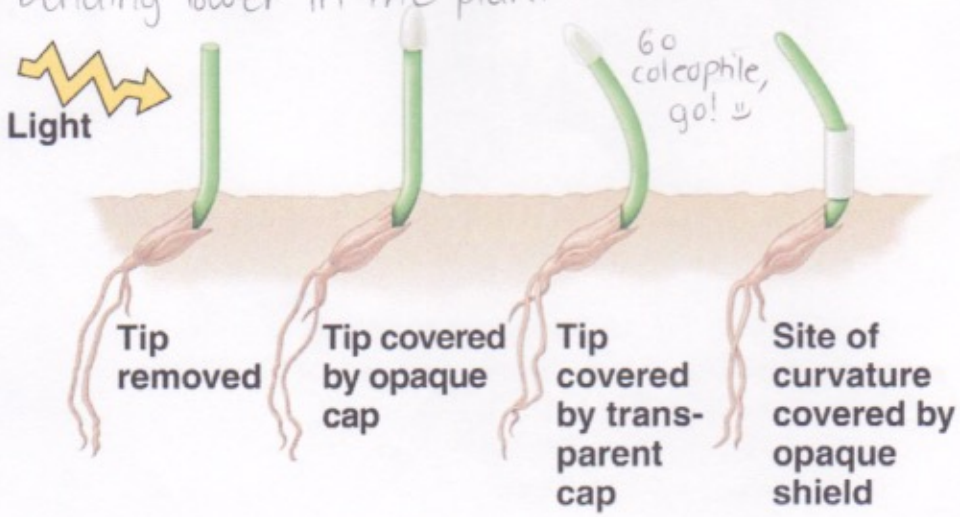
6. Both plants and animals have *hormones*. The definition of a hormone has three parts. What are they? Signaling molecule produced in tiny amounts
Transported to various parts of organism
Binds to receptor and triggers responses in target cells

7. Plant physiologists think the term *hormone* as defined above doesn't quite fit plants. What term do they use instead?
Plant growth regulator

8. What is a *tropism*?
A growth response to stimuli resulting in plant curving towards or away from it

9. The sketch below describes early experiments on *phototropism* conducted by Charles and Francis Darwin. What can be concluded from these experiments?

CONCLUSION This experiment suggests that only the tip of the plant will sense light and cause the plant to curve. It also suggests that a signal from the tip travels and causes bending lower in the plant.

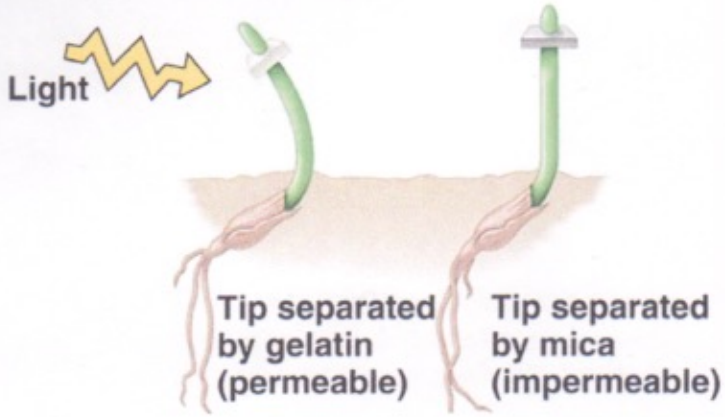


10. Here is a sketch of the *Boysen-Jensen experiment*. What conclusions can be drawn from it?

CONCLUSION The B-J experiment suggests that the bending signal is a light-activated mobile chemical.

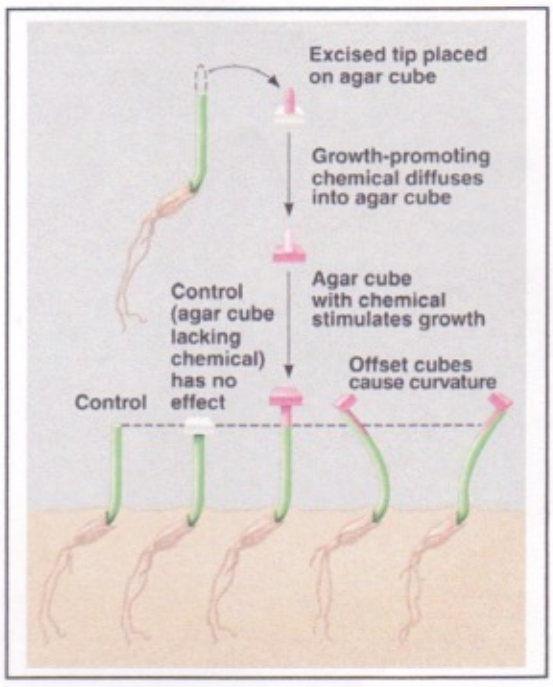
RESULTS

Boysen-Jensen: phototropic response when tip separated by permeable barrier, but not with impermeable barrier



11. Boysen-Jensen's work was published in 1913. In 1926, Frits Went modified the experiment using agar cubes with a chemical from the coleoptile tips. Explain the results of this experiment.

This experiment showed that the plant grew straight if the growth chemical was distributed equally. If it was unequal, the plant would curve away from the concentrated chemical. Experiment was performed in the dark. Went concluded that the curving happens due to a growth-promoting chemical concentration, which he called auxin.



12. What name did Went give to this chemical messenger? What was its chemical structure found to be?

He called it auxin. Chemical structure was found to be indoleacetic acid (IAA).

13. In jest, we tell our students that when in doubt about which plant hormone causes which plant response, just answer *auxin*. Auxin has so many functions, this answer often works. List and describe four functions of auxin.

Auxin Functions	Description
Growth	Auxin stimulates stem elongation and promotes formation of roots
Development	Regulation of development of fruit
Tropism	Functions in photo- and gravitropism
Leaf abscission	Auxin can slow/stop leaf abscission

14. Did you catch the discussion of auxins as herbicides? Perhaps you have used Weed-B-Gone to kill dandelions in your lawn. Explain how this product kills dandelions without killing the grass.

Monocots can inactivate the auxin herbicide (grass)
Eudicots (broadleaf weeds) can not do this.

15. How did *cytokinins* get their name?

They stimulate cytokinesis and were named after it.

16. List and describe three functions of *cytokinins*.

Cytokinin Functions	Description
Cell Division	Cytokinins stimulate growth by cell division Work together with auxins
Apical Dominance	Controlling axillary bud inhibition (buds on sides of plant)
Anti-aging	Slows aging by stopping protein breakdown, slows apoptosis, mobilizes nutrients, stimulate protein synthesis

17. *Gibberellins* occur naturally in plants, and like the previous two hormones, they have several effects. Describe three of them.

Gibberellin Functions	Description
Stem Elongation	Growth in stems and leaves (cell elongation + division)

Fruit Growth	Growth in fruits, stimulation of development
Germination	Embryo of seed has gibberellins that release b/c of H_2O + signal seed to break dormancy

18. *Abscisic acid (ABA)* is misnamed. Why?
ABA is no longer thought to play a role in leaf abscission, which researchers in the 60s thought it did.

19. Describe three effects of *abscisic acid*.

Abscisic Acid Functions	Description
Growth	ABA actually inhibits growth hormones from stimulating growth
Seed Dormancy	inhibits germination and allows seed to withstand dehydration
Drought Tolerance	ABA closes stomata to prevent water loss and can function as warning for wilting

20. *Ethylene* is the only hormone in our group that is a gas. Under what conditions is *ethylene* produced?
Drought, flooding, mechanical pressure, injury, infection, fruit ripening, apoptosis, external auxin

21. The effects of ethylene are many and varied. Describe them here.

Ethylene Functions	Description
Triple Response	Shoot can avoid obstacles through ethylene (slow stem elongation, thicken stem, horizontal growth)
Senescence	Ethylene is associated with apoptosis of cells during senescence (programmed death)
Leaf Abscission	Ratio of auxin to ethylene causes leaves to fall off the tree. Ethylene causes aging.
Fruit Ripening	Ethylene triggers ripening which triggers more ethylene (acid to sugar)

22. You have just finished a very complex look at plant hormones. Let's try to summarize it by completing the following chart.

Hormone	Action
Ethylene gas	leaf abscission

Gibberellins	breaking seed dormancy
Cytokinins	maintaining apical dominance
Gibberellins	making internodes of grape bunches elongate to obtain larger fruit
Auxin	gravitropism
ABA	drought tolerance
Ethylene gas	senescence
Auxin	phototropism
Gibberellins (Auxin)	cell elongation
Cytokinins	increased cell division

Concept 39.3 Responses to light are critical for plant success

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

Blue-light photoreceptors

Phytochromes

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

Mostly red light

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

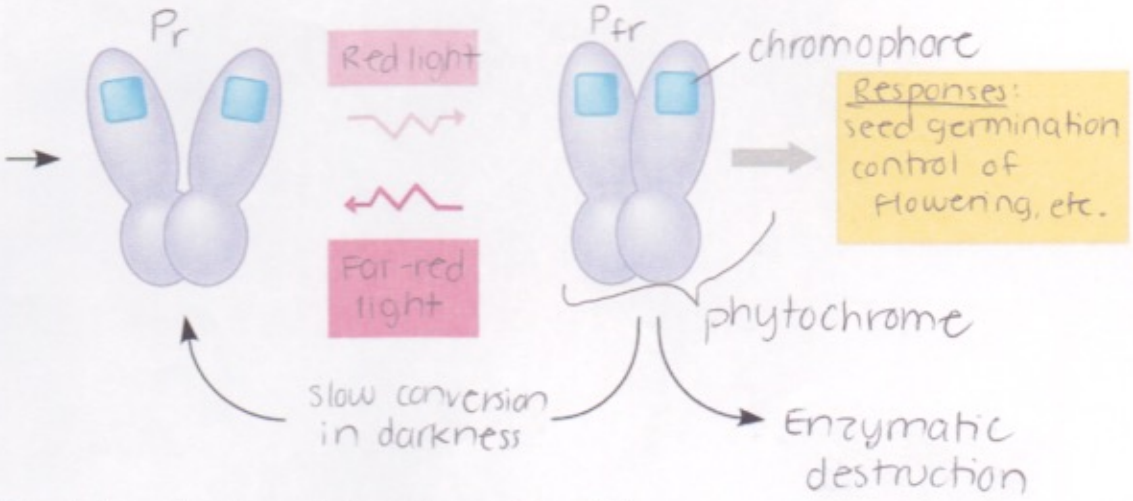
Phototropism

Opening of stomata

Slowing of hypocotyl elongation (when seedling breaks ground)

26. Read carefully the discussion of *phytochromes* and how they work. Pay attention to the two types of red light. What is the wavelength of *red light*? 660nm Of *far-red light*? 730nm

27. Phytochromes are photoreceptors that have two isomer forms, P_r and P_{fr}. Sketch the conversion of P_r to P_{fr} on this figure. Label all of the boxes, and also *chromophore*, *phytochrome*.



28. What is the active form of phytochrome, P_r or P_{fr}?

P_{fr} is the active form
(far-red light exposure causes Pr form)

29. Look again at the effect of light exposure on lettuce seed germination. What determines the seed's response?

A dark environment leaves the seed in Pr form, but when exposed to sunlight, ratio of P_{fr} to Pr changes and accumulation of P_{fr} will trigger germination.

30. To make sense of all this, you will want to read carefully the "Phytochromes and Shade Avoidance" section. Which type of red light is more common in a shaded area? Why?

A forest canopy will screen out more red light, causing far-red light to come through to the shaded area, stimulating Pr, which inhibits growth.

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

A circadian rhythm is a cycle not directly controlled by any environmental variable. Plants go throug "sleep movement" even in light. Humans go through jet lag.

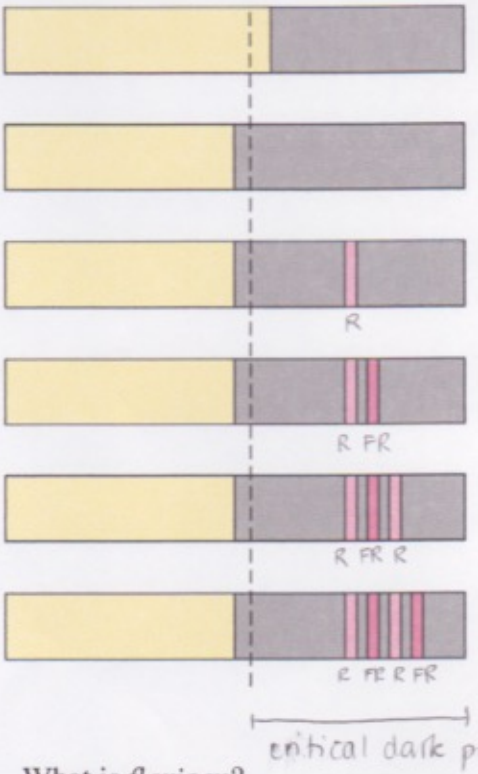
32. What is the *photoperiod*?

The photoperiod is the relative lengths of day and night.

33. 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.

short-day plant : night should exceed a critical dark period (shorter day)
(chrysanthemums)
long-day plant : night should be shorter than critical dark period (long day)
(spinach)
day-neutral plant: unaffected by photoperiods
(rice)

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



The night is not long enough and does not meet critical dark period.

The length of darkness exceeds critical dark period, causing flowering.

A flash of red light is effective in interrupting night

Far-red light is not detected as an interruption.

Red light was detected last, meaning night was interrupted.

No interruption detected because far-red was flashed last.

35. What is *florigen*?

A signaling molecule for flowering
(macromolecule)

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

36. What is *gravitropism*? How may a plant detect gravity?

Gravitropism is a response to gravity. The shoot continues to grow towards light, regardless of orientation on grand.

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

Thigmotropism is directional growth in response to touch. The plant grows straight until it touches something, which initiates a coiling response. Allows plant to take advantage of available mechanical supports.

38. Describe an example of a *rapid leaf movement*. What do these *action potentials* resemble?
An example of rapid leaf movement would be collapsing ~~of~~ and folding of leaf in response to touch. Action potentials in plants resemble nerve impulses in animals. ↳ internal communication

39. List six different ways in which a plant responds to water deficit.
Closing of stomata
Guard cells lose turgor (wilting)
Increase of ABA
Shedding of leaves
Less root growth
Death

40. Select any other stress situation besides water deficit, and explain plant mechanisms for dealing with this.
Excess of salt can also harm a plant. Plants can respond by producing solutes that balance water potential of cells with that of the soil. Mostly, plants die because of salt stress.

Concept 39.5 Plants respond to attacks by herbivores and pathogens

41. What are the two ways in which a plants combat excess herbivory?
Thorns! Ouchhh
Toxic compands! Eeeww

42. Describe two examples of a plant producing chemicals to deal with herbivory.
Production of protein that takes place of another in an insect and then kills that bug. Also, release of compands in damaged leaf can attract other insects that kill the other herbivore feeding on the plant.

Testing Your Knowledge: Self-Quiz Answers
Now you should be ready to test your knowledge. Place your answers here:

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

8._____ 9._____ 10._____