LABORATORY

31 Plant Responses to Stimuli

OVERVIEW

In plants, hormones are organic molecules that coordinate growth and development. Hormones are synthesized in one region of the plant and **translocated** (moved) to other regions where they cause a physiological response. Various types of responses may occur depending on hormone interactions and the plant organ affected.

There are five groups of hormones: (1) **auxins,** (2) **gibberellins** (3) **cytokinins,** (4) **abscisic acid,** and (5) **ethylene.** The effects of the hormones, either stimulatory or inhibitory, depend upon the hormone concentration, the tissue affected, and the developmental status of the tissue. Light, temperature, gravity, day length, and other external factors also play important roles in the growth responses of plants. Some growth responses are visible within a few days; others may take weeks. During this laboratory period you will examine the effects of auxins and gibberellins on plant growth and development.

STUDENT PREPARATION

Prepare for the laboratory by reading the text pages indicated by your instructor. Familiarizing yourself in advance with the information and procedures covered in this laboratory will give you a better understanding of the material and improve your efficiency.

EXERCISE A Auxins

PART I Bud Inhibition and Apical Dominance

Auxins occur naturally in several slightly different chemical forms. The most abundant is indole-3-acetic acid (IAA), often referred to simply as "auxin," which is synthesized in buds of young stems and leaves, embryos, seeds, and fruits. Once synthesized in a bud, IAA is translocated toward the base of the plant, the concentration of IAA remaining highest in the growing tips of the stem and decreasing toward the roots. IAA causes the lengthening of cells in the elongation region of a growing shoot (the area just behind the apical meristem). However, if concentrations of IAA increase beyond a certain optimum level, lengthening of the stem is inhibited rather than stimulated.

The product of IAA in the apical bud at the end of a growing shoot also inhibits the development of lateral buds. As a result of this **apical dominance,** a plant will appear to grow upward rather than outward. A simple experiment can be used to investigate the effects of IAA on stem growth.

Objectives

- ☐ State the effects of auxin on the nature and form of stem growth in branching plants.
- ☐ Describe how the presence or absence of an apical bud influences the growth form of a plant.

Procedure

First Week

1. Work in groups of four. Obtain a pot containing 4-week-old *Coleus* plants.
2. Leave two plants with apical buds intact. Mark them with small tags labeled "Apical Bud." All tags should be loosely tied.
3. Remove the apical buds from each of two plants. Mark them with small tags labeled "Removed."
4. Remove the apical buds from each of two additional plants and apply a small amount of lanolin paste to the decapitated surface. Mark these plants with tags labeled "Removed—Lanolin."
5. Remove the apical buds from each of two other plants and apply a small amount of lanolin paste containing 5,000 parts per million (ppm) IAA to the decapitated surface. Mark these plants with tags labeled "Removed—IAA."
6. In each pot, place a label with your names and laboratory section (do not write on pots). Give the pot to your instructor, who will keep it in a sunny spot for the next week.

Form a hypothesis about the effects of IAA on stem growth:

HYPOTHESIS:

NULL HYPOTHESIS:

What do you **predict** will happen to the eight plants used for this experiment?

What is the **independent** variable?

What is the **dependent** variable?

Second Week

Seven days after the decapitation procedure, measure to the nearest millimeter the length of the axillary buds (buds located in the angle formed by the leaf and stem) or branches that have developed. Record your data in Table 31A-1.

Table 31A-1 Apical Dominance and Bud Inhibition

Treatment	Average Bud on Branch Length (millimeters)
Intact plants	
Debudded plants	
Debudded plants + lanolin	
Debudded plants + lanolin and IAA	

a. Did branching occur in plants with an apical bud? _______ *b. Did branching occur in plants without an apical bud and without lanolin or IAA treatment?* _______ *c. Did lanolin substitute for the apical bud (that is, did it produce the same effect)?* _______ *d. Did lanolin and IAA substitute for the apical bud?* _______

e. What is the purpose of the lanolin treatment? ______________________________

What do you **conclude** *from this experiment?* ______________________________

____

f. Does IAA cause bud inhibition? _______ *Do your results support your hypothesis?* _______

Your null hypothesis? _______

g. In your experiment, what was the reason for leaving two plants intact? ______________________________

____

h. Gardeners commonly "pinch out" the apical bud of a plant. What effect does this practice have on plant form, and why do gardeners do it? ______________________________

____

PART 2 Leaf Abscission

Leaves of most perennial flowering plants have a relatively short life span. Produced in the spring, they serve a photosynthetic function throughout the summer. With the onset of fall, leaves begin to **senesce** (age).

During senescence, nutrients and reusable molecules are returned to the stem, and enzymes begin to break down the walls of cells near the base of the leaf petiole, forming an **abscission layer.** The eventual abscission (drop) of leaves following senescence is the result of the formation of this abscission layer. Continued breakdown of cell walls loosens contacts between cells in the abscission layer, while the formation of a protective layer of cells below the abscission area further isolates the petiole from the stem. Eventually, the only connection between the cells of the petiole and the stem is a strand of vascular tissue. Complete abscission of the leaf from the stem then occurs from the stress of wind and gravity.

Auxin, along with abscisic acid, plays a role in leaf abscission. When leaves are young, the leaf end of the petiole maintains a higher auxin concentration than the stem end. As a leaf ages, less auxin is produced at the leaf end of the petiole and eventually the stem end has a higher concentration than the leaf end. This change in auxin concentration causes leaf abscission. Abscisic acid, isolated from leaves (and fruits), accelerates the abscission process.

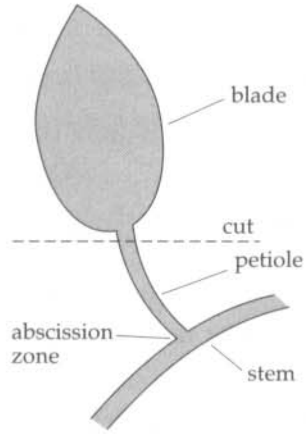
Objectives

- ☐ State the effects of auxin on leaf abscission.

Procedure

1. Work in groups of four. Obtain a *Coleus* plant. From near the apexes of three different stems, select one young leaf and cut off only the blade portion of the leaf. Do *not* cut the petiole from the plant (Figure 31A-1).
2. To the tip of one of the petioles, apply lanolin containing 5,000 ppm IAA. To the second petiole tip, apply only lanolin. To the third, apply nothing.
3. Label each petiole with a paper reinforcement ring or small piece of tape on the stem or adjacent leaf indicating the treatment applied. In each pot, place a label with your names and laboratory section (do not write on pots). Return the *Coleus* to your instructor. After one week, make observations and record the data (petiole on or off) in Table 31A-2.

Figure 31A-1 *Location of cut on* Coleus *leaf.*



What hypothesis can you test using this experimental method?

HYPOTHESIS:

NULL HYPOTHESIS:

What do you **predict** will happen to the three petioles?

What is the **independent variable**?

What is the **dependent variable**?

a. Does IAA promote or inhibit the formation of the abscission layer? ______________

b. Review your results and state where the auxin controlling the development of the abscission layer is produced.

____

Explain your reasoning. ______________

____

c. What was the experimental reason for placing lanolin on one petiole?

____

____

Table 31A-2 Leaf Abscission

Treatment	Observations
Debladed	
Debladed + plain lanolin	
Debladed + lanolin with IAA	

*What can you **conclude** about the role of auxins in leaf abscission?* ______________________

____

Do your results support your hypothesis? ______

Your null hypothesis? ______

EXERCISE B Gibberellins

Gibberellins are a group of naturally occurring plant steroid hormones. There are more than 90 different forms of gibberellins, although GA_3 (gibberellic acid) is the most prevalent in flowering plants.

Gibberellic acid is synthesized in meristematic regions (young leaves, shoot tips, and root tips) and is translocated in the xylem of vascular bundles. Very low levels are found in mature roots, stems, and leaves. Gibberellic acid is also synthesized in seeds.

In young plants, gibberellic acid, like auxin, promotes cell elongation. Shoot elongation and bolting (rapid growth) are under direct control of gibberellic acid. In seeds, gibberellic acid hastens germination by enhancing cell elongation and thus elongation of the embryonic root, so that it can penetrate the seed coat. Additionally, gibberellic acid produced by the embryo stimulates product of hydrolytic enzymes that digest the seed's endosperm, making food reserves available for growth.

Some plants, such as dwarf pea plants, lack the ability to synthesize GA_3, but remain sensitive to exogenous application of this hormone. In this exercise, the effects of gibberellic acid can be demonstrated using dwarf pea plants (Figure 31B-1).

Objectives

- ☐ State the effects of gibberellic acid on stem elongation in plants.

Procedure

First Week

1. Work in groups of four. Each group of students should obtain two pots containing dwarf pea plants.
2. Measure the height of the stems in each pot (in millimeters) and count the number of nodes along the stem. When you measure stem height, measure from the soil surface to the terminal bud. (Be careful not to confuse the petiole of a leaf with the stem—the terminal bud of the stem may not be the highest point of the plant.) Average your data and record the averages in the columns marked "Initial Treatment" in Table 31B-1.

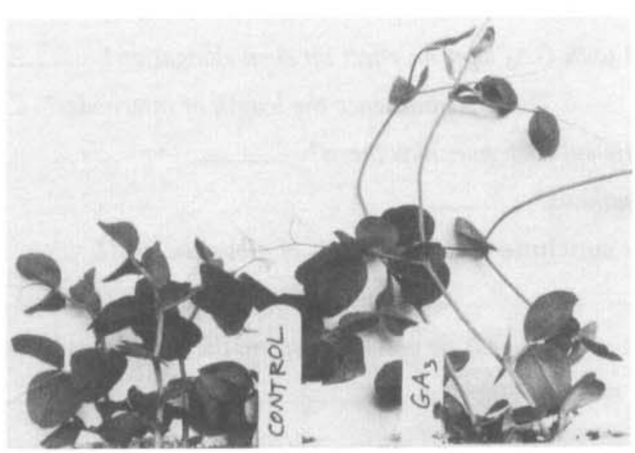


Figure 31B-1 *Effects of gibberellic acid on growth of dwarf pea stems.*

Table 31B-1 Shoot Length in Response to Gibberellins

Treatment	Initial Treatment: Stem Height (millimeters)	7 Days: Stem Height (millimeters)	Initial Treatment: Number of Nodes	7 Days: Number of Nodes
GA_3				
Control				

3. Add several drops of 100 mg/l GA_3 solution directly to the apex of the plants in one pot. In a similar manner, add the control solution (water plus Tween-20) to the plants in the second pot. (Both solutions contain Tween-20, a wetting agent that assists in the absorption of GA_3 by the pea plants.)
4. In each pot, place a label indicating the treatment, your names, and laboratory section (do not write on pots). Return the pots to your instructor.

Form a hypothesis that provides a tentative explanation for the effects of GA_3 on dwarf pea plants.

HYPOTHESIS:

NULL HYPOTHESIS:

What do you **predict** will happen to the plants treated by this experimental procedure?

What is the **independent variable**?

What is the **dependent variable**?

Second Week

After one week, measure the height of the stem of each plant in each pot and count the number of nodes present. Compare and record the average stem height and number of nodes for treated and control plants. When you measure the stem height, remember to measure from the soil level to the tip of the terminal bud. (Be careful not to confuse a petiole with the stem.)

a. Did treatment with GA_3 have an effect on stem elongation? ______ *b. Did GA_3 influence the number of nodes?* ______ *c. Did GA_3 influence the length of internodes?* ______

Do your results support your hypothesis? ______

Your null hypothesis? ______

What can you **conclude** *about the effects of gibberelic acid?* ________________________

d. Based on your results, what do you suppose are the differences between the amounts of GA_3 produced in dwarf plants and in normal plants? ________________________

e. Dwarfism in peas is a genetic characteristic. How would you relate this fact to the presence or absence of GA_3?

____

____

✓ EXERCISE C Tropisms

Tropisms are directional growth movements that occur in response to stimuli. Growth toward the stimulus is said to be a **positive response;** growth away from the stimulus is called a **negative response.** Movements occur because of unequal growth, resulting in a bending toward or away from the stimulus. Unequal growth appears to be the result of redistribution of auxin or some other hormone.

PART I Gravitropism (Geotropism)

Gravitropism is directional plant growth in response to gravity. Stems tend to grow up (negative gravitropism), whereas roots tend to grow down (positive gravitropism). Branches and leaves usually show intermediate responses (**plagiotropisms**).

Gravitropic responses occur in two steps. First, something within the plant must detect gravity (this "something" is thought to be starch grains called **statoliths**). Then differential growth must occur—one side of the plant part growing faster than the other, causing the plant part to bend. If a plant stem is placed in a horizontal position, starch grains fall toward the lower surface of the stem and seem to cause an increase in the auxin concentration in that region. The result is greater cell elongation in the lower surface of the stem than in the upper surface, causing an upward bending of the stem.

In roots, statoliths are found in the root cap. If a plant is placed in a horizontal position, statoliths cause an increase in concentration of a growth inhibitor called **abscisic acid** (ABA) on the lower surface of the root cap. Inhibition of growth on the lower surface causes a downward bending of the root.

a. Describe the differences between the gravitropisms of stems and roots.

____

____

Objectives

- ☐ Differentiate between the actions of auxin and abscisic acid (ABA).
- ☐ Describe how auxin causes negative gravitropic effects in stems.
- ☐ Describe how ABA causes positive gravitropic effects in roots.

✓ A. Negative Gravitropism in Stems

Two chicken gizzard plants (*Iresine* sp.) of approximately the same age and size were placed in the dark for 24 hours. Plant A remained in a vertical position. Plant B was placed in a horizontal position. In the space below, sketch these two plants.

Plant A Plant B

b. What must have happened to the distribution of auxin in Plant B?

c. How does this distribution result in the response observed in Plant B?

d. Why were the plants placed in the dark?

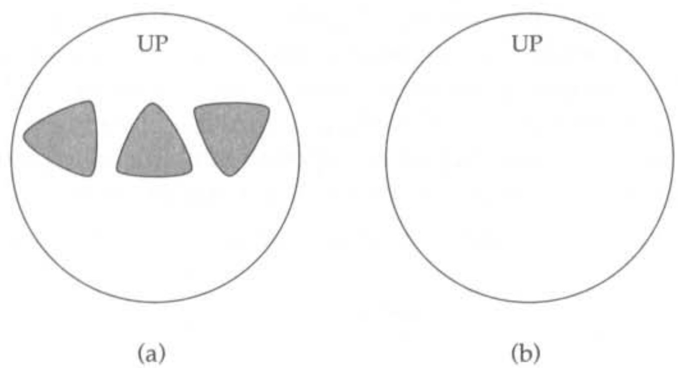
B. Positive Gravitropism in Roots: The Role of Seed Position

Procedure

First Week

1. Obtain three corn seeds, a Petri dish, and several paper towels.
2. Moisten a single paper towel and fold it so that it fits within the bottom of the Petri dish.
3. Place three seeds onto the paper towel oriented as indicated in Figure 31C-1a. Note the position of the corn seeds.

Figure 31C-1 *(a) Proper position of corn seeds to show positive gravitropism in roots. (b) Draw your results.*



4. Moisten a second towel and place it over the seeds. Cover with the top of the Petri dish, secure with tape, and label with your name and section. *Note:* The Petri dishes will be stored vertically. With this in mind, write "UP" on the lid of the dish as shown in Figure 31C-1a so the seeds will be stored in the correct horizontal direction.

Do you think gravity combined with the action of endogenous auxin will affect the development of roots as the seeds germinate? Formulate a hypothesis that addresses the question.

HYPOTHESIS:

NULL HYPOTHESIS:

What do you **predict** will happen to the three seeds?

What is the **independent variable**?

What is the **dependent variable**?

Second Week

After 1 week, observe the general direction in which the primary roots have grown and sketch your results in Figure 31C-1b.

e. How does the position of the seed affect the gravitropic response of the corn root?

____

Explain. ______________________________

f. Do roots exhibit positive or negative gravitropism? ______________________________

g. How might plants benefit from this gravitropic response? ______________________________

From the results of this experiment, what do you **conclude** *about the role of gravity in controlling root growth during development?* ______________________________

____

Do your results support your hypothesis? ______

Your null hypothesis? ______

Third Week

After 2 weeks, observe the general direction of coleoptile growth and sketch your results in Figure 31C-1b.

h. Does the coleoptile demonstrate a positive or negative gravitropic response? ______________________________
Compare this with your observations on stem gravitropism above.

C. Positive Gravitropism in Roots: The Role of the Root Tip

Procedure

First Week

1. Obtain four germinated bean seedlings with primary roots about 5 mm long. Place the seedlings on a moist paper towel so they do not dry out.
2. Obtain a razor blade and carefully cut the roots as follows (Figure 31C-2a):

   Seedling 1. Remove the entire root cap (the first millimeter of tissue).

   Seedling 2. Remove one-half of the root cap on one side.

   Seedling 3. Remove one-half of the root cap on the opposite side.

   Seedling 4. No treatment.

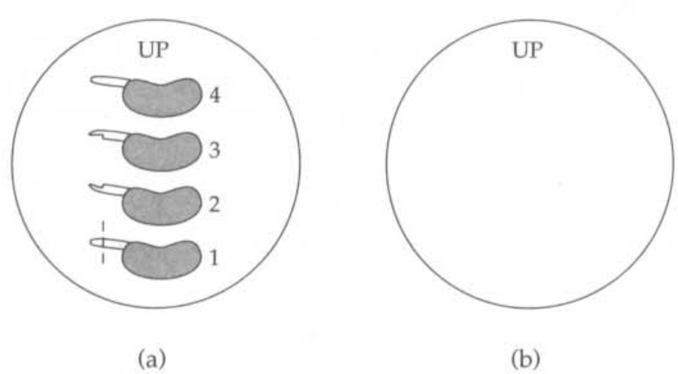


Figure 31C-2 *(a) Setup of germinated bean seedlings to show the role of the root tip in gravitropic responses of roots during seed germination. (b) Draw your results.*

3. Place the seedlings on a paper towel in a Petri dish as described in in Part 1B above, but make sure that all the roots are oriented in the same direction (Figure 31C-2a).

4. Cover the seedlings as described above and label the plate with your name and section. Mark "UP" as shown in Figure 31C-2a to ensure correct storage.

Formulate a hypothesis about the roles of the root cap and ABA in controlling root growth.

HYPOTHESIS:

NULL HYPOTHESIS:

What do you **predict** will happen to the roots of the four seeds? Why? ______

______

What is the **independent variable**? ______

What is the **dependent variable**? ______

Second Week

Observe the direction of root growth in each seedling. Diagram your results in Figure 31C-2b.

i. Is the root cap required for gravitropism in roots? (Compare seedlings 1 and 4.) ______

j. What happened to seedlings 2 and 3? ______

______

k. Did you find a relationship between the direction of bending and the side of the root with remaining root cap? ___

*Explain your **results.** What do you **conclude** about how ABA might be involved in controlling root growth?*

______

______

Do your results support your hypothesis? ______

Your null hypothesis? ______

PART 2 Phototropism

The growth of plants toward or away from light is called **phototropism.** Phototropism occurs because light influences the distribution of auxin in the region of elongation beneath the stem tip. Stems exhibit positive phototropic responses, while roots demonstrate negative phototropic responses.

Objectives

- ☐ Describe how differential accumulation of auxin in a stem affects how the stem responds to light.

Procedure

1. Examine the plants on demonstration. Note how the stems have bent toward the light (Figure 31C-3).

   a. In what region of the stem does the bending occur? ______

   b. Do the plants exhibit positive or negative phototropism? ______

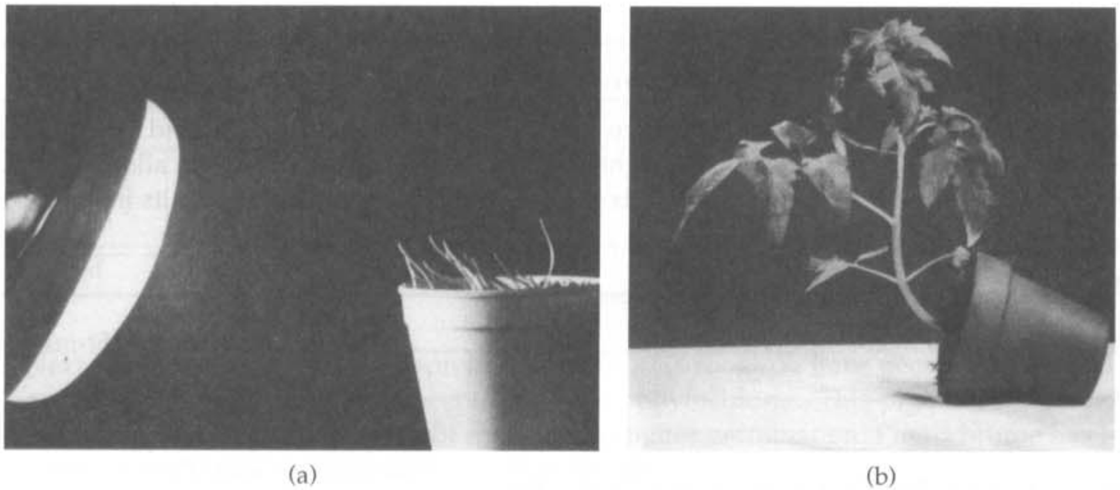


Figure 31C-3 *Phototropism in (a) germinating wheat seedlings (light at left) and (b) a young tomato plant (light from above).*

c. *Recall that auxin influences cell elongation. Based on what you have learned about other tropic responses, suggest how auxin is involved in stem bending.*

____

____

2. Sketch several cells in Figure 31C-4b to represent relative changes in size of cells on each side of the stem after exposure to light from one direction.

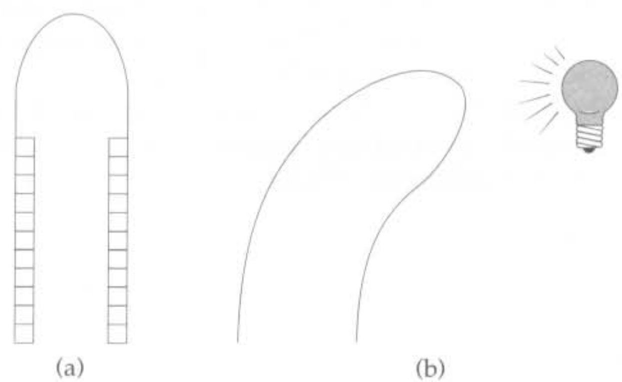


Figure 31C-4 *(a) Representation of cells in stem before exposure to a unilateral (one-sided) light source. (b) Diagram some cells to show relative cell length after exposure to a unilateral light source.*

✓ EXERCISE D Light-Induced Germination

Some plants regularly inhabit newly disturbed areas, such as cleared fields, while others grow only in areas that are already covered by vegetation. Some seeds that grow in disturbed areas require light to induce germination and will not germinate if covered by soil or other vegetation. In these *light-sensitive seeds,* the pigment **phytochrome** is the photoreceptor (light receiver).

Objectives

- ☐ State the role of the plant pigment phytochrome in light-induced growth responses.
- ☐ Explain how gibberellic acid affects the process of germination in light-sensitive seeds.

✓ PART 1 The Role of Phytochrome

Procedure

On demonstration are two varieties of lettuce seeds: Great Lakes and Grand Rapids. Fifty seeds of each variety were allowed to germinate in the light and 50 seeds of each variety were allowed to germinate in the dark. Count the number of germinated seeds in each category and enter the results in Table 31D-1.

a. Based on these data, which variety has a light requirement for germination? ______

b. Was the other variety light-inhibited? ______

c. Which variety has light-sensitive seeds? ______ *Which has light-insensitive seeds?* ______

Table 31D-1 Light Induced Germination in Lettuce Seeds

	Light		Dark	
Variety	Grand Rapids	Great Lakes	Grand Rapids	Great Lakes
Total number of seeds	50	50	50	50
Number germinated				
Percent germinated				

PART 2 The Forms of Phytochrome

From your results in the previous experiment, you have determined which variety of seeds is light-sensitive. In this experiment you will use the light-sensitive seeds to determine which *wavelength* of light is responsible for inducing germination.

Do you think that different wavelengths (different colors) of light affect germination in light-sensitive seeds? Formulate a hypothesis offering a tentative explanation about what might happen to seeds illuminated by different wavelengths of light.

HYPOTHESIS:

NULL HYPOTHESIS:

What do you **predict** will happen to seeds exposed to different wavelengths of light?

What is the **independent variable**?

What is the **dependent variable**?

Procedure

1. Fifty seeds were germinated in different colors of light. Count the number of germinated seedlings in each of the pots and determine the percent germination for each type of light. Record the data in Table 31D-2.

Table 31D-2 Effect of Wavelengths of Light on Germination

	A	B	C	D	E	F
Light conditions	Light	Dark	Blue	Green	Red	Far red
Total number of seeds	50	50	50	50	50	50
Number germinated						
Percent germinated						

2. Next, plot these data on the graph in Figure 31D-1. What you have generated is called an **action spectrum** for the photoreceptor pigment, phytochrome. This pigment is a protein and is responsible for absorbing the light required to trigger germination. Phytochrome has two forms: one absorbs red light and the other absorbs far-red light.

   a. *Which form of phytochrome induced germination in the light-sensitive lettuce seeds?*

   ____

   b. *Does the action spectrum indicate that red light is the only color absorbed by phytochrome?*

   ____

   From your results, what do you ***conclude*** *about how light of different wavelengths affects germination?*

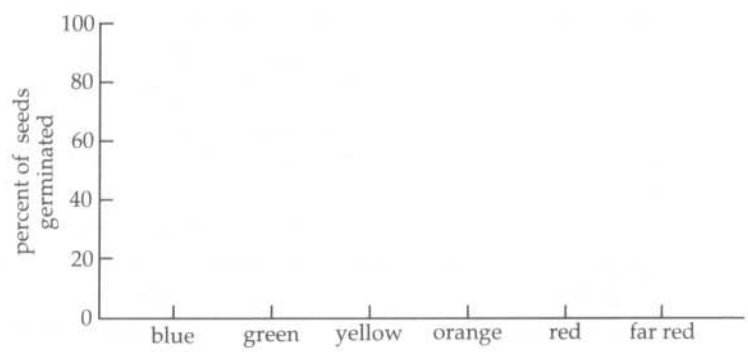
   ____

   ____

   Do your results support your hypothesis? ______ *Your null hypothesis?* ______

   c. *Based on the action spectrum, what color is phytochrome?* ______________________________

Figure 31D-1 *Effects of different wavelengths of light in inducing germination of lettuce seeds.*



PART 3 Germination and Gibberellins (*Optional*)

Some seeds require low temperatures, long days, or red light to germinate. In some species, the application of gibberellic acid can substitute for these dormancy-breaking conditions.

Procedure

1. Prepare four Petri dishes by placing a square of blotter paper in each.
2. In two dishes, soak the blotter paper with water. Mark the dishes "H_2O." In the other two dishes, soak the blotter paper with a solution of gibberellic acid. Mark these dishes "GA_3."
3. Place 20 light-sensitive lettuce seeds on the filter paper in each of the four dishes. Cover the dishes.

4. Wrap one of the "H_2O" dishes and one of the "GA_3" dishes in aluminum foil. The other two dishes will remain unwrapped.
5. Place the dishes in very low light. Keep moist. After 1 to 2 weeks of incubation, determine the percent germination and record your data in Table 31D-3.

Table 31D-3 Germination and Gibberellins

Treatment	Percent Germination
H_2O/foil	
H_2O/light	
GA_3/foil	
GA_3/light	

a. Did seeds germinate in the dark? ______ *Under what conditions?* ________________

b. What effect does gibberellic acid have on the germination of light-sensitive seeds?

____

EXERCISE E Photoperiodism

Everyone is aware that certain plants bloom only during particular seasons. But how do plants "know" when to bloom? They use several environmental cues, including temperature. However, most plants determine their seasonal responses by detecting the length of the day. The phenomenon is called **photoperiodism** and depends on the pigment phytochrome.

Plants are categorized as **long-day,** flowering only when light periods are longer than a critical length; **short-day,** flowering only when light periods are shorter than a critical length; or **day-neutral,** flowering independently of day length.

As noted in the previous exercise, phytochrome has two forms: a red-absorbing form (P_r) and a far-red-absorbing form (P_{fr}). Phytochrome is synthesized in the P_r form and can be converted to P_{fr} when it absorbs a photon of red light (in daylight, red wavelengths predominate over far red). And P_{fr} can be converted back into P_r when it absorbs a photon of far-red light. P_{fr} can also revert spontaneously to P_r in the dark.

During the day, the interconversion of $P_r \leftrightarrow P_{fr}$ reaches an equilibrium: approximately 60 percent of the phytochrome is in the P_{fr} form at noon on a sunny day. At night, the level of P_{fr} steadily declines as it is destroyed or converted to P_r.

P_{fr} inhibits flowering in short-day plants; when the night is long enough, a critical amount of P_{fr} is removed so the plant can flower. (If a short flash of red light interrupts the night, however, flowering is inhibited. Why?) In long-day plants, P_{fr} promotes flowering; if the night is short enough, sufficient P_{fr} is left at the end of the night to promote flowering (Figure 31E-1). Thus, it is the dark-period length (not the light-period length) that is important in determining flowering response, and phytochrome is responsible for mediating this activity. (It is generally agreed, however, that the control mechanism is more complex than phytochrome conversion alone.)

Objectives

- ☐ Describe how the length of the night affects flowering in long-day, short-day, and day-neutral plants.

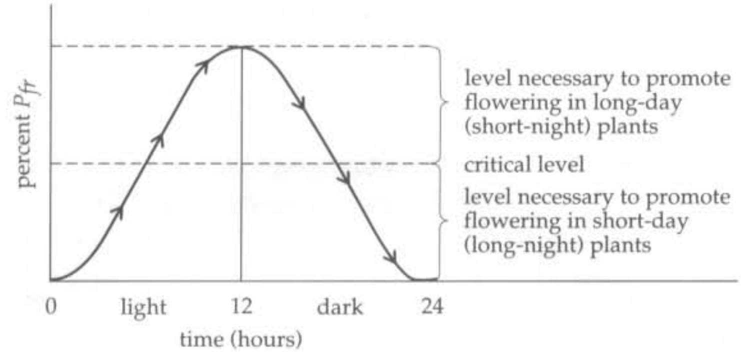


Figure 31E-1 *At dusk most phytochrome is in the* P_{fr} *form.*

Procedure

Observe each of three species of plants on demonstration. One plant of each pair was exposed to 8 hours of light and 16 hours of dark; the other to 16 hours of light and 8 hours of dark. In Table 31E-1, record the presence or absence of flowers or flower buds and determine whether each species is long-day, short-day, or day-neutral.

Table 31E-1 Photoperiodism

Species	Photoperiod (hours) Light	Dark	Flowering (+ or −)	Category: Long-Day, Short-Day, or Day-Neutral
A	8	16		
	16	8		
B	8	16		
	16	8		
C	8	16		
	16	8		

a. For each species of plant A, B, or C, relate the conversion of $P_{fr} \rightleftharpoons P_r$ *to the light-dark cycle and the effect on flowering.*

A. ____________________

B. ____________________

C. ____________________

Laboratory Review Questions and Problems

1. Normal plant development depends upon the interaction of external (environmental) factors and internal (chemical) factors. List at least four examples of each.

2. The word "hormone" comes from the Greek *hormaein*, which means "to excite." Why is this not a completely accurate description of the role that hormones play in controlling plant responses?

3. Explain how differential accumulation of auxin in a root and a stem apparently affects how the root and stem respond to gravity.

4. From your data and observations, complete the following table showing the mechanism of action and plant response for auxins and gibberellins (the table is partly filled in to help you organize your thoughts).

Hormones	Mechanism	Plant Response
Auxins	1.	1. Gravitropism
	2. Produced in apical bud	2.
	3.	3. Leaf or fruit drop
	4. Light influences auxin distribution	4.
Gibberellins	1.	1. Stem lengthening, bolting
	2. GA_3 substitutes for effects of red light to break seed dormancy	2.

5. Three other groups of hormones are important in the control of plant responses. From your reading, complete the following table.

Hormone(s)	Mechanism	Plant Response
Cytokinins	1.	1. Shoot growth; increase in callus tissue
Ethylene	1. Produced by fruits	1.
	2.	2. Leaf and fruit abscission
Abscisic acid	1.	1. Prevention of water loss from leaves
	2.	2. Acceleration of abscission

6. Explain how auxins might interact with cytokinins, ethylene, or abscisic acid (often antagonistically) to control plant responses.

7. Explain the relationship between the P_r and P_{fr} forms of phytochrome. Which of the two is the active form that induces a biological response?

8. Two groups of plants are exposed to a light cycle of 8 hours of light and 16 hours of darkness. The plants in group A normally flower under these conditions, but those in group B do not. In another experiment, groups of plants of the same two species are exposed to the same light cycle, but the dark hours are interrupted by flashes of red light every hour, then the results are reversed: plants in group A do not flower, but those in group B do flower. Explain these results.