Plant Growth: Tropisms

SC Academic Standards: 4.L.5B; 6.L.4A; 6.L.4B; 7.L.3A; 7.L.3B; H.B.2B; H.B.2C

NGSS DCI: 4-LS1.C; 5-LS2.B; MS-LS1-A; MS-PS3.D; HS-LS1.A

Science and Engineering Practices: S.1A.1; S.1A.2; S.1A.3; S.1A.4; S.1A.5; S.1A.6; S.1A.7

Crosscutting Concepts: Cause and Effect: Mechanism and Explanation; Structure and Function; Scale, Proportion, and Quantity; and Systems Models.

Focus Question(s): What is a tropism? What kind of growth responses to plants have to light, gravity, and centrifugal force?

<u>Background</u>: Tropisms are directional movement (or growth) responses that occur in response to a directional stimulus. Plants are not able to relocated if they happen to start growing where conditions are suboptimal. However, plants can alter their growth so they can grow into more favorable conditions. To do so requires the ability to detect where the conditions are better and then alter their growth so they can "move" in the appropriate direction. Plants growing on earth have evolved to respond to many different stimuli to help them orient themselves to their best advantage. One of the most commonly observed tropic responses in plants is **phototropism**, in which plant stems grow towards light (houseplants tend to lean towards the window where the light is usually stronger than inside the room). The word 'tropism' comes from a Greek word, *Tropos,* which means 'to turn'. Therefore, a tropism is a turn towards or away from a stimulus. When the growth or movement is towards the stimulus, it is called **positive tropism**. Likewise, when the growth or movement is away from the stimulus, it is called **negative tropism**. For example, roots respond *positively* to gravity by growing down into the soil. The trunk and branches respond *negatively* to gravity by growing up toward the sky. Tree trunks and branches respond *positively* to light, growing towards the sun and away from shady areas.

The downward growth of roots and the upward growth of shoots are examples of **gravitropism**. Germinating seeds grow best when the stem is vertical – so leaves will be in a position to capture maximum light levels – and germinating seeds also need water, and the water will be down in the soil. **Geotropism** is movement towards or away from the earth. Sometimes gravitropism and geotropism are used interchangeably, but geotropism may have applications for space travel. We can test this with a simulated gravitational field created by a record turntable - the rotating turntable creates a gravity with an outward force instead of the normal down. **Thigmotropism** is a growth response to touch, and is the reason vines will curl and wind their way around a fence pole or another plant – the side of the plant being touched doesn't grow as fast as the side not being touched, causing it to curl around the object it is touching. There is also **hydrotropism** and **electrotropism** – what do you think they mean? Last, plants also respond to physical stress, like wind, usually by a reduction in growth rate. Plants growing alongside a busy highway receive gusty bursts of wind and often have stunted growth (a growth response to mechanical stress). Plants growing near the ocean shore often have a windswept look caused both by winds and salt spray. **In this lab, we will investigate phototropisms, geotropisms, and gravitropisms.**

Tropic responses result from differential growth. Phototropism is generally the tropism that makes the most sense. We know that plants grow towards the sun, so they can make food through photosynthesis. This movement in response to sunlight is called **phototropism**, and is a blue-light-dependent response controlled by the action of specific blue light photoreceptors in the stem called phototropins. The way sunflowers turn in the direction of the sun throughout the day is an example of phototropism, as is houseplants bending toward the window. **Gravitropism**, which is the movement towards or away from gravity, is dependent on the presence of starch-filled plastids (amyloplasts) in specialized cells. When the orientation of the cells changes, the mass of the starch-filled plastids causes them to sink to the lower end of the cell. In all cases, phototropism, geotropism, and gravitropism, the plant growth hormone **auxin** is produced in certain cells and those cells grow bigger. With gravitropism, the tumbling of the amyloplasts triggers, through unknown mechanisms, an auxin buildup and differential growth that causes curvature to develop (as one side of the plant grows faster than the other side, kind of like wheels in a car that is turning – wheels on the outside edge of the curve cover a greater distance in the same timeframe). Roots and shoots respond differently to the auxin: roots curve down; shoots curve up. In the geotrophic lab exercise, below, auxin is produced and the outward force of the turntable causes the auxin to build up in the outermost parts of the plant - the parts nearest the edge of the turntable. Roots respond positively to the auxin and grow toward the auxin buildup; shoots respond negatively and grow towards the inside of the turntable, away from the auxin. Charles Darwin (of evolutionary theory fame) and his son Francis did a simple experiment with seedling shoots and phototropism: they exposed seedlings to light from one direction, and all grew toward the light. Then, they covered the base of some seedlings, and the tips of others, to determine which part of the seedling was "sensing" the light – and they discovered that when the tips were covered the plants did not bend toward the light. Other scientists furthered this research by cutting the tips off – still no bending. But if you cut the tip off and cover the stump with a layer of gelatin, then reattach the tip, the plant responds by bending towards the light! This suggested that a chemical signal was a growth stimulant as the phototropic response involves faster cell elongation on the shady side than on the illuminated side. Today we know that chemical is auxin, and that stems are positively phototropic and roots are negatively phototropic.

<u>Materials:</u> Ziploc bags or plastic petri dishes, stapler, <u>soaked</u> corn and/or bean seeds (use runner, or pole, beans if you are testing thigmotropism), radish seeds, water, paper towels (white, from grocery, not brown school ones), cotton balls, graduated cylinder (25ml), tape, wax pencil or marker, scissors, filter paper, record turntable ($25 at most thrift shops, need 45 rpm), light source, tin foil, protractor, twist ties, 5 small milk cartons per group.

<u>Previous Knowledge: (physics)</u>: Consider gravitropism as it relates to conditions found in space – we might better call this geotropism (movement towards or away from the earth). In order for humans to stay in space for prolonged periods of time, they must be able to grow their own food. Will this be possible? How will astronauts create an artificial "gravity" that initiates root and stem growth? Here, *centrifugal force* is used as a substitute for gravity in space.

Centrifugal force is an outward force that acts upon a mass rotating about an axis. Centrifugal force is generally expressed in multiples of the force of *gravity,* or G's. Therefore, the force of gravity on the surface of the earth is, by definition, one G. For this experiment it is useful to measure the magnitude of the centrifugal force on the plant. The magnitude of the centrifugal force exerted on an object depends on its angular velocity and distance from the center of rotation. Relative centrifugal force (FR) is represented by the following equation:

$F_R = 0.204v^2/D$ where v = peripheral speed of the seed in meters/sec

D = diameter of the circle of rotation in meters

Students will need to measure the diameter of the circle of rotation (and divide by two to determine the radius), calculate the circumference (2m) and record revolutions per minute (rpm) of the turning table.

To calculate v (in meters/sec), use the following equation:

v =(_______meters/rev)(________rev/min)(l min/60 sec)

<u>Part 1: Gravitropism</u>

*NOTE: One, you will want to soak the corn / bean seeds overnight prior to the start of this lab. Take a cookie sheet, cover it with very wet paper towels, add seeds, and cover with more wet towels (alternatively, you can soak seeds in a jar of water overnight). You will want to soak about twice as many seeds as you think you will need, not all will germinate. Two, The petri dishes are kept in a dark cupboard so that the only variable being tested is the seeds' response to gravity. Their response to light is not being tested. Students should find that the roots grow downward, illustrating the effects of gravitropism.

Question: Do plant roots and shoots respond to gravity?

Hypothesis: If plant roots are negatively gravitactic they will grow down, regardless of orientation of seed. Similarly, if plant shoots are positively gravitactic they will grow up, regardless of seed position.

Predictions: Roots will grow down, shoots will grow up.

Procedure:

1. Take a petri dish, and on the outside of the bottom use a marker or wax pencil to divide the round bottom into 4 sections. Label one section U (for up), D (for down) and L (left) and R (right).
2. Take four pre-soaked corn seeds that have been soaked overnight. Place them flat in the bottom of a petri dish with the seeds' pointed ends facing inward. Think of them as "hands on a clock" at 12, 3, 6, and 9, with one seed in each of the 4 sections.
3. Cut a piece of filter paper so that it just fits in the petri dish. Place the filter paper into the petri dish, covering the seeds. (Be careful not to disturb the positioning of the seeds.)
4. Without moving the petri dish, pour 15 milliliters of tap water on the filter paper. Then place enough cotton over the filter paper so that when the cover of the petri dish is put on, the paper and the seeds will not be able to move. The cotton should absorb any excess water.
5. Once you've placed the cover on the petri dish, tape it shut. Turn the petri dish over. You should be able to see the seeds in the bottom of the dish, in the same position they were originally placed.
6. With a wax pencil or marker, write the name of your group on the side of the petri dish.
7. Tape the petri dish containing seeds to the wall of a cupboard, with the bottom of the dish (showing the seeds) facing out. Close the cupboard door so that no light is exposed to the seeds for the next few days. You will open the door briefly to record observations each day, then shut the door again so seeds are kept in the dark (we want to test gravitropism, not phototropism).
8. Record length of root and shoot, as well as direction of growth, each day for the next week (5 days). What are your conclusions?

DAY	Root Length (mm)				AVG (mm)	Direction Root Points				Shoot Length (mm)				AVG (mm)	Direction Shoot Points			
seed	1	2	3	4		1	2	3	4	1	2	3	4		1	2	3	4
1																		
2																		
3																		
4																		
5																		

Table 1. Root and Shoot lengths (mm) and direction of growth (up, down, left, right).

Part 2: Geotropism (The 45 r.p.m. rotating turntable creates a gravity with an outward force instead of the normal down).

Question: Do plant roots and shoots respond to centrifugal force?

Hypothesis: If plant roots are positively geotactic they will grow toward the outward force, regardless of orientation of seed. Similarly, if plant shoots are negatively geotactic they will grow away from the outward force, regardless of seed position.

Predictions: Roots will grow towards the outside of the turntable, shoots will grow towards the center of the turntable.

Procedure:

1. Each group needs 4 pre-soaked bean seeds, 1 petri dish, filter paper, tin foil, and cotton balls. Place seeds in bottom of petri dish, oriented so the inner curved part is facing the center of the dish, and all 4 seeds are like the 12, 3, 6, 9 hands of a clock.
2. Place the filter paper over the seeds and add the 15 ml water to soak. Then, pack with cotton balls and place lid on petri dish, taping edges shut so water doesn't escape. Wrap with tin foil, so no light gets in.
3. Tape to the rotating disc of record player but don't turn on yet! Probably not more that 4-5 groups is best.
4. After two days Turn the turntable 'On' and set to 45 rpm (revolutions per minute). Let machine rotate continuously for 5 days.
5. Each day, open foil and peek at seeds and record root / shoot lengths and direction of growth. For lengths, measure main root, not branches (if any). For direction, imagine a line connecting the center of the turntable with the outer edge of the spinning turntable

and passing through your seed. Zero degrees will be the end of line connected to the center of turntable, and 180 degrees will be opposite end, at the outer edge. 90 degrees would be the line extending at a right angle upward, and 270 degrees will be the right angle down. Use a protractor to take angle measurements that are in between. So 0° means it is growing in ward, away from the outward force and 90° means it is growing toward the outward force. Again, auxin is produced and builds up toward the outside of the machine. Roots will grow towards the auxin buildup; stems will grow away from the auxin build up.

6. If the filter should dry, add water to dampen.

DAY	**Root Length (mm)**				**AVG (mm)**	**Angle of Root**				**AVG (deg)**	**Shoot Length (mm)**				**AVG (mm)**	**Angle of Shoots**				**AVG (deg)**
seed	**1**	**2**	**3**	**4**		**1**	**2**	**3**	**4**		**1**	**2**	**3**	**4**		**1**	**2**	**3**	**4**	
1																				
2																				
3																				
4																				
5																				

Table 2. Root and Shoot lengths (mm) and direction of growth (0°= in towards center of record player, 180°=out at right angles to edge of record player)

<u>Part 3: Phototropism</u> (*Note:* The goal is to determine how exposure to different amounts of light affects the growth of the plants. You may need to experiment with the amount of light (the number of holes), the duration of exposure, the height of the holes, or other factors to get a clear result).

Question: Do plant roots and shoots respond to light?

Hypothesis: If plant roots are negatively phototactic they will grow away from light. Similarly, if plant shoots are positively phototactic they will grow towards the light.

Predictions: in well-lit containers shoots will grow up, roots down. In containers with light coming from only one direction, shoots will grow toward the light (roots will still grow down as they are positively gravitactic).

Procedure:

1. Each group needs 5 small milk cartons.
2. Using a permanent marker, label the sides of the milk cartons with the numbers 1–5.
3. For carton # 1, cut off the top of the carton with the scissors.
    a. The plants in this carton will grow in normal lighting.
4. For carton # 2, do not make any holes.
    a. The plants in this carton should germinate and start to grow, but will be kept in total darkness.
5. For the following cartons, use the hole punch to make holes in <u>one</u> side of each carton, about 6 cm from the bottom. You will need to open the top of the milk carton to make the holes.
    a. Carton #3: One hole
    b. Carton #4: Two holes; should be near each other, but not overlapping
    c. Carton #5: Four holes; should be near each other, in a cluster
6. Be sure to write in your lab notebook the number of holes in each carton, and what each carton's conditions will be once the experiment begins (lighting).
7. Now make some additional holes to allow air into the cartons and excess water to drain out by punching 10 holes in the bottom of each carton using a pen. Each hole should be about 5 mm in diameter.
8. Put about 3 centimeters (cm) of moist potting soil into each carton. Keep the amount of soil equal in each carton.
9. Moisten the potting soil with water. It should just be moist, not saturated.
10. Put four pre-soaked radish seeds in each carton. Bury the seeds to a depth of about 1 cm, or follow the directions on the seed package for the recommended depth. Plant all of the seeds at the same depth.
11. Use the permanent marker to put a letter on the side of the carton near each seed so that you can identify them as they grow. For example, label them A, B, C and D, with markings inside the carton.
12. Close cartons 2–5 and seal them with clear tape. Orient boxes so that those with holes have holes all facing the same direction.
13. Wrap the tops and sides of cartons 2–5 in aluminum foil to block light from reaching the plants. Don't cover the holes in the bottom. Write the number of the carton onto the aluminum foil with the permanent marker.
14. Check carton #1 each day. Wait until the seeds in carton #1 have germinated and grown about 3 cm. Then begin the exposure to light for the plants in cartons 3–5 (remember, carton #2 stays sealed). *Note:* Start the exposure to light in the morning so that the plants have a full day of light on the first day.
15. Using the scissors, remove the foil only from over the hole in carton #3. Leave the rest of the foil in place to keep the plant in darkness, except for the light from the one hole. Likewise, remove the foil only from over the holes in cartons #4 and #5. Leave the rest of the foil in place to keep the plant in darkness, except for the light from the holes.
    a. Use the clear tape to hold the aluminum foil in place around the holes, if desired.

16. Place the cartons in a well-lit room, but out of direct sunlight. As an option, you can use a grow lamp as a light source. Expose the plants to light during the day. Keep them in darkness at night.
17. The next morning (day 1), take the all of the cartons to a dimly lit room, open the cartons, and observe the plants.
    a. Use the protractor to measure the angle of the stems. If the protractor is too big to fit into the cartons, use a twist tie to obtain the angle for the stem. Position a twist tie parallel to the base of the stem to be measured. Bend the twist tie to match the angle of the bend in the stem. Use the protractor to record the angle of the twist tie.
    b. Record your observations of the plants from all five cartons in your lab notebook.
    c. As an option, check the plants more often than once per day in the morning. Keep the light exposure to a minimum while taking measurements.
    d. Do not let the soil dry out. If needed, add some water (equal amounts) to each plant, using an eye dropper or graduated cylindar.
18. Return the cartons to their original states (covered or uncovered), place them in the light again, and allow them to grow for another day.
19. The next morning (day 2), again take the cartons to a dimly lit room, open the cartons and observe the plants. *Note:* Remember to treat all of the plants exactly the same. The only difference between the plants in the different cartons should be the amount of light to which they are exposed.
20. Repeat steps 17-18 for five days.
21. For each day you collected data on the angles of the plants, graph the angle of the stems vs. the amount of light (the number of holes) to which the plants were exposed. You can graph the data for each plant individually, or graph the average of the angles within a carton, or class averages (replication!).

DAY	**AVG (deg)**	**Shoot Length (mm)**				**AVG (mm)**	**Angle of Shoots**				**AVG (deg)**
seed		**1**	**2**	**3**	**4**		**1**	**2**	**3**	**4**	
1											
2											
3											
4											
5											

Table 3. Phototropism: container 1 (full light)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 4. Phototropism: container 2 (full dark)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 5. Phototropism: container 3 (1 hole)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 6. Phototropism: container 4 (2 holes)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 7. Phototropism: container 5 (4 holes)

Container #	AVG Angle of Shoots (degrees)	AVG shoot length (mm)
1 (light)		
2 (dark)		
3 (1 hole)		
4 (2 holes)		
5 (4 holes)		

Table 8. Class data on phototropism

Data Analysis: For gravitropism, you can easily graph average root length and average shoot length on the Y versus Time (days) on the X. For geotropism, you may want to graph average root and shoot length versus time, as in gravitropism, and/ or do a pie chart for roots, and angle of direction of root growth (0-10 degrees, 10-20 degrees and so on). Do the same with shoot growth. For phototropism, it is easiest to graph day 5 class data (after shoots are established, and growing. Using Table 8, graph angle of stem versus amount of light received (= number of holes, light, and dark). This way you can emphasize the importance of replication.

Extensions:

Light in a Shoebox - At one end of a shoebox, cut out a small opening that will allow sunlight in. Create a "maze" by placing one or two cardboard dividers (with a "window" hole cut out, positioned so the plant would have to grow in an S-curve to reach the top of the box where the light source is). Plant a runner (pole) bean seed in a small pot and water well. Place pot in the box. Close box up, water as needed, and watch for the runner bean plant to get to the top of the box.

For **phototropism**, try these ideas:

- Keep the number of holes the same and vary the time of light exposure. For example, use a carton with four holes and expose the plant to light for 1/2, 1,

2, 4, and 8 hours per day for three days. What is the minimum amount of time required to observe initial growth toward the light?
- Devise a way to determine if the color of the light affects the phototropic effect.
- Try different kinds of lamps. For example, a grow lamp, a fluorescent lamp, and an incandescent lamp.
- Which is more effective for producing the phototropic response: a bright light with a short exposure, or a dim light with a long exposure? For example, try comparing eight holes for 1 hour, and one hole for 8 hours.
- Cut off the tips of the growing stems before you expose them to light. What is the minimum size you need to cut off to block the phototropic response?
- What happens if you put one hole on one side of the carton, and two holes on the opposite side? Or two holes each on opposite sides? Keep the surrounding light uniform.

Reflection Questions:

- **Which grows first, the shoot or root?** (the root emerges first)
- **How does the response of a root to gravity help a plant?** (so the root grows down into the soil where it can get water and dissolved nutrients and attach to a firm base / support / anchor).
- **Consider plant roots and stems. Explain which tropisms affect both these plant organs. Do any tropisms affect both plant organs? Consider both positive and negative tropic responses.**
- **Rain forests are unique and diverse plant habitats. Discuss tropisms that plants need to survive at various levels in the forest. Include the canopy, the understory, and the forest floor in your discussion.** (for example, plants on forest floor need to grow up, fast, towards any light available or risk being shaded - so many grow tendrils that – with thigmotropism – grab on to other plants and vine their way upwards.
- **Observe flowers growing in your neighborhood. Do they change the way they grow depending on where the light is? If so, how does this help the plant survive?** Many plants, especially dandelions, hold their flowers directly facing the sun – and as the Earth moves (and thus sun appears to move) the flower tracks the sun from east to west).
- **What do you think would happen if you place a light source below the plant? How would the stem grow?** (towards the light).

Models and Explanations: In this lab we explored plant growth responses to stimuli. These responses are called tropisms, and can be positive (moving or growing towards the stimulus) or negative (moving or growing away from the stimulus). **A student who demonstrates understanding** of these concepts will correctly explain the direction of growth in a given situation (such as the light box extension). Students will know that roots are negatively phototactic but positively gravitactic, and shoots are positively phototactic and negatively gravitactic. **Further, students who understand these concepts can extrapolate** to animals, explaining why some animals might be negatively or positively phototactic.

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Student Worksheet:

Tropisms are directional movement responses that occur in response to a directional stimulus. Plants are not able to relocated if they happen to start growing where conditions are suboptimal. However, plants can alter their growth so they can grow into more favorable conditions. To do so requires the ability to detect where the conditions are better and then alter their growth so they can "move" in the appropriate direction. One of the most commonly observed tropic responses in plants is **phototropism**, in which plant stems grow towards light. As anyone who has grown plants near a window knows, the plants tend to lean towards the window where the light is usually stronger than inside the room. Another commonly observed tropic responses is **gravitropism**, where a plant will grow so that it stays oriented relative to the source of gravity (a potted plant that gets knocked over doesn’t grow horizontally). With **geotropism**, imagine the plant growing in outer space: how will it orient towards the earth? We can test this with a simulated gravitational field created by a record turntable - the rotating turntable creates a gravity with an outward, centrifugal, force. Remember, tropisms can be positive or negative. In this lab we will test the effects of phototropism, gravitropism, and geotropism on plants.

DAY	Root Length (mm)				AVG (mm)	Direction Root Points				Shoot Length (mm)				AVG (mm)	Direction Shoot Points			
seed	1	2	3	4		1	2	3	4	1	2	3	4		1	2	3	4
1																		
2																		
3																		
4																		
5																		

Table 1. Gravitropism: Root and Shoot lengths (mm) and direction of growth (up, down, left, right).

DAY	Root Length (mm)				AVG (mm)	Angle of Root				AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed	1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4	
1																				
2																				
3																				
4																				
5																				

Table 2. Geotropism: Root and Shoot lengths (mm) and direction of growth (0^o= in towards center of record player, 180^o=out at right angles to edge of record player)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 3. Phototropism: container 1 (full light)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 4. Phototropism: container 2 (full dark)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 5. Phototropism: container 3 (1 hole)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 6. Phototropism: container 4 (2 holes)

DAY	AVG (deg)	Shoot Length (mm)				AVG (mm)	Angle of Shoots				AVG (deg)
seed		1	2	3	4		1	2	3	4	
1											
2											
3											
4											
5											

Table 7. Phototropism: container 5 (4 holes)

Container #	AVG Angle of Shoots (degrees) after 5 days	AVG shoot length (mm) after 5 days
1 (light)		
2 (dark)		
3 (1 hole)		
4 (2 holes)		
5 (4 holes)		

Table 8. Class data on phototropism – day 5 results.

Reflection Questions:

- **Which grows first, the shoot or root?**
- **How does the response of a root to gravity help a plant?**
- **Consider plant roots and stems. Explain which tropisms affect both these plant organs. Do any tropisms affect both plant organs? Consider both positive and negative tropic responses.**
- **Rain forests are unique and diverse plant habitats. Discuss tropisms that plants need to survive at various levels in the forest. Include the canopy, the understory, and the forest floor in your discussion.**
- **Observe flowers growing in your neighborhood. Do they change the way they grow depending on where the light is? If so, how does this help the plant survive?**
- **How would a forest plant respond to water (Hydrotropism)?**
- **Will plants respond differently to different colors of light?**
- **Describe how the plant growth hormone auxin is responsible for phototropism.**