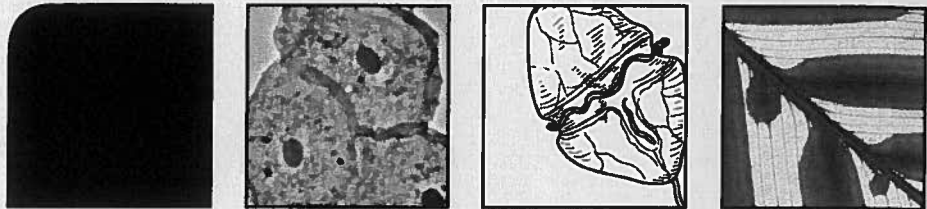


## CHAPTER 2



### HYPOTHESIS FORMATION AND EVALUATION

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*"Applications of scientific knowledge influence all aspects of modern life...an understanding of science can be personally rewarding. It can add to our appreciation of day-to-day events, leading to a sense of awe about how nature works." (Cain, et al., 2000)*

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This course aims to help you develop a better understanding of the process which scientists use to generate knowledge. An understanding of this process will enable you to more critically evaluate and apply scientific information. Imagine that your neighbors asked you to attend a meeting to help sort through the opposing claims of two groups. In the meeting, one group presented scientific evidence supporting the establishment of a biotechnology business adjacent to your neighborhood; a second group presented scientific results suggesting the establishment of the biotechnology firm could lead to release of dangerous pathogens. Your neighbors would expect you, as an educated member of society, to help them sort through the validity of the two opposing claims. While it is unrealistic to expect that we can become fluent in all the minute details of science, we do hope that becoming familiar with general principles and becoming familiar with the process that has generated this knowledge will help us effectively, and more critically, evaluate the validity of scientific claims.

Although scientists use a wide range of approaches in their work, science as a knowledge-producing process uses a fairly well-defined method to generate and evaluate ideas. Science begins with activities which stimulate a well-honed and informed sense of curiosity about a subject. Scientists may be studying interactions between proteins in a bacterium or they may be studying interactions between mammals in the canopy of a tropical rainforest. Regardless of their subject, they must foster a desire to observe their subject, to discuss the subject with other scientists, to be involved in applications of their studies to societal problems, and to teach and learn. As scientists continue to explore a subject, this creative mix of observation and communication may lead to the formation of a specific type of idea—a hypothesis. A biological hypothesis is a tentative claim about a pattern in nature or an explanation of an underlying biological mechanism. To be considered a hypothesis, these claims also must be able to generate testable predictions.

Once a scientist has generated a hypothesis, and used it to develop a prediction, she conducts an experiment to test the accuracy of the prediction, and by doing so, to test the validity of the hypothesis. If the observed results of the experiment match the predictions of the hypothesis, the test has supported the hypothesis. If the observed results do not match the predictions of the hypothesis, the hypothesis has not passed the test; it has not been supported. Either outcome makes a valuable contribution to the growing body of scientific knowledge.

#### INTRODUCTION TO THE EXERCISE

One of the fundamental goals of this laboratory course is to provide you with a more complete understanding of the way science works. This understanding will help you live a healthier, more productive, and simply more interesting life. Science is an important part of our personal lives; for example, we rely on products of medical science throughout our lives. In addition to affecting our personal lives, our ability to evaluate and carefully apply science to societal issues influences the quality of our professional and civic contributions to society. As we apply scientific methods and information to both personal and societal problems, we are participating in the process of science. These applications of science test the strength of scientific theories and often identify parts of theories that need to be refined or replaced.

Understanding the entire process that generates and evaluates scientific ideas will help you more critically and effectively appreciate scientific ideas and apply them to issues in your life. Generally, this process works its way through the following stages:

#### EXPLORATION AND HYPOTHESIS FORMATION

The goal of this stage is to generate an interesting and testable hypothesis. A **hypothesis** is a testable statement that suggests a pattern or proposes an explanation of a pattern. Hypothesis formation is a subjective and creative process usually based on observation or previous knowledge. It cannot be simply prescribed; however, it is possible to create conditions which increase the probability that an interesting hypothesis will be created. These conditions include fostering a strong sense of curiosity while making and considering initial observations of a phenomenon. Hypothesis formation is also promoted by considering observations in light of general theories. A **theory** is an overriding concept that ties together many hypotheses.

#### EXPERIMENTAL DESIGN AND PREDICTED RESULTS

In this stage of scientific process, we determine a way to manipulate and observe a system to test our hypothesis. Experiments are designed so that the results observed during the experiment can be fairly compared to the results predicted by the hypothesis.

Many hypotheses propose relationships between two variables. For example, someone might propose the hypothesis that infectious diseases spread more quickly in crowded populations. A standard approach to testing such a hypothesis is to isolate the two variables, change one, and see if this causes a change in the second variable. The variable that the experimenter changes or manipulates is called the **independent variable**; the response that the experimenter observes is the **dependent variable**. In our example, the independent variable is population density and the dependent variable is the spread of disease. In many cases, it is either impractical or unethical to experiment with the actual system, so the researcher uses a **model system**, such as non-human subjects or even computer simulations.

#### CONDUCTING THE EXPERIMENT AND OBSERVING THE RESULTS

This stage requires careful attention to detail as the independent variable is manipulated and as the results are observed and recorded. If scientists conclude that the observed results of an experiment do not support the hypothesis, they may discover that there are other factors influencing the dependent variable and altering any possible relationship between the independent and the dependent variable. A **confounding variable** is a variable that is not the focus of the experiment, but may be correlated with the independent or the dependent variable and may cause the scientists to interpret the observed results incorrectly. Whenever possible, confounding variables should be eliminated by setting up the appropriate controls in the design of the experiment.

#### CONCLUSION

At this point, scientists compare the results predicted by the hypothesis to their observed results to determine if the hypothesis was supported or if it should be rejected. This stage should also include careful considerations of the methods: were they conducted in a manner that was consistent with the original design? Were there any hidden assumptions in the original design that may have influenced the results or the conclusion?

#### IMPLICATIONS

At the end of an experiment, scientists consider how their conclusion might relate to other ideas. How might it be used to help people solve problems or address issues? What do the experimental results or conclusion tell us (or imply) about larger issues in science or medicine or in the natural world? Should the hypothesis be modified? Should a new hypothesis be proposed and tested? At this point scientists often engage in discussions with other scientists and with people from other professions as they attempt to determine the importance of their conclusions. In a healthy research program, hypotheses are often rejected and new, improved ones are proposed and subsequently tested.

## CONCEPT MAPS

Figure 2-1 is a visual representation of the relationships between components of the scientific process. This type of diagram is called a concept map. Concept maps have been used in classrooms for more than 30 years (Novak, 1988). They are a very effective mechanism for organizing a body of knowledge and representing the connections between ideas or concepts. Concept maps consist of nodes (such as the gray nodes in Figure 2-1) connected by directional lines. Each node contains one or two words representing a key idea of the topic. Very often the concepts are organized in a hierarchical manner. The connecting lines are labeled to identify the relationship between two concepts (Zeilik, no date).

Concept maps will be an integral component in a number of your lab exercises this semester. Initially, you will construct concept maps while working with your fellow students during lab. By the end of the semester, you will become more experienced with constructing maps of your own. The basic steps of constructing a concept map are as follows:

1. List all of the key concepts (main ideas) that relate to the topic of your concept map.
2. Rank the list of concepts. This ranking can be from most general to most specific or most important to less important concepts.
3. Begin to organize your map, placing concepts on the map. You may choose to place the concepts in a hierarchy if this is the best way to organize them.
4. Add the connecting lines between concepts. Each line should be directional (either unidirectional or bidirectional) and must be labeled to indicate the relationship between the concepts. The relationship between two connections should make logical sense when you read it.
5. Look for cross-links. Look for relationships between concepts in different regions of your map.

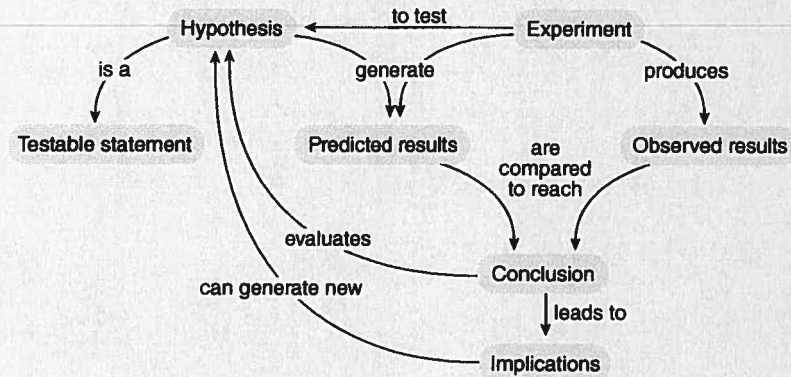


FIGURE 2-1. Concept map of the scientific process.

Consider the concept map for the topic of scientific process (Figure 2-1). During today's lab activities, your instructor will guide you in a discussion to answer the following questions:

1. List all the concepts shown on the map.
  
2. Explain, in your own words, the relationship between "hypothesis" and "experiment."
  
3. How can two concepts be joined together in their relationship to a third concept? For example, how do the "hypothesis" and the "experiment" both relate to the "predicted results"?

4. One relationship on the map states that the “conclusion evaluates (the) hypothesis.” What does this mean? Is this relationship valid only if the experimental results support the hypothesis?

#### E X P E R I M E N T A L D E S I G N

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Throughout this course you will perform experiments based on the scientific process. At first it may seem difficult to approach a problem using this method. In reality, we use the scientific process everyday. Our basic problem solving techniques involve the same steps seen in the scientific process.

Seven experiments are described on the following pages that illustrate the components of designing a good experiment. During lab today, the class will be divided into small groups of three to four students. Each group will be assigned to analyze one or two of these experiments and report their answers to the class. In your analysis you should identify a hypothesis and make a specific prediction from it. You should also identify the independent and the dependent variables.

EXPERIMENTAL DESIGN PRACTICE #1

John's parents would not let him study while listening to CDs in his room. They did not believe he could concentrate with the background noise. He decided to test this idea with an experiment on his class. Each Friday his English class took a vocabulary quiz on 25 new words learned that week. John obtained his teacher's permission to try his experiment. On the first Friday of the experiment John played a rock song in the classroom while the class took the test. The following week, the class took the test with the normal quiet atmosphere of a classroom. John calculated the average score on the two vocabulary tests.

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HYPOTHESIS:

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PREDICTED RESULTS:

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INDEPENDENT VARIABLE:

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DEPENDENT VARIABLE:

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## EXPERIMENTAL DESIGN PRACTICE #2

Sam wished to investigate how fertilizer run-off affects the growth of algae in freshwater lakes and streams. He set his experiment up in this way: He placed 900 mL of water into each of five 1000-mL glass beakers. To each beaker he added 5 mL of water from an aquarium which contained a large concentration of algae. The beakers were placed under a grow light that was timed to provide 12 hours of light each day. Liquid fertilizer was added to the beakers in the following amounts: beaker 1—no fertilizer, beaker 2—2 mL fertilizer, beaker 3—4 mL fertilizer, beaker 4—6 mL fertilizer, beaker 5—8 mL fertilizer. Each week a random sample from each of the beakers was examined under a microscope to get a count of the number of algal cells present.

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HYPOTHESIS:

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PREDICTED RESULTS:

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INDEPENDENT VARIABLE:

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DEPENDENT VARIABLE:

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EXPERIMENTAL DESIGN PRACTICE #3

Stephanie conducted an experiment to determine if the color of a maze would affect the time it took for a mouse to learn to run through it. She constructed five identical mazes of plywood. She painted them white, yellow, red, blue, and green. She purchased 10 young mice at a local pet store. She ran two mice through each maze until the mice could run it twice without making an error. She then compared the number of runs it took the mice in each color maze to learn it.

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HYPOTHESIS:

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PREDICTED RESULTS:

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INDEPENDENT VARIABLE:

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DEPENDENT VARIABLE:

## EXPERIMENTAL DESIGN PRACTICE #4

Lilly is big on milk; she's an active 12-year-old kid and goes through a gallon of regular whole milk in about a week. Her brother, Bennett, is in high school and thinks he knows everything. He doesn't drink a lot of milk, but he's heard that organic milk is better for building muscle and bone, so that is the only kind he'll drink. Lilly is surprised that Bennett's milk doesn't go bad in the carton as quickly as hers, and sometimes lasts as long as three weeks, whereas her regular milk goes bad after about 10 days. She decides to conduct an experiment where she buys different brands of milk, including organic milk, milk from a local dairy, and store-brand milk purchased at the supermarket. She pays her brother Bennett to taste a sample of each one after 15 days and records his comments about the freshness of each.

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HYPOTHESIS:

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PREDICTED RESULTS:

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INDEPENDENT VARIABLE:

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DEPENDENT VARIABLE:

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## EXPERIMENTAL DESIGN PRACTICE #5

Kim's Dalmatian, Tigger, always eats the same brand of food. Although he does everything else at lightning speed, he is a very slow eater. After watching a TV commercial touting the irresistible taste of Puppy Yums Dog Vittles, she decides to conduct an experiment comparing Tigger's regular food (K-9 Crunchy Bits), Puppy Yums Dog Vittles, and a store brand that cost 1/3 as much as the advertised food. Kim gave Tigger the same quantity of each different food, on three successive evenings, and used a stopwatch to determine Tigger's dinner-time munching speed.

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HYPOTHESIS:

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PREDICTED RESULTS:

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INDEPENDENT VARIABLE:

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DEPENDENT VARIABLE:

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EXPERIMENTAL DESIGN PRACTICE #6

Timothy heard that a girl is more likely to talk with a guy she doesn't know if he wears something red. Cool colors like blue and green bore girls, and they won't be interested, he was told. Ever the scientist, Timothy decides to conduct his own experiment, using two of his friends on two different days. On the first day, one friend wears a medium blue shirt, and the other wears a red one. At a local bookstore they count how many girls they each engage in conversation for a period longer than four minutes before leaving the aisle. On the second day, after swapping shirt colors, they repeat the experiment, in the same bookstore.

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HYPOTHESIS:

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PREDICTED RESULTS:

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INDEPENDENT VARIABLE:

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DEPENDENT VARIABLE:

## EXPERIMENTAL DESIGN PRACTICE #7

Jack and Jill live in the New Mexico mountains near a lake and love to fish. They differ in bait preferences, however, and decide a wager is the only way to settle the issue. They conduct an experiment with Jack selecting his favorite bait—bits of cheese—and Jill selecting hers—pieces of hotdog. They go fishing on three different days. Each day, Jill spends some of the time fishing with Jack's cheese and some time using the pieces of hotdog. Jack does the same. They compare the total number of fish caught with the cheese with the number of fish caught with the hotdog.

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HYPOTHESIS:

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PREDICTED RESULTS:

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INDEPENDENT VARIABLE:

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DEPENDENT VARIABLE:

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## WRITING A LABORATORY REPORT

*Everything should be made as simple as possible, but not simpler.*—Albert Einstein

Scientific writing is often judged by how easily it conveys ideas and facilitates learning (McMillan, 1997). To communicate well in a laboratory report, you must understand what you did, what you want to say, and why it is important. It is often challenging to clearly convey laboratory methods and results in written form. Scientific writing is a skill that must be learned and practiced. Laboratory reports are written in the same style as research papers intended for publication. These types of reports are generally divided into six distinctive sections: Abstract, Introduction, Methods, Results, Discussion, and References. Appendix 1 of this laboratory manual, “Writing an Effective Laboratory Report,” provides an analysis of the content and format of each section of a lab report.

Writing partial or complete laboratory reports will be a large part of this course. The following exercise will familiarize you with the format of research papers and laboratory reports.

In the next few pages of this chapter is a laboratory exercise entitled “Plant Behavior” that has been used in another introductory biology laboratory manual. Within the lab exercise, student responses and the student’s observed results have been filled in. Following the lab exercise, you will find a sample laboratory report written upon completion of the “Plant Behavior” exercise. You should carefully read both the exercise and the lab report before answering the questions.

After reading the lab exercise on plant behavior and the sample student lab report, answer the following questions concerning the student lab report.

1. Title.
  - Why is the title of the lab report so long? The title is not cute and catchy like a newspaper headline. Why not?
2. Abstract.
  - What kind of information does the abstract contain? Does the abstract contain information from the Results or Discussion section of the lab report? How long is the abstract?
3. Introduction.
  - Highlight or underline an example of background information on plant behavior found in the Introduction. Are there references in the Introduction? If so, highlight and label an example. Why would references be found in the Introduction? Does the Introduction address the question that is being asked in this paper? Find the hypothesis within the report and highlight or underline it. Is the hypothesis clearly stated? Do the authors explain the results predicted by the hypothesis?

- 
- The hypothesis of an experiment is usually included in the Introduction of a lab report. Find the hypothesis in the lab report and compare it to the way the hypothesis was stated in the “plant behavior” exercise. Exactly how was it stated in the exercise? Exactly how was it stated in the lab report?
4. Methods.
    - Does the Methods section of the lab report provide a list of equipment used in the experiment? Does the Methods section provide you with step-by-step instructions for performing the experiment? In other words, is the Methods section written like your lab manual? Are there any references cited in this section?
    - Describe the style of writing used in the Methods section of the paper.
    - Did the author write in the first person using “I,” “my,” “we,” or “our”? If not, what is the format of the sentences?
    - Identify the dependent variable and the independent variable.
    - Highlight and label an example of a specific procedure the researchers used.
  5. Results.
    - The results of the experiments are described in words. The tables, graphs and figures support the information given in the results.
    - Highlight and label two examples of information in the written results that are supported by a table or a figure.
  6. Discussion.
    - Does the Discussion repeat any information given previously? Highlight and label an example. Why is this done?
    - Find an example of a reference in the Discussion. Highlight and label it. Why was this reference important to the lab report?
    - Did the experimental results support or refute the original hypothesis?
    - Did the researchers pose any new questions or ideas? Highlight and label an example.
  7. References.
    - Is every one of the References cited somewhere in the body of the lab report?

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## SAMPLE LAB EXERCISE

## PLANT BEHAVIOR: STIMULUS AND RESPONSE

One of the defining characteristics of living organisms is the ability to sense and respond to their environment. An animal's ability to see, hear, or taste are clear examples. Sensory systems in all organisms include the common components of a **stimulus**, a **receptor** and a **response**. The organism must have a receptor that detects the stimulus. A series of biochemical and cellular events translate the stimulus into a response by the organism. For example, as you read this page, light (stimulus) enters your eyes until it reaches your retinas (receptor). A series of neurological events carries the information from the stimulus to your brain for assimilation. In response, your eyes continue to scan across the page.

Plants also sense and respond to their environment. Many plants have the ability to respond to touch or wind (stimulus) by stiffening their cell walls (response). This results in shorter, stockier plants that are more resistant to damage from the wind. The receptor and the events that translate touch or wind into the plant's response are currently not known.

Some plants produce long, thin tendrils that are modified leaves or modified stems. Tendrils wrap themselves around any solid object they contact, allowing the plant to cling and climb. This growth pattern is one of many types of tropism. A **tropism** is a response to the external environment that triggers a movement or a directional growth by the plant. Tendrils are exhibiting **thigmotropism** (thigma, touch). Identify the environmental stimulus and the plant's response during thigmotropism.

Stimulus: *physical touch*

Response: *plant changes direction of growth*

Another type of tropism is involved in seed germination. Consider the placement of a seed in the soil. As the seed germinates, the root grows downward and the shoot grows upward, regardless of the seed's orientation in the soil. In this case, what stimulus do you propose the seed is detecting? What is the plant's response to this stimulus?

Stimulus: *gravity*

Response: *plant grows upward*

Can you propose a specific name for this type of tropism? *gravitropism*

One stimulus that plants are extremely responsive to is light. Plants utilize light as an environmental signal to regulate many aspects of their life cycle including germination, growth, and flowering. Plants can sense and respond to different properties of light including the light wavelength, light intensity, or the duration of exposure to the light. One characteristic of plant growth is phototropism. **Phototropism** is growth or movement toward light. Some of the early experiments in phototropism were published by Charles Darwin (1881). After observing that plants tend to grow toward sunlight, Charles Darwin and his son Francis began to investigate what might be controlling this phenomenon. They germinated seeds of canary grass in the dark. The seedlings were then positioned next to a single source of light—a candle. The candle provided full light (all wavelengths) to the plant and the seedlings began to bend toward the candle. If they placed a solution of potassium dichromate between the candle and the seedling, no bending occurred. Potassium dichromate filters out blue light so Charles and Francis Darwin concluded that the plants were responding only to the blue wavelengths of light.

The Darwins continued their experiments to determine what part of the grass seedling was receiving the light signal. If they placed an opaque cover over the tip of the plant, phototropism did not occur even though the rest of the seedling was exposed to light from one side. If they buried the plant in fine black sand so that only the tip was exposed, there was no interference with phototropism—the buried seedling bent in the direction of the light. They concluded that the light stimulus was being perceived by a receptor only at the tip of the plant while the response, the bending of the seedling, occurred below the tip of the plant.

You will use methods derived from work of the Wisconsin Fast Plants group at the University of Wisconsin (1998a, 1998b) as you work with germinating seedlings of Wisconsin Fast Plants (*Brassica rapa*). Plants in the genus *Brassica* are members of the cabbage and mustard family. The life cycle of Wisconsin Fast Plants is very rapid allowing us to collect data within days of setting up an experiment. Prior to germination, the seed is in a dormant state. As it begins to germinate, the seed imbibes water and becomes metabolically active. The cotyledons act as a source of nutrients until the seedling breaks through the surface of the soil and begins photosynthesis. The stem of the seedling below the cotyledons is called the hypocotyl. In *Brassica* seedlings, the hypocotyl is the first structure to push through the soil to reach the sunlight. The hypocotyl pulls the cotyledons through the soil as well. Once the cotyledons have emerged, the hypocotyl will straighten and the shoot will begin to grow above the cotyledons. The first primary leaves of the plant will grow from the epicotyl.

### Hypothesis Formation and Experimental Design

During the hypothesis formation stage of this experiment, your group will propose a set of questions about the behavior of germinating seedlings and then propose a tentative explanation, or answer to one of these questions as your formal hypothesis. You will design and carry out an experiment to investigate how germinating seedlings of *Brassica rapa* respond to their environment. There are a number of independent variables you can manipulate during this experiment. These independent variables are associated with specific factors which could stimulate a response in a growing seedling. You will use your hypothesis to predict the response (dependent variable) to your manipulation of the stimulus (independent variable). After your instructor has had a chance to comment on your experimental design, you will be ready to initiate your experiment by manipulating the independent variable. After giving the seedlings a few days to respond to your manipulation of a stimulus, you will be ready to collect your observed results.

As you begin, work with your lab group to develop a list of the questions you may wish to address. It may help your group to start with general questions (such as, What are the seedlings doing? How are they responding to their environment?), and to then progress toward more specific questions.

#### Exploratory Questions

What color of light do plants respond to?

How much light is required for a plant to show a response?

Is there a minimum amount of time that a plant must receive light before it will respond?

Propose a tentative answer to one of the questions listed above, as your hypothesis.

Hypothesis:

Plants must sense that there is a sufficient amount of light available to them before they change their growth pattern. Therefore, there is a minimum amount of time of light exposure required before a plant will show a response.

### Materials and Methods

Today you will observe germinating seedlings, design your experiment, and apply your experimental treatments to the plants. Depending on your hypothesis and the experiment you have designed, you may choose to start with *Brassica* seeds or with *Brassica* plants that have been germinating for 24 hours (available from your TA). You will set up the growth chambers, manipulate the independent variable, and leave the seeds to germinate or continue growth. After 48 hours, the growth chambers will be moved to the refrigerator to stop their growth. The growth chambers will remain in the refrigerator until next week when you will collect the data from your experiment.

Black film canisters have been modified for use as growth chambers. The growth chamber has a small hole in the side approximately 1.5 cm below the rim. The hole can be covered with black electrical tape if your experiment calls for the seed to germinate in the dark. Cotton will be placed at the bottom of the growth chamber and soaked with water. A strip of wet paper towel will be placed on the inside wall of the growth chamber. A *Brassica* seed will adhere to the paper towel as long as the paper towel is wet. The cotton acts as a reservoir of water and the paper towel is a wick to carry water to the germinating seed.

As you design your experiment, you can assume that both light and gravity will be present. In addition, you will have the following materials available:

- aluminum foil
- light filters of various wavelengths and intensities
- protractors
- rulers

Use the space below to list the steps of your experimental procedure. Your experimental method should be written with enough detail that another student could perform the experiment from your instructions. Be sure to control as many variables as possible.

What is your independent variable?

*amount of time the plant is exposed to the light*

What is your dependent variable?

*growth of plant toward light*

**General description of your methods**

- begin with seedlings that have been germinating in the dark for 24 hr
  - expose each plant to a different length of time of light exposure
- exposure times: 1 sec, 5 sec, 10 sec, 30 sec, 60 sec
- observe whether plants grew toward the light source
  - measure the angle of growth of each plant

**Predicted Results**

- plants exposed to light for less time will show less bending toward the light

**Results**

Wisconsin Fast Plants grow very quickly. Data may be recorded 24 and 48 hours after beginning the treatment. The specific data you collect will depend on the design of your experiment. Dependent variables may include length or color of the seedling or the angle of growth of the hypocotyl. A diagram of a protractor is provided for measuring and recording angles of growth. Your TA will explain the procedure that will be used for collecting the data.

Table 2-1. Results.

PLANT #	Time of Light Exposure (sec) ( TREATMENT )	Angle of Growth ( MEASUREMENT OF DEPENDENT VARIABLE )
1	0 sec	90° (plant grew straight up)
2	1 sec	82° (slight bending)
3	5 sec	45°
4	10 sec	50°
5	30 sec	50°
6	60 sec	50°

} significant bending toward light

SUMMARY OF ASSIGNMENT

- Abstract. Write 3–4 sentences to describe the purpose of the experiment and provide a brief summary of the results and conclusion.
- Write an introduction to provide your reader with the background necessary to understand the experiment. You should describe how you developed your hypothesis and how it was tested.
- Methods section. In your methods section, carefully describe your experimental methods. Write a detailed description of what you have done, not a numbered list of directions. Concentrate on how the independent variable was manipulated and how the dependent variable was measured.
- Results section with text, data table, and graph.
- Discussion. Include the conclusion and address the implications of the experiment.
- Include a list of references for any sources you cited in writing your lab report.

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## SAMPLE STUDENT REPORT

Student Name  
BIOL 211 Lab section 17  
January 15, 2008

### Effect of Short Light Exposures to the Growth of Seedlings

#### Abstract

Plants require light for photosynthesis and are phototropic, growing toward light in order to meet their needs. This experiment was conducted to determine if there is a minimum period of time required for plants to receive the light stimulus and respond to it by changing their direction of growth. The experimental results indicate that less than 5 seconds of exposure to light is a sufficient stimulus to elicit a growth response in plants.

#### Introduction

It is commonly known that plants require light for photosynthesis. Plants are so dependent on light that they are phototropic. Phototropism is the process in which plants respond to the stimulus of light and respond by changing their direction of growth toward the light (Preszler, *et al.*, 2007). Plants exhibit positive phototropism which is defined as growth toward the light source (Sengbusch, 2001). Positive phototropism allows a plant to sense the light stimulus and change its direction of growth toward the light source in order to obtain more light energy for photosynthesis. This behavior is especially important for plants growing in shady areas such as under large trees on the forest floor (Schamp, *et al.*, 2007).

Many aspects of light, such as the light wavelength or light intensity, can act as stimuli, causing the plant to respond. The focus of this experiment was the amount of time that a plant is exposed to light. When a plant is responding to a stimulus such as light by changing the direction of growth, it uses a lot of energy to grow in the new direction. It seems reasonable that a plant should not change its direction of growth unless it senses that there will be a sufficient amount of light energy received from the light source. A plant might determine whether

enough light will be available from the light source by detecting the intensity of the light or the length of time that the stimulus is present. It would not be beneficial to the plant to change its direction of growth if the light source is of low intensity or will not last long enough. Therefore, the hypothesis of this experiment is that there is a minimum time period of light exposure required for a plant to show a phototropic response.

To test this hypothesis, young seedlings of *Brassica rapa*, initially germinated in the dark, were exposed to varying time periods of light exposure. These time periods were short bursts of light ranging from 0 to 60 seconds. The plants then continued to grow in the dark for 24 hours before they were observed for changes in their growth pattern. It was predicted that plants exposed to shorter periods of light would show less phototropic response and that the shortest light periods might be insufficient to cause any growth response in the plant.

### Methods

Six (6) Wisconsin Fast Plants (genus *Brassica*) were obtained for use in this experiment. The seeds had been growing in black film canisters in the dark for 24 hours (Preszler, *et al.* 2007). A cap had been placed on the top of the film canister and a hole in the side of the film canister was covered with black electrical tape to prevent any light from entering the container. The 24 hour seedlings were exposed to different time periods of light (independent variable) by removing the electrical tape and allowing light to enter the container. Each of the six plants was exposed to a very specific time period of light ranging from 0 to 60 seconds (see Table 1). After light exposure, the electrical tape was placed over the hole again and the seedlings continued to grow for 24 hours. The film canisters were then placed in the refrigerator to stop the growth of the plant until data could be recorded at the next lab period (1 week later).

The growth of each seedling was observed and measured. Each seedling was removed from its film canister and laid flat on a protractor to measure the angle

of growth (dependent variable). Because plant roots grow downward regardless of light exposure, the main axis of the plant was established by aligning the plant roots with the  $90^\circ$  vertical mark on the protractor. The angle of growth for each plant was determined by comparing the direction in which the leaves were growing with the degree marks on the protractor.

### Results

Six *Brassica* plants were exposed to different periods of light to determine if there is a minimum time of light exposure required for the plant to sense the light and respond to it. The time periods for light exposure varied from 0 to 60 seconds and the angle of growth measurements are shown in Table 1. The plant that was continually grown in the dark (0 sec of light exposure) grew straight upward (measured as  $90^\circ$ ). Extremely short light exposure times produced a slight response, measured as a minor bending of  $7^\circ$  in the direction of the light source. At a light exposure of 5 seconds, the plant showed a significant change in the angle of growth. That angle of growth ( $45^\circ$  to  $50^\circ$ ) was maintained for all time exposures greater than 5 seconds. The results of the experiment are shown graphically in Figure 1.

Table 1. Angle of growth in response to time of light exposure.

Light Exposure (sec)	Angle of Growth (degrees)
0	90
1	82
5	45
10	50
30	50
60	50

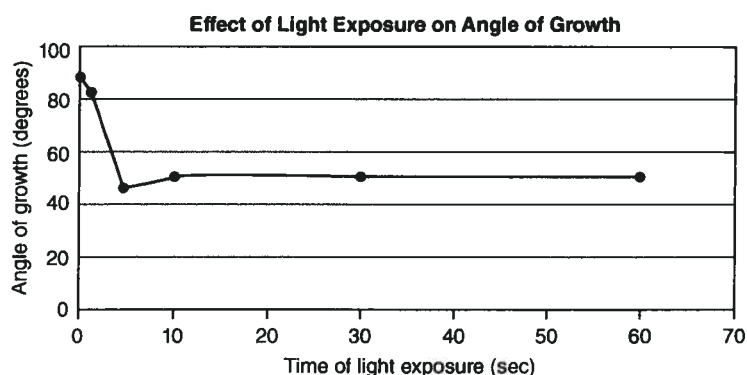


Figure 1. The angle of growth of *Brassica* seedlings is shown for each light exposure time period. A measurement of 90° indicates the plant grew straight upward. Angles less than 90° indicate a change in the direction of growth toward the light source.

### Discussion

The phototropic response of plants is essential to their survival. Plants must obtain light energy for photosynthesis and phototropism allows plants to gather as much light energy as possible by responding to the light in their environment (Sengbusch, 2001). This experiment was conducted to determine if there is a minimum period of light exposure required for a plant to respond to light. Six different time periods from 0 to 60 seconds were tested for their effect on the angle of plant growth. The plant grown in continual darkness did not change its

angle of growth, demonstrating that the light stimulus is required in order for the plant to change its direction of growth. The plant exposed to 1 second of light showed a slight change in the angle of growth. This indicates that even a very short light exposure is sufficient to cause the plant to begin to change its growth, but that 1 second of light is not long enough to cause a significant change in the direction of growth. At 5 seconds, and all higher light exposure times tested, the plant showed a significant change in the direction of growth. The plants showed the same response at 5 seconds as they did at all longer time periods. Overall, the results of this experiment support the hypothesis that there is a minimum time period of light exposure required for a plant to sense and respond to the light. A light exposure of 1 second was not long enough to cause a significant change, but an exposure of 5 seconds was sufficient. This experiment indicates that the minimum length of time of light exposure required to elicit a response in the plant is between 1 and 5 seconds.

The conclusion that plants require a minimum time period of light exposure before they respond to the light stimulus has a number of implications. Plants grown in shady areas such as under trees will require at least short periods of light in order to sense the light and determine the best direction of growth for obtaining more light. House plants grown indoors often grow toward a primary light source, such as a window. These plants would respond quickly to light received from another direction. Alternatively, many people rotate their house plants to create an even pattern of growth in the plant. The results of this experiment indicate that turning the house plants toward a window would change the direction of their growth almost immediately.

## References

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