Pocket Seed Experiment

Ask A Biologist activity for the classroom and home

By Elena Ortiz and CJ Kazilek

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This is a companion PDF for these online articles:

Virtual Pocket Seed Experiment
http://askabiologist.asu.edu/experiments/vpocketseeds

Time Traveling Plants
http://askabiologist.asu.edu/stories/time-traveling-plants

Table of Contents

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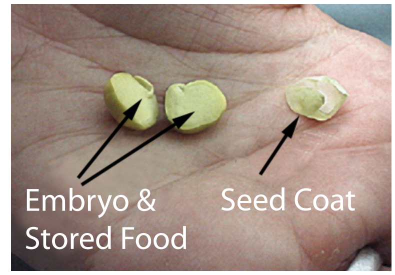
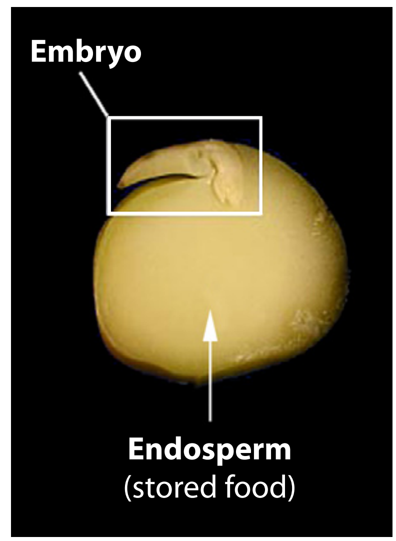
http://askabiologist.asu.edu/contact/permissions
Version 2.0

Seeds

A brief background



A seed is the part of the plant containing the **embryo** from which a new plant can grow. Usually the seed contains one embryo and a food supply. Larger seeds have more stored food than small seeds. Food stored in larger seeds is called the **endosperm**. In smaller seeds, there are seed leaves called cotyledons, which must be in the light soon after emerging so they can provide food from photosynthesis for the developing seedling. Larger seeds can develop in the dark for much longer than small seeds, but eventually even seedlings that come from large seeds must reach a light source if they are to survive.

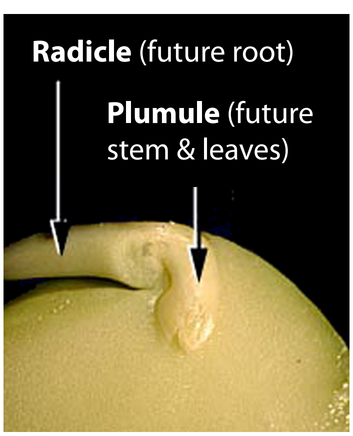


Germination is when a seed begins to sprout and grow. In order for a seed to germinate, conditions must be right. There must be enough moisture, and the right temperature. For different plants, the ideal conditions are different. This is true not only for different species, but also for the different offspring from one plant. This variation is necessary for the survival of the species. If all the offspring germinate at once, they can easily all be wiped out, either eaten or destroyed by unfavorable conditions.

Some seeds germinate in the cooler temperatures of Spring, others in warmer temperatures of Summer. Some seeds are more likely to germinate in the light while others prefer the dark. The first thing to happen is the seed re-hydrates by soaking up water. Then the seed coat cracks. Next, either the **radicle** (the root) or the **cotyledon** (the seed leaves) emerge out of the seed coat.

The developing seedling responds to light and gravity. Developing shoots grow against gravity, while developing roots grow towards gravity. This will happen even in the dark. It is called **gravitropism**, meaning movement in response to gravity. Developing shoots also grow towards the light. This is called **phototropism**.

Seed Anatomy



When you take a close look at a seed you can see why they are great time capsules. Bundled inside the protective seed coat is the potential embryo and plenty of food to begin growing when the time is right.

If you take a look at the photo in the upper right corner you can see the seed coat and the seed split in half. One half has the embryo and some of the stored food, and the other half holds the rest of the stored food.

When we magnify the image of the seed you can see the part of the embryo called the **radicle**, which will grow and develop into the roots. You can also see the part called the **plumule**, which will grow and develop into the stems and leaves.

Materials

Estimated cost per packet = 6-8 cents

For the Experiment

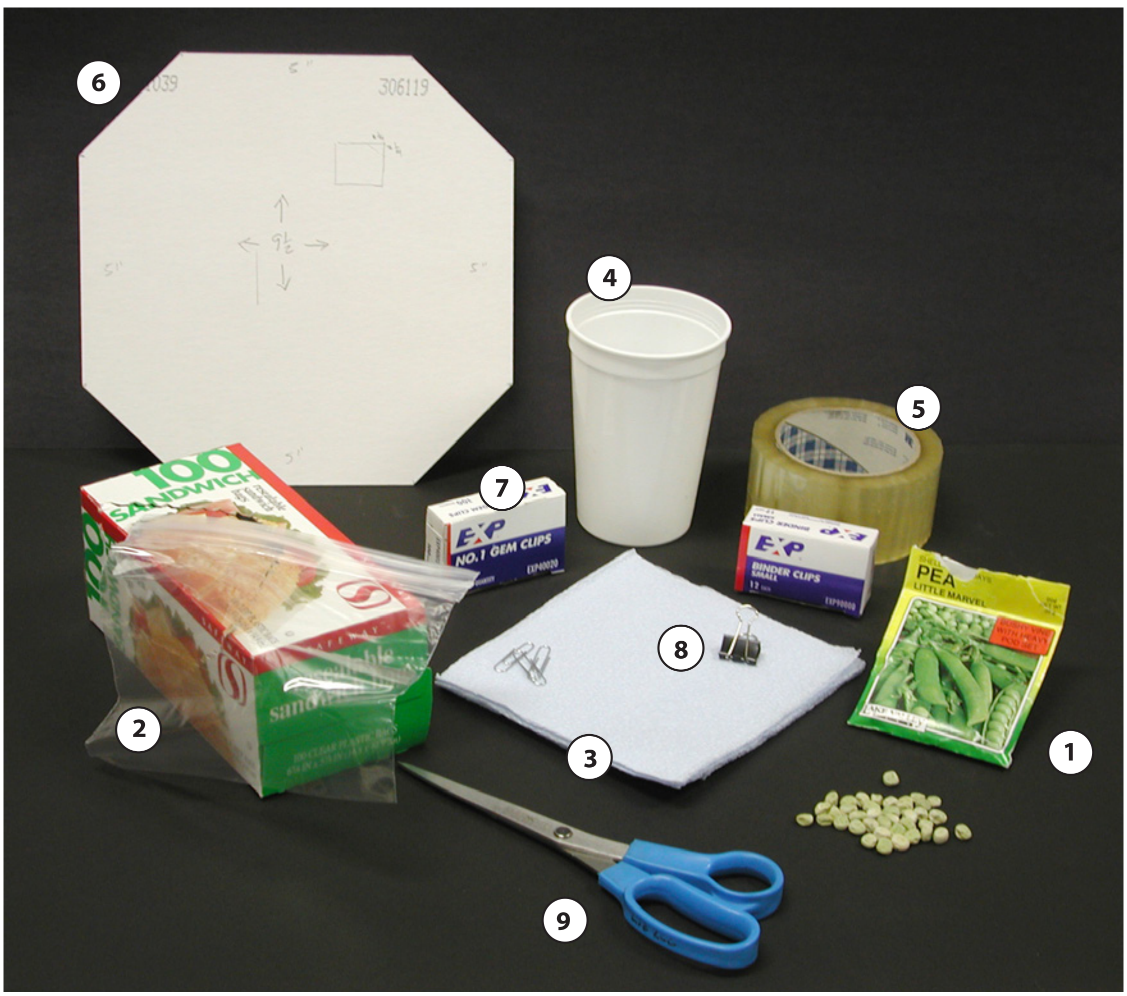
1. Seed packets (this experiment uses Peas, Little Marvel)
2. Re-sealable plastic bags (sandwich or quart size)
3. Paper towels or napkins
4. Water and cups
5. Tape
6. Cardboard (optional)
7. Paper clips (optional)
8. Binder clips (optional)
9. Scissors

For Measurements and Data Collecting

- Worksheets
- String
- Ruler

Optional Equipment

- A computer with Microsoft Office to be used with Excel spreadsheet



Methods

How the experiment works

Day 1

Soak a group of the seeds overnight to speed up the germination process. You can also set some seeds aside to compare the time it takes for the germination process to begin between presoaked and dry seeds.

It is interesting to compare the soaked and dry seeds. The change in size and shape can be dramatic. If a precision balance is available, the weight can also be compared between the soaked and dry seeds.

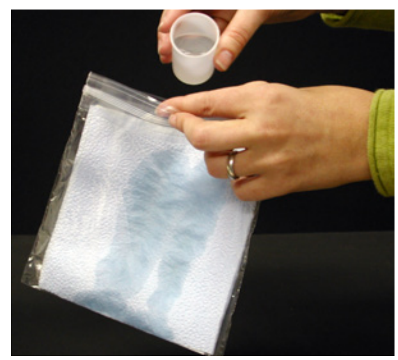
Placing seeds in water to soak overnight

Comparison of soaked and dry seeds

Day 2

Prepare the packets

Prepare seed packets for the seeds using re-sealable plastic bags (sandwich or quart size). The larger bags allows the plants more room to grow and permits longer experiments. Fold and place paper towels or napkins into each bag. Thicker, more absorbent paper towels will hold more water, which reduces the need to add water during the experiment. Once the paper towels are placed in the plastic bags, add water to the bag. For a sandwich size bag with an absorbent paper towel asingle filled film container will provide enough water (approximately 35 ml/cc).



Pouring water into bags with paper towels

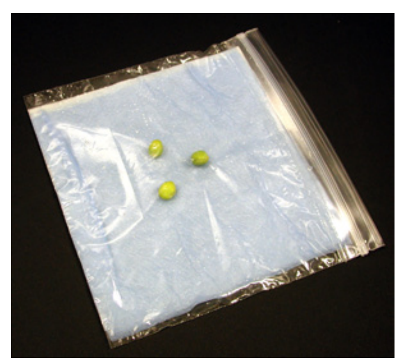
Place three seeds into each re-sealable bag

It is best to place them about an inch apart and in the middle of the bag. It is important to place more than one seed in each bag. Some seeds fail to germinate, some germinate, but fail shortly afterwards. Having more than one seed will help to insure there will be some results.

Having more than one seed in each bag also permits extended analysis of the results, such as averaging the data from each bag.

Reseal and Label

Reseal and label the bag to track the different experimental treatments. Be sure to have at least one control bag to compare your results of the other treatment bags. The Pocket Seed Viewer is now ready!



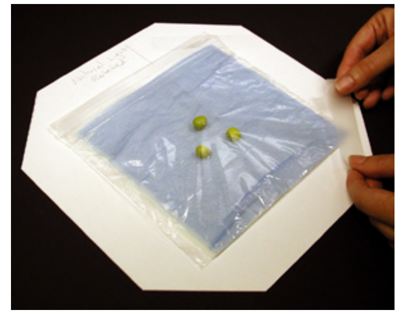
Completed Pocket Seed Viewer

Optional Steps

Tape to Cardboard

Once the seeds are in each bag and resealed they can be taped to cardboard or matte board cut in an octagon shape. This helps to track the rotation of the seeds that are being tested for gravitropism.

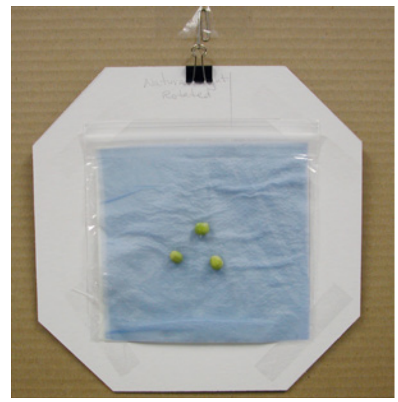
The octagonal shaped cards allow for rotation of the card in precise increments, and also work well when just resting the cards on a counter, or in a cabinet used to test how seeds grow in the dark.



Taping bags to matte board

Label the cardboard

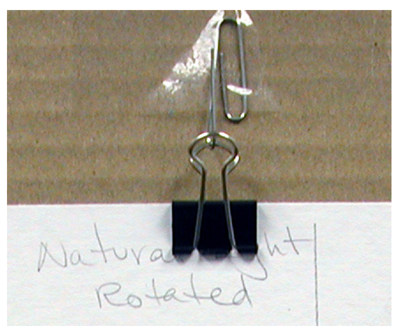
Label the cardboard. For the pocket seed viewers that will be testing gravitropism, draw an arrow in the direction the seeds should be turned each day. If multiple sets are testing the effects of gravity, try turning some sets in a clockwise direction, while the others are turned counter-clockwise. Use Binder clips to hang each card. If you have a bulletin board they can be hung on push pins. It is also easy to hang the cards from a scrap piece of cardboard using paper clips and tape for the hooks.



Completed optional seed viewer setup

Binding Clips

Use binder clips to hang each card. If you have a bulletin board they can be hung on push pins. It is also easy to hang the cards from a scrap piece of cardboard using paper clips and tape for the hooks.

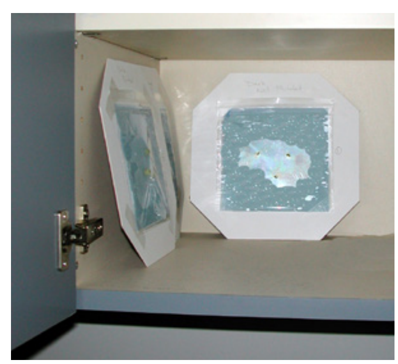


Close-up of binder clip and paper clip used as a hanger

Set of six cards hanging from a scrap piece of cardboard

Dark Treatment

The seeds you want to grow in the dark can either be placed in a light tight cabinet, or they can be wrapped with aluminum foil. In either case, it is very important that no light reach the seed except when measuring. Measuring should be done in low light conditions or using a green light to minimize exposure to light.



Inside cabinet to test for the effects of growing in the dark

One Page Pocket Seed Instructions

For students

Follow these steps and you will be ready to experiment with your own seeds.

Preparing the Packets

1. Fold a single paper towel into 1/4 section. It should now fit inside a sandwich or quart-size re-sealable plastic bag. If not, trim the excess edges with a pair of scissors.

2. Slide the folded paper towel into the plastic bag.

3. Add 30-40 ml of water. This should soak the paper towel well, but not leave too much extra water in the bag.

4. Place 3 seeds in each bag. To speed up the experiment it helps to soak the seeds overnight before adding them to the pocket viewer.

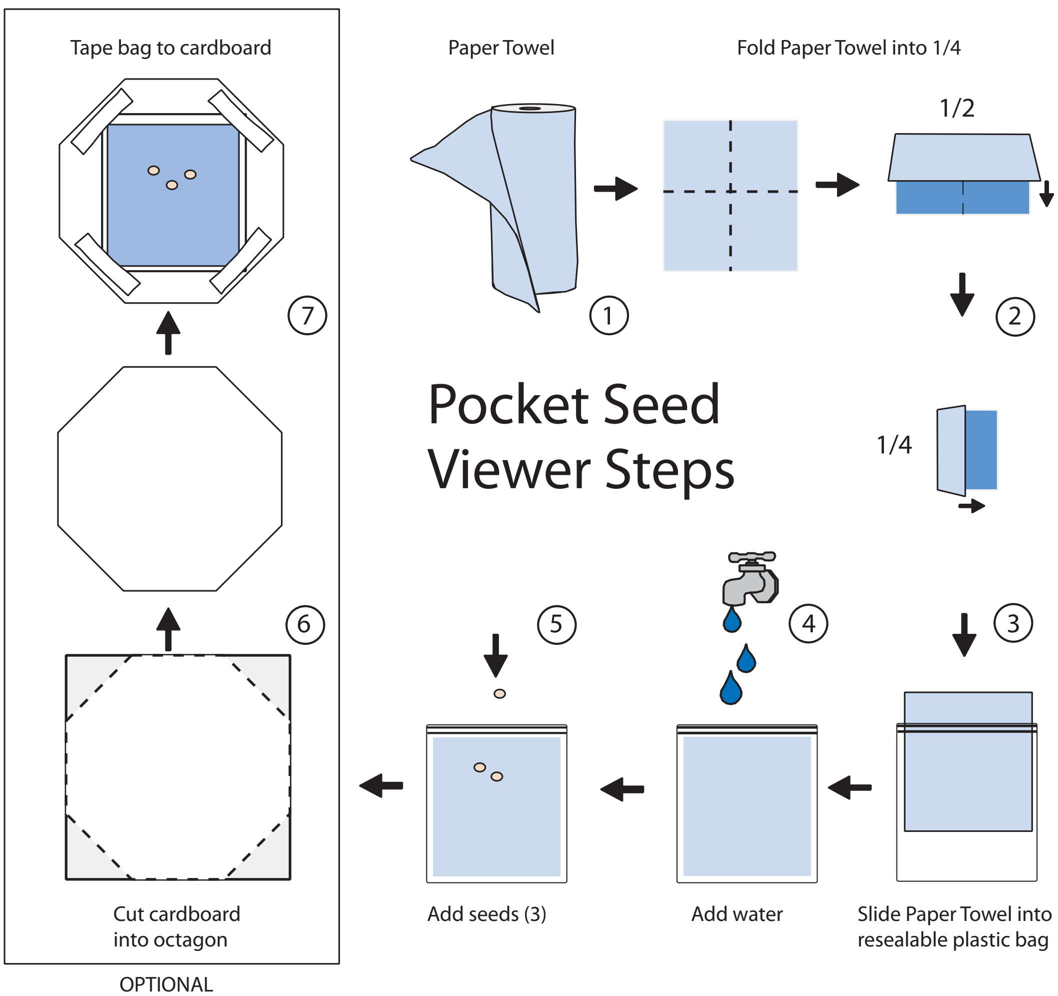
5. Seal the bag and label it with your name and experimental treatment.

Optional Carboard backing

1. Measure 2 inches from each corner and place a mark. Draw a line between the marks at eachcorner (figure 6).

2. Cut the corners along the lines you just made.

3. Tape the pocket seed viewer to the cardboard using transparent tape.



Virtual Pocket Seed Viewer

An overview

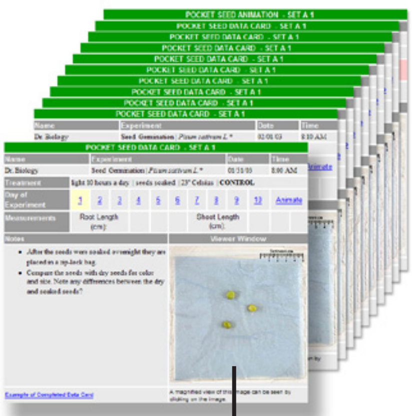
Dr. Biology has been busy working on his own pocket seed experiment and he needs your help. He has collected so much information from the experiment that he needs someone to analyze the data. All the results have been recorded in photographs, including some cool animations.

To become Dr. Biology's assistant, just read the information below. Then collect and analyze the data from the experiment. Use the information in this packet along with the blank data cards, tables and graph paper to complete the experiment. Even if you are doing your own pocket seed experiment, you can compare your results with those of Dr. Biology's.

Below is an overview of what you will find at the Virtual Pocket Seed web address and here is the address:
http://askabiologist.asu.edu/experiments/vpocketseeds_overview

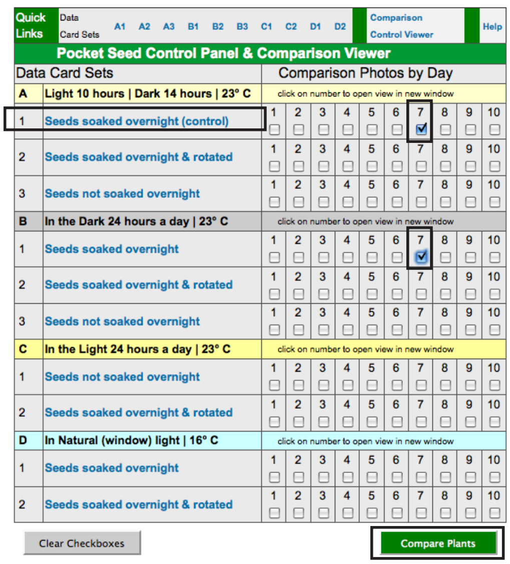
Quick Links Viewer to be accessed Data Card sets and Comparison Viewer

Data Cards in sets of 11, one for each day + animation, and matching the format of blank data cards in the PDF download book

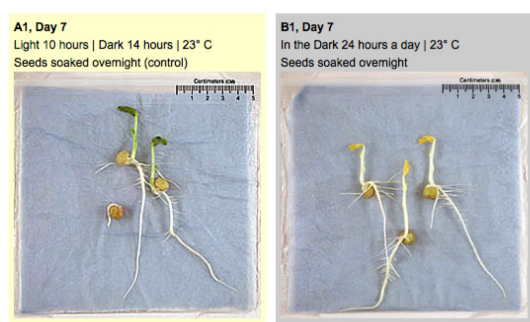


Magnification window can be opened from either the Comparison Windows or from individual Data Cards

Comparison Viewer used to compare treatments by day and also links to the Data Card sets



To compare plants, select two or more boxes and check the **Compare Plants** button.



All viewing windows have a scale bar used for measurements

Measuring

The roots and shoots

When you do your experiments at home or in the classroom you can use a ruler to measure your seed sprouts. To measure the seed sprouts in Dr Biology's pictures you need to measure a little bit differently. If you look at the seed pictures you will see a small ruler on the upper right-hand corner. This is called the scale, it tells you how big the objects in the picture really are.

The pictures on the data cards look much smaller than actual size. When you click on the small pictures you can then see a magnified picture, in this picture the peas look larger than actual size. You will also notice that the length of the scale bar changes between the smaller and larger pictures. Because the scale bar adjusts in size along with the pictures, you can use it to measure the real length of the seed roots and shoots. You can also use the scale to measure your own seed experiments and then compare them to Dr. Biology's.

Making Your Own Flexible Ruler

Roots and Shoots do not grow in a straight line. To measure them requires a flexible ruler. One way to measure the seed sprouts is to use a string. Cut a length of string about 30 cm or about 12 inches long and make a knot at one end. Next make marks on it that corresponds to the lines of the scale. Now you can use the string to measure the roots and shoots even if they are not straight.

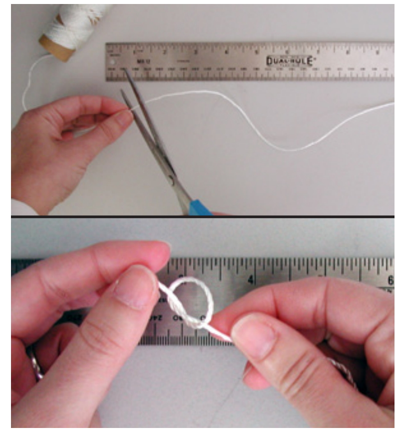
Another way to measure the roots and shoots is to measure the scale with a ruler. This is necessary since, different computer monitors will produce different size images. You then divide the actual size by the scale size this gives you a ratio. You can then measure the seed sprouts using the ruler. To get the actual size of the sprout, simply multiply your measurement by the ratio of actual to scale size.

Example: The scale on the magnified picture of soaked seeds grown in 10 hours of light (Data card A1 - Day 4) measures 9.3 cm, but it represents 5 cm on the picture.

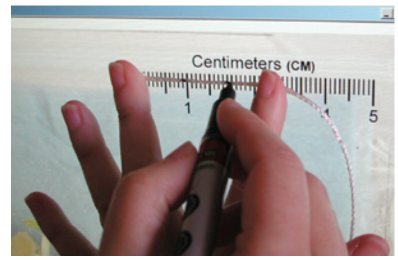
- Divide the value in the picture by the actual measurement
  5cm /9.3cm = 0.54

- Using a piece of string, the root in the picture above right measures 10 cm. Now multiply the factor we just calculated above:
  10 cm x 0.54 = 5.4 cm

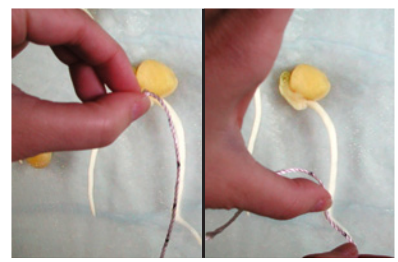
- The actual size of the shoot is 5.4 cm.



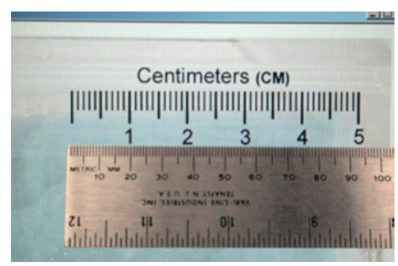
Cutting string and making a knot for a flexible ruler



Marking scale lines on the string



Measuring the root of one seed



Finding the ratio of picture scale bar and ruler

After measuring a root, placing the string next to a ruler to calculate the actual root length.

Analyzing

The best way to see the results of an experiment is to make a graph. The kind of graph you make depends on the question you want to answer and what kind of information you have gathered on your results. For example, using Dr Biology's data cards, we can try to answer the question "What is the difference in growth between seeds that have been soaked overnight, and seeds that haven't?"

To answer this question, we would have to compare the data cards of two seed viewers that were treated exactly the same way, except in one the seeds were soaked and in the other they weren't. This leaves us two choices; we can compare the soaked and unsoaked seeds that were in the dark, or the soaked and unsoaked seeds that were in the light.

Once we decide which seed viewers we want to compare, then select the data from our measurements. One way to answer the question is to graph the seed sprouts data in the two seed viewers on the last day of the experiment. We will then have 12 numbers, 3 shoot lengths for unsoaked, 3 shoot lengths for soaked, 3 root lengths for unsoaked and 3 root lengths for soaked seeds. We can now make many different kinds of graphs. You could graph all the numbers on a point graph (figure 1), or the average of each type of measurement on a bar graph (figure 2). An average is when you add a group of numbers (in this case 3) and divide the result by their total number (again three).

Example: In our example (Data card A1 - Day 10) there are three root length values.

We add them together
11.3 + 2.3 + 10.4 = 24

Next divide the result by the total number
24 / 3 = 8

8 is our average value

Another way to answer the question is to measure the seed sprouts each day, and graph the averages on a line graph (figure 3).

Each kind of graph can help you see how the two seed viewers are different, and may tell a little bit different story. The bar graph tells you that on day 10, there's little if any difference between unsoaked seeds and soaked seeds. The point graph shows more of the story, the difference looks bigger, and you can see that there's one point that looks out of place (dotted circle). This point represents the one soaked seed that failed to grow. When this seed is included in the average for the bar graph, it lowers the average.

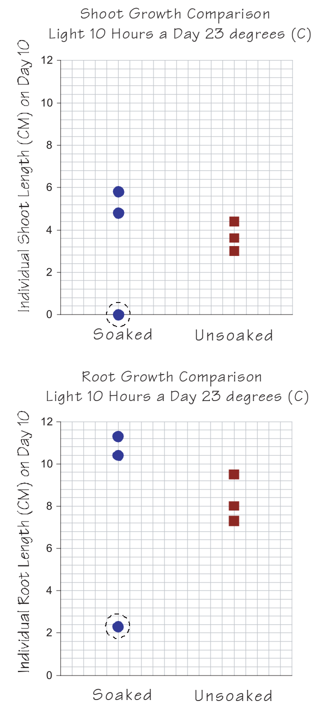


Figure 1

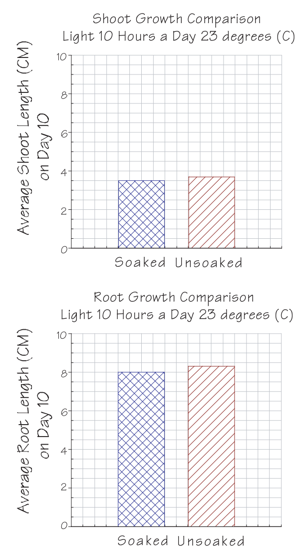


Figure 2

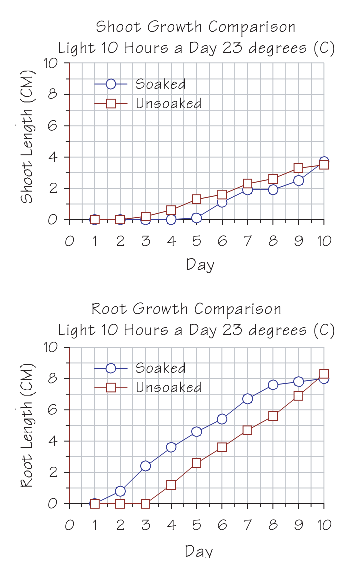


Figure 3

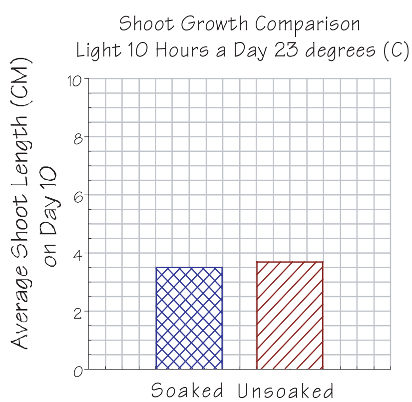
You might say that because one of the soaked seeds failed that means soaking causes seeds to fail more than not soaking. However, you cannot make that conclusion without first repeating the experiment to see if you get the same results. In fact, scientists often repeat experiments many times before they make any conclusions.

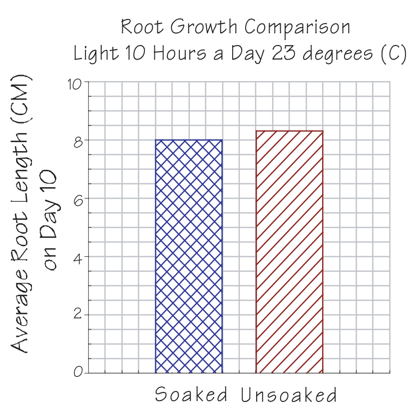
Finally, when we look at the line graph, we see more of the story. It shows that unsoaked seeds take longer to sprout, and that on days 2-9 there is a bigger difference between the length of the seed sprouts, than there is on day 10, when the average seed sprout length is very similar. As you can see from these graphs, you need to use the right graph and analysis tools to write and publish sound scientific results.

If you have access to a computer with Microsoft Office, you can download a free Excel spreadsheet where students can enter data which is automatically averaged and graphed.

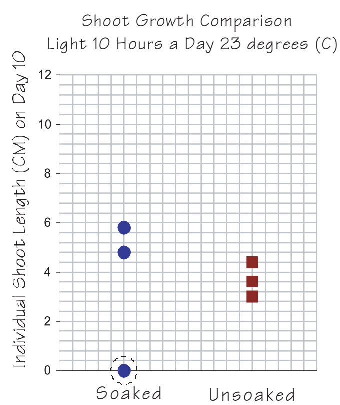
Summary of Graphs

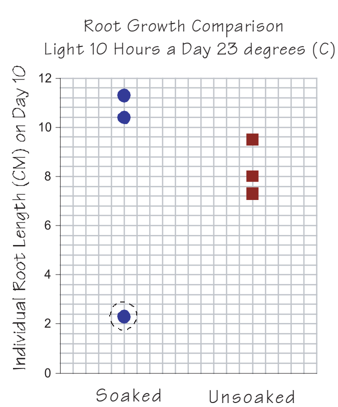
Bar Graph



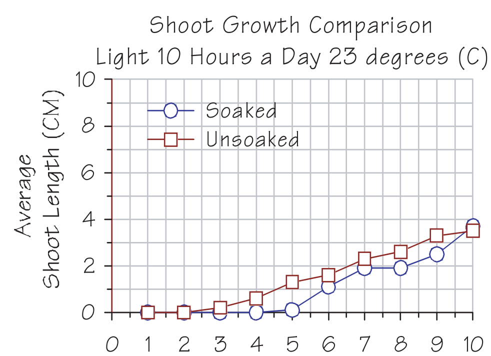


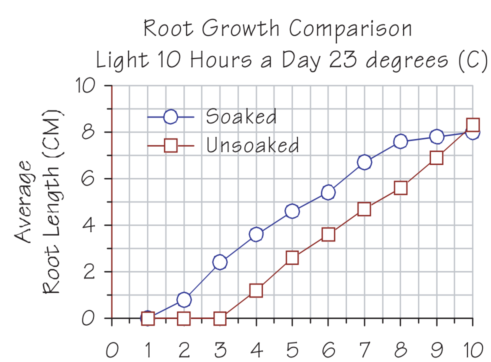
Point Graph





Line Graph





Dr. Biology's Virtual

Pocket Seed Experiment

Name Date Class

What question do you want to explore?

Which seed viewers will you compare in order to explore that question?

What do you think your results will show?

Copy enough blank data cards to record your data and attach them to this card to make your own Seed Viewer Experiment Logbook.

Example Data Card

POCKET SEED DATA CARD			
Name	Experiment	Date	Time
Dr. Biology	Seed Germination of Pisum sativum	02/04/03	8:07
Treatment	light 10 hours a day, seeds soaked, 23° C, CONTROL		
Day of Experiment	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14		
Measurement	Root Length (cm): 0.0, 1.9, 1.7	Shoot Length (cm): 2.0, 6.0, 5.2	

Notes	Drawing Window
The shoot from the first seed has not grown. The root also has stopped growing. The shoots are turning green. The roots roots are still white. Both roots and shoots are growing in a mostly vertical direction. The shoot from the third seed began growing from the bottom., but has turned direction and is growing upwards.	

POCKET SEED DATA CARD

Name	Experiment	Date	Time

Treatment														
Day of Experiment	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Measurement	Root Length (cm)							Shoot Length (cm)						

Notes	Drawing Window

POCKET SEED DATA CARD

Name	Experiment	Date	Time

Treatment														
Day of Experiment	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Measurement	Root Length (cm)							Shoot Length (cm)						

Notes	Drawing Window

Data Entry Table

This table can be used to collect your measurement data along with some basic comments. Use one table for each experimental treatment. Once the experiment is finished, the tables can be used to analyze and graph the results.

Pocket Seed Experiment						Seed Name				
Treatment										
Day	Time	Root Length (cm)				Shoot Length (cm)				Comments and observations
		1	2	3	AVG	1	2	3	AVG	
Final comments and observations										

Lesson Plan Example

Materials:

- Seed packets
- Re-sealable plastic bags (sandwich or quart size)
- Paper towels or napkins
- Water and cups
- Tape
- Cardboard (optional)
- Paper clips (optional)
- Binder clips (optional)
- Worksheets
- String

Basic set-up methods

Germination viewers were constructed as follows:

1. Cardboard holders were cut
2. Seeds were soaked overnight
3. Paper towels were placed inside re-sealable plastic bags
4. Approximately 30 milliliters of water were added using an empty film canister
5. Soaked or unsoaked seeds were placed inside the bags. More than one seed is used, because not all seeds will germinate, and by using more than one seed you can be sure at least one will germinate if the conditions are right
6. Bags were sealed and taped to the cardboard holders
7. A binder clip was attached to the holder and used as a hook to hang the viewer on a large piece of cardboard. Germination viewers can also be laid on a table, or taped to a window.
8. Seeds will germinate more quickly if they are first placed in a cup of water and allowed to sit and soak-up water
9. We placed some seed viewers in the dark, some in rooms with only artificial light, some had the light on 24 hours, some had the lights on for 10 hours, and other seed viewers were placed by the window, where they received natural light. Some seed viewers were rotated.
10. For these seedlings gravity changed direction every time they were rotated

Activity

We took pictures of our seed viewers everyday for 2 weeks. Your students can use these images to study the effects of our experimental treatments.

1. Discuss the structure and parts of the seed. Have students label seed dissection diagram.

2. Discuss with students the concepts of:

    Experimental treatments – what was done to each seed viewer to answer a specific question

    Control – the viewer you want to compare with an experimental viewer

For example, if I want to know what effect does darkness have on the development of a seedling, I have to choose two identical viewers. The only difference between them should be that one was in the dark and the other wasn't. These two viewers should both have the same amount of water, the same kind of seeds and weren't rotated. Any of these other factors would complicate the analysis of the results. If I want to know what effect does 24 hour light have, I should compare that treatment to a viewer that had the same type of light, but not for 24 hours. One complication to be aware of is that light and heat often go hand in hand. In our experiment, the seeds in natural light were warmer that those in artificial light, when we compare these two treatments, we cannot be sure if the differences we see are because of the light or the heat.

3. Discuss with students which treatments are available on the online image library. Help them decide what questions they can ask, and which two treatments they should compare to answer those questions.

Some possible questions are:

- What is the difference between the germination of soaked seeds and unsoaked seeds?
- What is the difference between the germination of seeds in the dark and seeds in the light?
- What is the difference between the development of rotated and unrotated seeds?
- Do unsoaked seeds grow differently in the dark and light?
- What is the difference between the development of seeds in 24 hour light and those in _______ hours light?

4. Have students write their question, which treatments they will compare, and their predictions of what they might see.

5. Students should then observe and record changes in the two seed viewers using the worksheet.

6. Students should use the scale on the images and string or rulers to measure the different parts of the seedling. (If using rulers, they must remember to calculate and use conversion factors)

7. Measurements should be recorded and graphed

8. Have students present their methods, findings and the answer to their initial question to the class.

More Activities/Experiments

Based on their results, students should have further questions. You can have them try their own experiments in the classroom using the same basic germination viewer. Some experiments to try include

- Effects of temperature (for each type of plant there is an optimum temperature where there is maximal germination, above and below that temperature not as many seeds germinate)
- Compare seeds of different sizes, they will have different responses to light and dark
- If gravity and light are coming from the same place (if the light source is coming from below), which will win, which way will the plant grow?
- If a seedling is continuously rotated (as on a turntable) will it know which way to grow? (This is similar to the problem of growing plants in space where there is no gravity)

- What happens to a seedling that has been grown in the dark when it is placed back in the light? What about one moved from the light to the dark? Chlorophyll is only produced in the light, how long does it take to be produced in noticeable quantities?
- Engage students in a discussion about why treatment "D - In Natural (window) light | 16/ C" of the Virtual experiment does not allow a person to draw a conclusion about this treatment data set. The key concept is to get students to see that more than one variable was changed i.e. temperature and also the direction the window faces. Ask how further experiments could be designed to see if natural light is better for plant growth.

Evaluation:

Diagram labels (1)

Worksheet completion and report (2, 3 and 4)

Objectives

For the educator

1. Students will know the parts of a seed
2. Students will understand the requirements for seeds to germinate and grow
3. Students will be able to explain the growth patterns of seedlings
4. Students will recognize differences between plants in their germination and growth requirements

Readiness

1SC-R5. Perform simple measurements and comparisons
1SC-R7. Observe and describe changes in a simple system
4SC-R2. Describe the basic needs of living organisms

Foundations

1SC-F3. Identify and record changes and patterns of changes in a familiar system
4SC-F3. Identify the basic structures and functions of plants
4SC-F1. Describe and explain cause-and-effect relationships in living systems
4SC-F6. Recognize that offspring within families have both similarities and differences

Essentials

1SC-E3: Organize and present data gathered from their own experiences, using appropriate mathematical analyses and graphical representations

For the student experimenter

1. To observe the effect of the environment on seed germination and growth.
2. To practice the scientific method

Readiness

2M-R2. Collect, organize and describe simple data.
2M-R3. Construct concrete displays of data; read and interpret elementary tables, graphs and charts.

Foundations

2M-F1. Collect and analyzed data using the concepts of largest, smallest, most often, least often and middle.
2M-F2. Construct, read and interpret displays of data to make valid decisions, inferences and predictions.
5M-F1. Demonstrate that a single object has different attributes that can be measured in different ways (e.g. Length, mass/weight, time, temperature, area and volume).
5M-F2. Explain the concepts related to units of measure and demonstrate the process of measurement with non-standard (e.g., using paper clip lengths), U.S. customary and metric units.

Essentials

2M-E1. Construct, read, analyze and interpret tables, charts, graphs and data plots (e.g., box-and-whisker, stem-and-leaf, and scatter plots).
2M-E3. Display and use measures of range and central tendency (i.e., mean, median and mode)
5M-E1. Estimate, make and use measurements (U.S. customary and metric) to describe and make comparisons.
5M-E4. Develop and use formulas and procedures to solve problems involving measurements.

Proficiency

2M-P1. Construct and draw inferences including measures of central tendency, from charts, tables, graphs and data plots that summarize data from real-world situations.

Standards

National Science Education Standards

Unifying Content Standard: K-12
As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes:
• Constancy, change, and measurement

CONTENT STANDARD C: K-4
As a result of activities in grades K-4, all students should develop understanding of:
• The characteristics of organisms
• Life cycles of organisms
• Organisms and environments

CONTENT STANDARD C: 5-8
As a result of their activities in grades 5-8, all students should develop understanding of:
• Structure and function in living systems

National Math Standards

Instructional programs from prekindergarten through grade 12 should enable all students to:
• Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
• Develop and evaluate inferences and predictions that are based on data
• Select and use appropriate statistical methods to analyze data
• Understand measurable attributes of objects and the units, systems, and processes of measurement
• Apply appropriate techniques, tools, and formulas to determine measurements

Arizona Science Standards

Kinder - 4th grade

SC00-S1C1-02 SC01-S1C1-02 SC04-S1C1-02	Ask questions based on experiences with objects, organisms and events in the environment (see M01-S2C1-01) Formulate a relevant question through observation that can be tested by an investigation (see M04-S2C1-01)
SC00-S1C2-02 SC01-S1C2-02 SC02-S1C2-02	Participate in guided investigations in life, physical, and earth and space sciences
SC00-S1C2-03 SC01-S1C2-03 SC02-S1C2-03 SC03-S1C2-04 SC04-S1C2-04	Perform simple measurements using non-standard units of measure to collect data. Use simple tools to collect data. Use metric units to measure objects Measure using appropriate tools and units of measure
SC01-S1C2-04 SC02-S1C2-04 SC03-S1C2-05 SC04-S1C2-05	Record data from guided investigations in an appropriate format Record data in an organized and appropriate format
SC00-S1C3-02	Compare objects according to their measurable characteristics (e.g., longer/shorter, lighter/heavier)
SC03-S1C3-01	Organize data using the following methods with appropriate labels: bar charts, tally charts.
SC04-S1C3-01	Analyze data obtained in an investigation to identify trends
SC04-S1C4-02	Choose an appropriate graphic representation for collected data
SC02-S1C3-04 SC03-S1C3-04	Generate questions for possible future investigations based on the conclusions of an investigation
SC00-S4C3-03	Describe changes observed in a small system (e.g., ant farm, plant terrarium, aquarium).
SC01-S4C1-01	Identify the following characteristics of living things: growth and development, response to stimulus, reproduction

5th-8th grade

SC05-S1C1-02 SC06-S1C1-02	Formulate a relevant question through obserbvation that can be tested by an investigation (see M04-S2C1-01)
SC05-S1C2-04	Measure using appropriate tools and units of measure
SC05-S1C2-05 SC06-S1C2-05 SC07-S1C2-05 SC08-S1C2-05	Record data in an organized and appropriate format Keep a record of observations, notes, sketches, questions, and ideas using such tools as written and/or computer logs
SC05-S1C3-01 SC06-S1C3-01 SC07-S1C3-01 SC08-S1C3-01	Analyze data obtained in an investigation to identify trends

SC05-S1C4-02 SC06-S1C4-01 SC07-S1C4-01 SC08-S1C4-02	Choose an appropriate graphic representation for collected data
SC06-S1C4-02 SC07-S1C4-02	Display data collected from a controlled investigation
SC06-S4-06	Relate the structures to their functions: Plants, response to stimulus (phototropism, geotropism)

High school

SCHS-S1C1-02	Develop questions from observations that transition into testable hypotheses
SCHS-S1C2-05	Record observations, notes, sketches, questions, and ideas using tools such as journals, charts, graphs and computers
SCHS-S1C3-06	Use descriptive statistics to analyze data, including: mean, frequency, range
SCHS-S1C3-07	Propose further investigations based on the findings of a conducted investigation
SCHS-S1C4-02	Produce graphs that communicate data
SCHS-S4C3-02	Describe how organisms are influenced by a particular combination of biotic (living) and abiotic (nonliving) factors in the environment

Arizona Math Standards

Kinder - 4th grade

M00-S2C1-01 M01-S2C1-01 M03-S2C1-01 M04-S2C1-01	Formulate questions to collect data in a contextual situation
M00-S4C4-01 M01-S4C4-01 M03-S4C4-08	Verbally compare objects according to observable and measurable attributes Compare the measurable characteristics of two objects
M00-S4C4-02	Communicate orally how different attributes of an object can be measured
M01-S4C4-07 M02-S4C4-06	Measure a given object using the appropriate unit of measure (e.g., length in centimeters)
M04-S4C4-03	Select an appropriate tool to use in a particular measurement situation
M01-S3C4-01 M02-S3C4-01 M04-S3C4-01	Identify the change in a variable over time (e.g., object gets taller, colder, etc.)
M03-S2C1-02 M04-S2C1-02	Construct horizontal bar, vertical bar, pictograph or tally chart with appropriate labels and title from organized data Construct a single-bar graph, line graph or two set Venn diagram with appropriate labels and title from organized data

5^{th}-8^{th} grades

M05-S2C1-01 M06-S2C1-01 M07-S2C1-01 M08-S2C1-01	Formulate questions to collect data in a contextual situation
M05-S2C1-02	Construct a double-bar graph, line plot, frequency table or three set Venn diagram with appropriate labels and title from organized data
M08-S2C1-03	Determine the appropriate type of graphical display for a given data set
M05-S2C1-05 M06-S2C1-05 M07-S2C1-06	Identify the mode and mean (average) of given data Find the mean, median, mode, range and extreme values of a given numerical data set
M06-S2C1-06 M07-S2C1-07	Identify a trend from displayed data Interpret trends from displayed data
M05-S2C1-07 M06-S2C1-07 M07-S2C1-08 M08-S2C1-08	Compare two sets of data related to the same investigation Compare trends in data related to the same investigation
M06-S4C4-11	Determine the actual measure of objects using a scale drawing or map

High School

MHS-S2C1-02	Organize collected data into an appropriate graphical representation
MHS-S2C1-03	Display data as lists, table, matrices, and plots
MHS-S2C1-04	Construct equivalent displays of the same data
MHS-S2C1-10	Apply the concepts of mean, median, mode and quartiles to summarize data sets.