Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

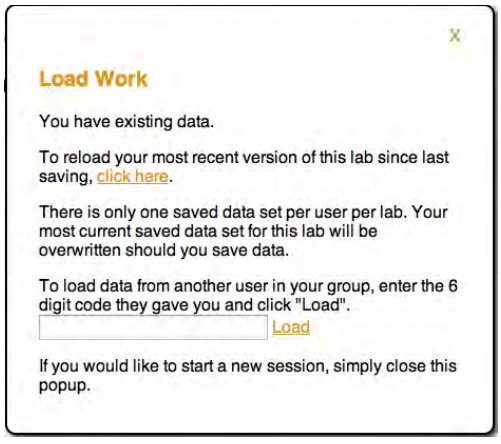
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

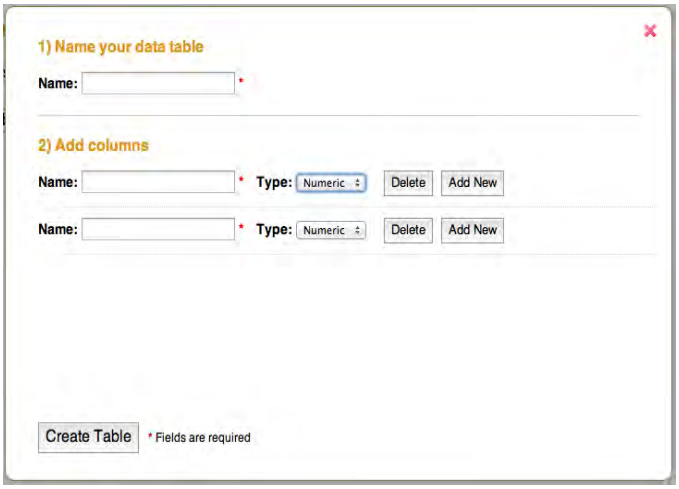
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



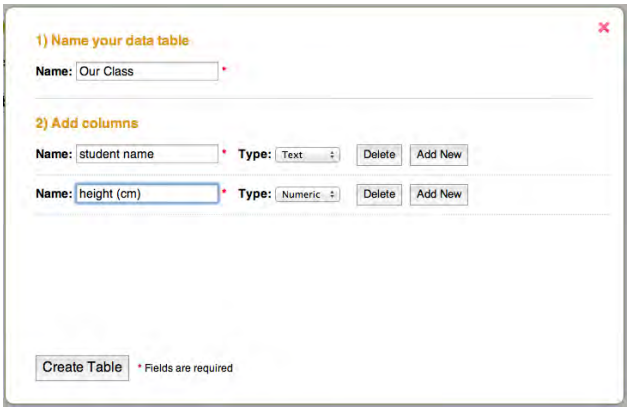
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

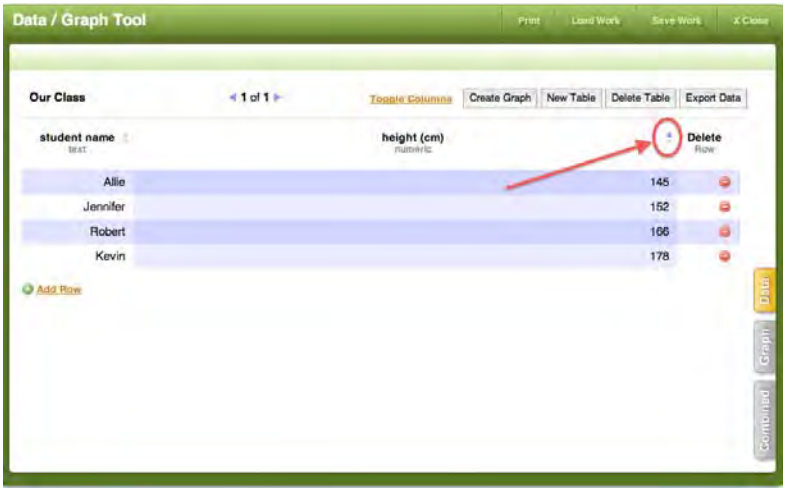
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

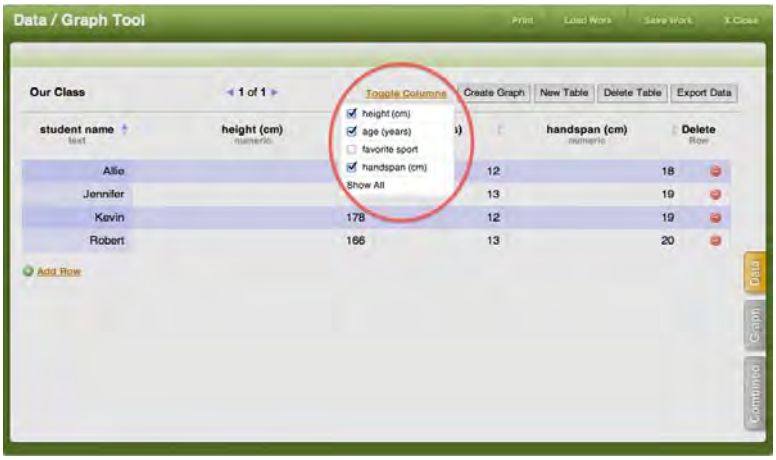


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

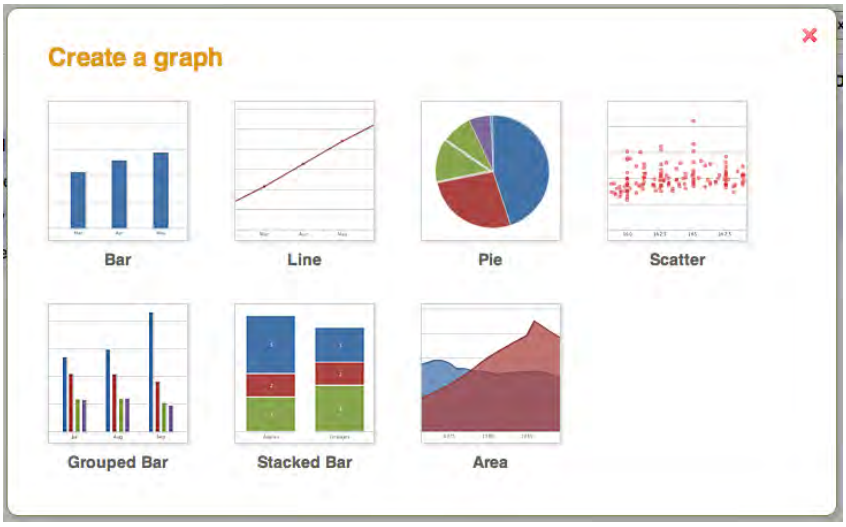
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

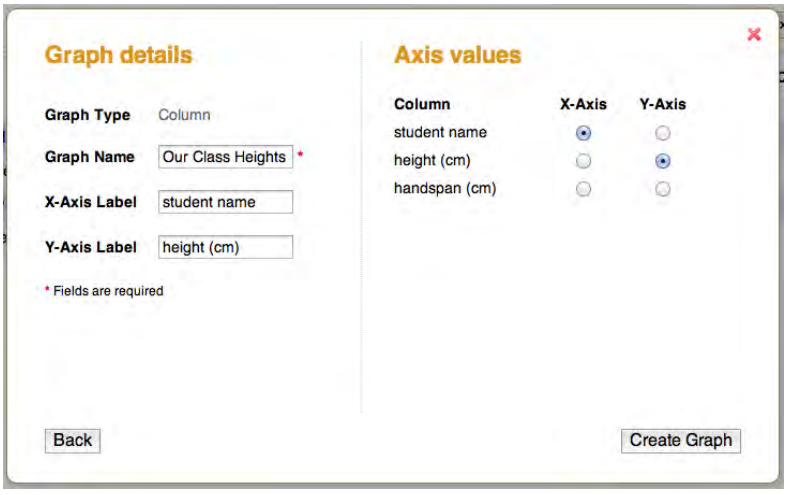
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

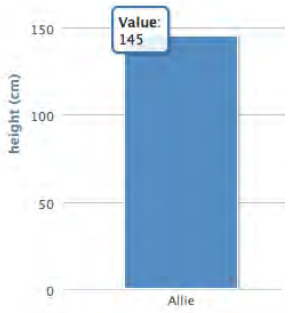


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

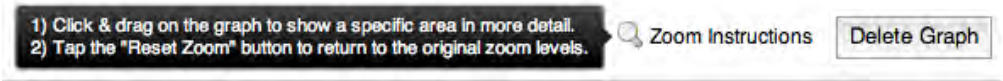
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Magnetic Polarity Sequences

Timing: one 90-minute class session

Objective(s):
Students will compare and align five different magnetic polarity patterns. The students will compile one "master sequence" from the five composite sequences. Finally, students will explain a scenario that would produce the sequence.

Safety Precautions:
Make sure students use scissors appropriately, and take scissors away from any students who use them in a dangerous or disrespectful manner.

Materials:
Per student:

- Five magnetic polarity sequences from different locations (see below)
- Paper
- Pencil
- Red pencil
- Scissors
- Ruler
- Globe or global map displaying latitude and longitude

Teacher Preparation:

- Because global maps are necessarily distorted due to Earth's curvature, globes are preferable if available.
- Create a rubric for yourself for grading purposes.
- Prepare a copy of the laboratory, including the Student Investigation Sheet, for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently.

They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Introduce the topic after completing the **Elaborate** section of the **Core Interactive Text** for the **Earth's Spheres** Concept. At this point, students should know that Earth's magnetic field periodically reverses. This record is maintained in iron-rich rocks, primarily the igneous rock basalt. Scientists reconstruct the history of magnetic polarity by piecing together sections of the record from different areas around the planet. They take the sections and create a "master" record. The students will practice this concept in this lab.

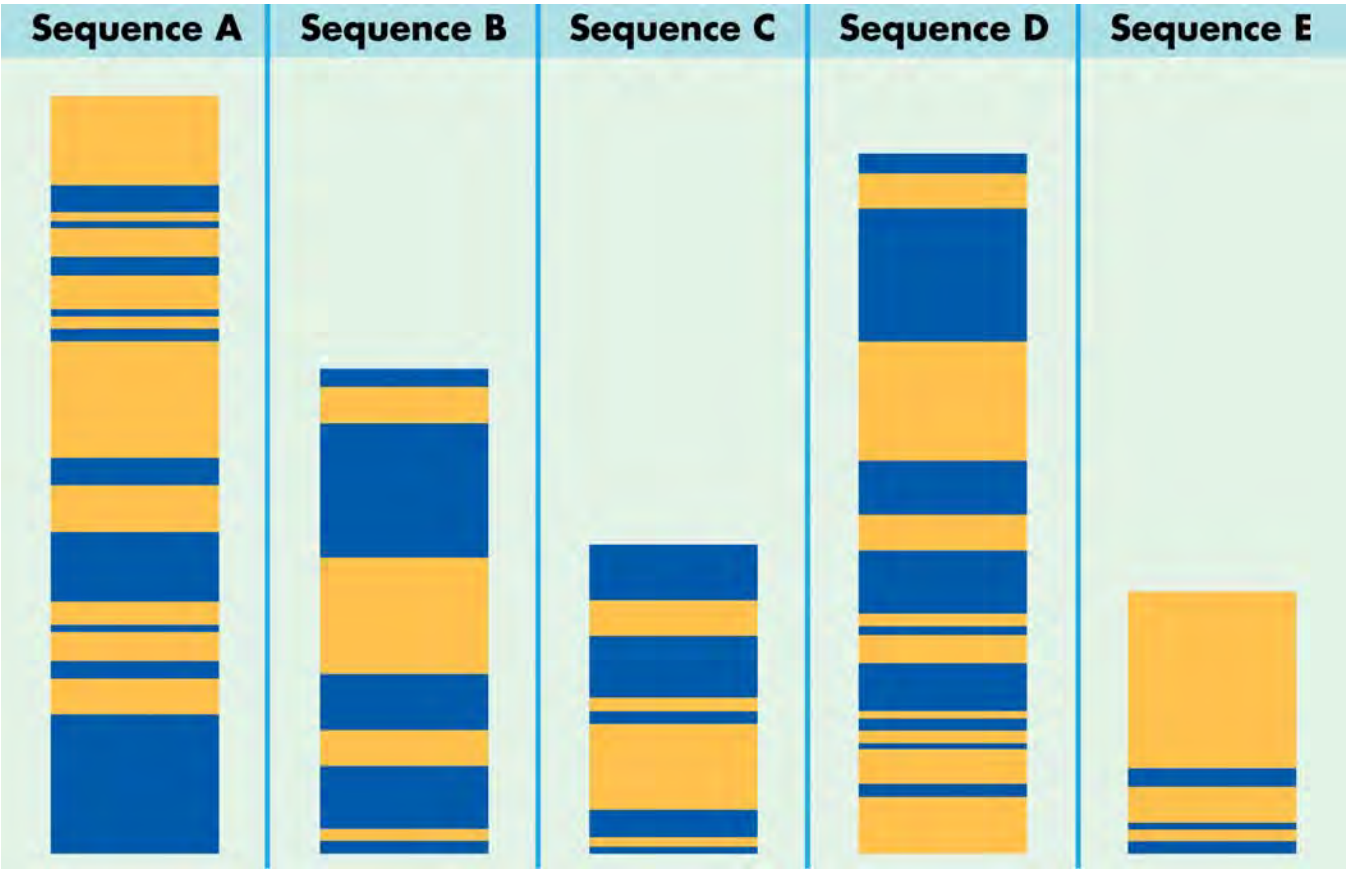
The lab begins with the students cutting each magnetic polarity sequence into separate strips. (See the following page for sample sequences.) The students should use the latitude and longitude information provided below to identify the location of each sequence on a map. Students will examine the location for the sequence and categorize it as either ocean or land. Once the students have oriented the location of each sequence, have them compare the sequences. A pattern is defined as consisting of similar duration (shown by thickness in the sequence) and number of normal and reversed polarity events. The white sections of a sequence equal a normal event. The black sections of a sequence equal a reversed event.

Students should follow the following procedure when analyzing their strips:

1. Look for similar patterns in the different sequences.
2. Move sequences back and forth to align patterns.
3. Identify anomalies in the patterns that do not match the other sequences.

At this point, the students should begin exploring ideas for the differences and similarities in patterns. Ask students to work in pairs or small groups, discussing how the sequences may be moved back and forth to align patterns. Partners should work together to agree on a position for each sequence relative to the other sequences. Discuss the results with the class as a group. Place an enlarged copy of each sequence (they should be separate sheets) on a board or project the sequences onto a screen. Ask each group to arrange the enlarged sequences based on its own analysis of the patterns (or to draw lines connecting similar patterns in the projected sequences). If groups disagree in their analyses, work as a class to determine the source of the disagreement and to correct any errors that appear.

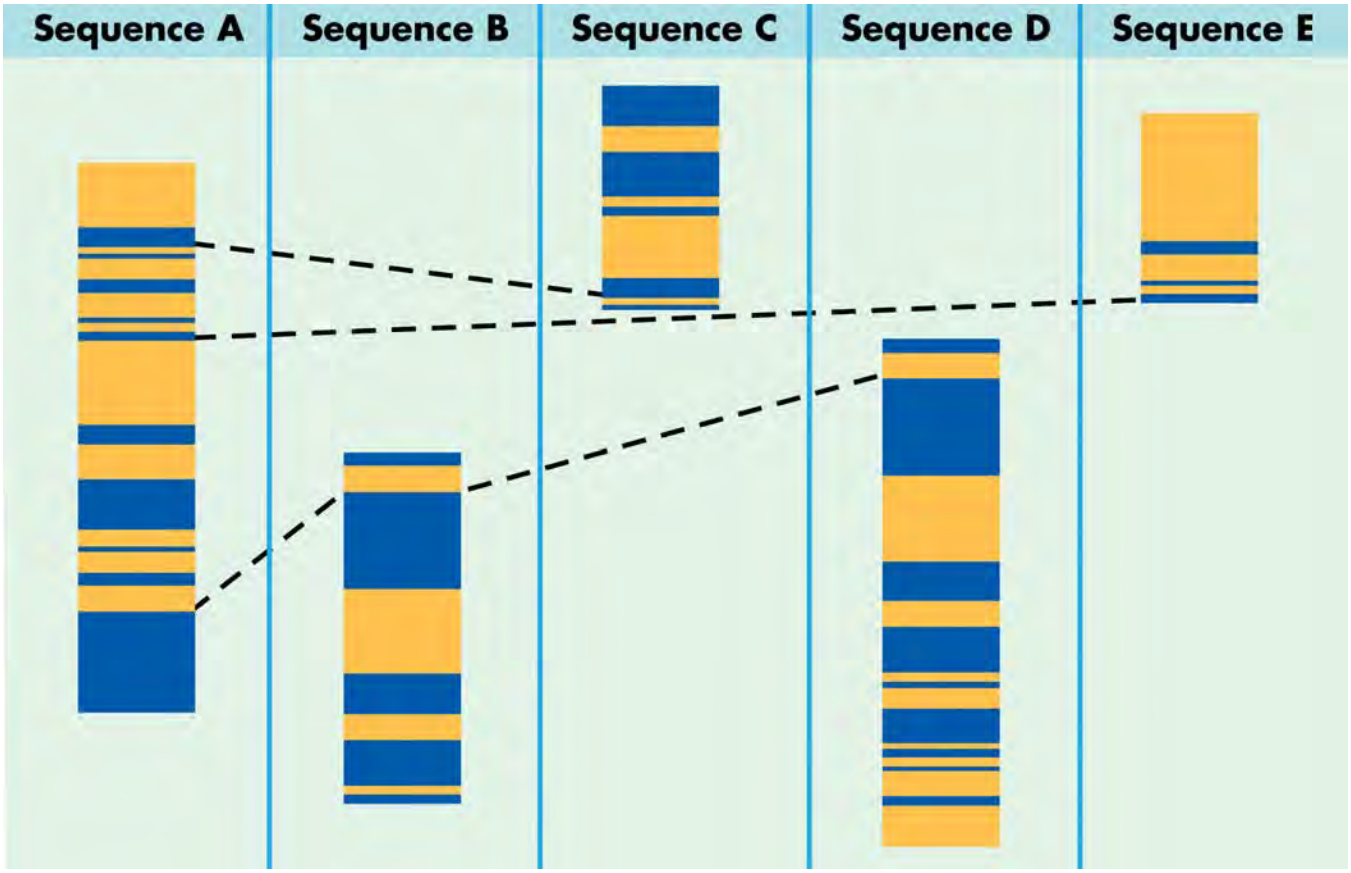
Return to the discussion concerning where each sequence was produced. Ask students how location may play a role in the similarities and differences in the sequences. Allow the students time to review the text from the **Core Interactive Text** and examine their ideas. The students should conclude by creating a "master" sequence that combines information from the five composite sequences into one sequence. At this point, you may consider mentioning that in nature the thickness in different units is seldom similar because more igneous rocks may be produced in one area compared to another area.



Locations of Sequences:

	Latitude	Longitude
Sequence A	46.09	–123.14
Sequence B	66.23	85.43
Sequence C	15.79	–126.21
Sequence D	36.88	–35.16
Sequence E	27.37	74.88

Answer Key:



Guided Inquiry

Students can develop their own plans for collecting data, based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry:

- Where were the polarity sequences produced?
- What do the polarity sequences illustrate?
- Can you find similar patterns in the different sequences?

Instruct the students to examine each polarity sequence carefully. Students should look for similar patterns and begin matching the patterns in the different sequences. The students should decide how to arrange the sequences based on the questions above.

Analysis and Conclusions:

In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. What do the dark and light sections of the sequences indicate?
The dark and light sequences show the alternating reverse and normal magnetic episodes. The dark sections indicate a reversed episode. These sections record the time when Earth's magnetic field exited the north magnetic pole and entered at the south magnetic pole. The light sections indicate a normal episode, when Earth's magnetic field exited at the south magnetic pole and entered at the north magnetic pole.

2. Which section contains the oldest rocks in the sequence? Where is the section located? How might this section of rock have been produced?
The sequence was obtained from the middle of the Atlantic Ocean. It was produced at a spreading center. The rock formed when magma from Earth's interior welled to the surface. The lava stuck to the side of the ridge and cooled rapidly, forming basaltic rock. This rock formed new oceanic crust. The crust pushed the adjacent rock away from the spreading center.

3. Which section contains the youngest rocks in the sequence? Where is the section located? How does this sequence compare to the older rocks in the sequence?
The sequence was obtained from the eastern Pacific Ocean. It was produced at a spreading center. These rocks formed many years after the rocks produced in the Atlantic Ocean. However, it is impossible to place an age on the rocks without additional information obtained by techniques such as radiometric dating.

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing
    - Allow the testing of a hypothesis with results that can be extrapolated to the real thing
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Properly citing all equipment and materials
  - Practice lab safety by:
    - Following lab safety procedures
- Gather Data
  - Choose appropriate tools to conduct an investigation:
    - Ruler/tape Measure
  - Use the appropriate format to record data:
    - Table
    - Chart
    - Sketch
- Interpret Data
  - Sort and classify using scientific reasoning by:
    - Sorting objects, substances and organisms by characteristic
  - Identify and interpret patterns using:
    - Trends in data
    - Repeating physical or data patterns
    - Tables and graphs
    - Analysis of data collected during an investigation
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Reporting trends and patterns in the data
    - Extrapolating results beyond the investigation
- Communication in Science
  - Report results using:
    - Scientific illustration with proper labeling
- Patterns and Systems
  - Patterns and Change:
    - Patterns in nature may be simple repeating patterns or complex growing or changing patterns.

Exploration Teacher Guide: Ecosystems

Overview

Ecosystems are populated by a large variety of organisms belonging to diverse species. In this Exploration, students learn about the interactions and relationships shared between different organisms.

Student Learning Objectives

- Identify the organism which shares a particular relationship with another organism.
- Identify the relationship shared between two organisms.
- Classify the organisms based on their diet.
- Classify the organisms based on the trophic level they belong to.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students use the *Organism* radio button to identify the organism that shares the displayed relationship with the displayed organism. Students use the *Relationship* radio button to identify the relationship between two displayed organisms. When the *Organism* radio button is selected, students use the *Previous* and *Next* buttons of the *Select Organism 2* navigator to identify the organism which shares the listed relationship with the first organism. When the *Relationship* radio button is selected, students use the *Previous* and *Next* buttons of the *Select Relationship* navigator to identify the relationship between the two displayed organisms.

Students use the *Check* button to validate their selections. They may use the *Show Me!* button to generate the correct combination. Students then use the *Proceed* button to classify the organisms based on their diet and also on the trophic level they belong to. They use radio buttons provided and then use the *Submit* button to validate their selections. Students may use the *Reset* button to undo changes made to the selected combination of organisms and the relationship between them or the *Start Over* button to restart the Exploration.

In the *Tracker* tab, students review the type and trophic level of each of the correctly identified organisms. They also observe the relationship shared between the organisms.

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Answers to Questions in the Student Worksheet

1. List three types of relationships that organisms share in an ecosystem.

   Answer: Organisms could share relationships such as mutualism, commensalism, competition, predation, or parasitism between them.

2. Differentiate between mutualism and commensalism.

   Answer: Mutualism exists between two organisms that are symbiotically associated with each other where both organisms benefit from the relationship. This means that both organisms depend on the other for a function that they are inherently incapable of performing. On the other hand, commensalism exists between an organism which depends on another organism without any benefit or harm caused to it.

3. Explain the difference between intra-species and inter-species competition.

   Answer: When organisms belonging to the same species compete for natural resources in the ecosystem, the relationship shared between them is called intra-species competition. On the other hand, inter-species competition exists between organisms from two or more different species.

4. List two examples of organisms which share a predator-prey relationship.

   Answer: Snakes prey on mice and leopards prey on deer. These are examples of predator-prey relationships.

5. Describe how organisms are classified on the basis of their diet.

   Answer: On the basis of their diet, organisms are classified as herbivores, carnivores, and omnivores. Herbivores primarily feed on plants, whereas carnivores depend on other animals for food. A third group of organisms called omnivores exist. They are characterized by a mixed diet of both plants and animals.

6. Explain the role of detritivores in the food chain.

   Answer: Detritivores are also called scavengers. They feed on dead and decaying matter (detritus) and help in cleaning the environment. Earthworms are examples of detritivores.

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7. Give an example of commensalism in aquatic ecosystems.

   Answer: Remoras are an example of fish which attach themselves to bigger sharks and feed on the remains of the shark food. The sharks do not gain or lose anything from this relationship. This is an example of commensalism in aquatic ecosystems.

8. Describe the relationship between leguminous plants and nitrogen fixing bacteria.

   Answer: Nitrogen fixing bacteria are found in the roots of leguminous plants. The bacteria derive carbohydrates from the plant, in turn supplying ammonia to the plant, which performs the role of a fertilizer. This is an example of mutualism.

9. Give two examples of parasites.

   Answer: Mosquitoes and hornworms are parasites which affect mammals and tomatoes, respectively.

10. Explain how the relationships between organisms play a role in their evolution.

    Answer: Relationships such as predation, parasitism, mutualism, commensalism, and competition dictate the populations of organisms in a species. Depending on their numbers, these organisms develop characteristics which further enhance their ability to survive in the surrounding environmental conditions. This has a direct impact on their evolution over a period of hundreds of thousands of years.

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Activity Sheet

Name _____

Date _____

Ecosystems

Work with a partner. Read the Explore section of “Ecosystems.” Use the Interactive Glossary to write new words in the chart below. Talk about their meanings. Use the Note-Taking took in Techbook to add your own definition for each word.

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish? _____

Word	Meaning	Picture

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Exploration

TEACHER guide

The Ever-Changing River

Exploration Summary

Students will match pictures of the stages in the maturation of a river to their appropriate positions in a timeline.

Student Learning Objectives

- Recognize that a river's characteristics change as the river ages.
- Describe the effects that water erosion can have on a river over time.

Student Worksheet

The student worksheet includes questions to check understanding, instructions for how to use the Exploration, and a section for recording Exploration data. Why do the questions come first? In following best practices for teaching science, students are asked to review questions before participating in an activity. When the questions come first, students are more focused on the intended content of the activity. Then they can respond to the questions during the activity or after completion of the activity.

Exploration Procedure

Explain that the purpose of this Exploration is to learn about the effects that water erosion can have on a river over time. Follow the appropriate procedure below.

Student Performs Exploration

1. Tell students how much time they will have to complete the Exploration and the student worksheet.
2. Explain how students should proceed:
   - Read the questions before starting the Exploration.
   - Follow the instructions on the worksheet to perform the Exploration.
   - Take notes or record data as necessary.
   - Respond to the questions in writing.
3. Explain that you will be available to help any students who raise their hands.
4. Tell students to begin the Exploration.
5. When time is up, ask students to share their answers.
6. Talk about the Discussion Question below.

The Ever-Changing River

Teacher Performs Exploration

1. Display the questions from the student worksheet and ask students to tell you what they think they will learn from the Exploration based on its questions. Highlight key words.
2. Read the Introduction and click the Continue button.
3. Identify the Exploration components.
4. Roll your mouse over each river picture and read its description.
5. Select a picture and ask the class where it belongs on the timeline. Drag the picture to its place in the timeline on the right.
6. After completing the timeline, click the Next button to read and discuss the descriptions of those stages in sequence.
7. Pose each of the questions below and ask for answers from the class. Replay parts of the Exploration as necessary to illustrate the answers.
8. Talk about the Discussion Question below.

Optional: Use this Exploration as a small-group activity at a computer station. Assign it to students who need specific reinforcement of the concept.

Questions

1. What is an ox-bow lake?
   Answer: A small river segment that was cut off from the rest of the river as the river changed course.
2. What effects did the maturing river have on the land around it?
   Answer: Its meandering widened the valley and the flood plain.
3. What was the first visible effect of water erosion on the river itself?
   Answer: Its course began to curve.
4. What was the effect of water erosion on the river's water flow over time?
   Answer: The water flowed more slowly.

Discussion Questions

What are some of the most visible signs of water erosion in a river?

Possible answers

- cracks in the soil along the river bank
- exposed tree roots along the edge of the river bank
- trees leaning over into the water from the edge of the river bank
- areas of the river bank worn away underneath
- a collapsed river bank
- clumps of grass in the river
- brown or colored water

Hands-On Activity

Food Webs and Trophic Levels

Objective:
Students will be assigned an organism within an ecosystem and organize themselves into trophic levels. Students will then use yarn to model the energy connections within the ecosystem.

Estimated time to complete: 20 minutes

Materials:

For entire class:

- 6 labeled pieces of construction paper, one for each trophic level
- 20-foot pieces of yarn, one for each producer in the activity

For each student:

- 1 index card labeled with the name of an organism

Procedure:
Prior to beginning the activity, place six labeled pieces of construction paper on the classroom floor. Each piece of paper serves as a "placeholder" for one of the following trophic levels:

- Producers
- Primary consumers
- Secondary consumers
- Tertiary consumers
- Decomposers
- Detritivores

Give each student in the classroom an index card labeled with the name of an organism; all organisms should fall clearly into one of the six trophic levels, but do not identify which trophic level each organism belongs to. Here are some suggestions:

- producers: algae, sea grass, marsh plant
- primary consumers: oyster, dragonfly, fly, cricket, minnow, snail, squirrel
- secondary consumers: flounder, water snake, frog, largemouth bass, duck
- tertiary consumers: bald eagle, osprey
- decomposers: bacteria, mushroom
- detritivores: earthworm, fiddler crab

Instruct students to work cooperatively to organize themselves into the correct trophic levels, so that all producers stand around the piece of paper labeled "producer," all primary consumers stand around the piece of paper labeled "primary consumer," etc. Try to allow students to figure out their groups on their own, but supervise and regroup students if needed. You may want to give hints such as telling students what their organisms eat.

When all students are correctly organized, give each “producer” student a piece of yarn. Explain to the class that the yarn will be used to show connections among the organisms in a food web. Work together to make the connections, one organism at a time. For example, you could begin by asking students to name an organism that eats algae. If they name the oyster, the student with the “algae” index card would hand one end of his or her yarn to the student with the “oyster” index card, and so on. It is not important to cover each and every connection; however, students should understand that all of the organisms are connected to the decomposers and detritivores, as they are responsible for breaking down decaying plant, animal, and fecal matter. Work until a simplified food web model has been created. To help you with the food web, below is a list of some connections that could be made:

- algae → oyster
- algae → minnow
- fly → frog
- dragonfly → frog
- any organism → earthworm
- any organism → fiddler crab
- minnow → largemouth bass
- fiddler crab → osprey
- water snake → bald eagle
- sea grass → duck
- frog → largemouth bass

Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated.
- Scientific Endeavor
  - Characteristics of Science
    - One way to make sense of something is to think of how it relates to something familiar.

Hands-On Lab

Stream Ecology

Timing: one 90-minute class session

Objectives: In this lab, students will complete a quality analysis of stream water to investigate how organisms, populations and communities respond to external factors such as pollution. They will analyze their results by comparing their data to acceptable standard data and discussing ways in which human activities may affect stream ecosystems.

Safety Precautions:
Remind students to wear gloves, goggles, and closed-toe shoes, and not to eat or drink anything in the lab (including the experimental materials). Tell students to report any broken glass and not to try and clean it up themselves. If students are involved in collecting water samples be sure to follow local regulations regarding field excursions. If the class visits the stream, tell students to wear appropriate outdoor clothing (especially footwear) and bring along a change of clothing in case they get wet.

Materials:
Per group of 4 or more:

- (1) water sample (50 mL or more) from a local stream. For the guided inquiry collect samples from a wider range of locations within a stream's watershed.
- (1) eyedropper
- (1) freshwater quality analysis kit that includes tests for pH, dissolved oxygen, nitrates, phosphates, and salinity
- (1) Petri dish
- (1) sheet of 1 cm x 1 cm grid paper, cut into a circle and taped under the bottom of the Petri dish
- (1) dissection microscope
- (1) Stream Water Quality Standards chart (see end of this Hands-On Lab)
- (1) illustration of Common Stream Macroinvertebrates (see end of this Hands-On Lab)
- (2) Pieces of flip chart paper
- (3) Marker pens (various colors)

Teacher Preparation:

Collect enough stream water so each lab group has at least 50 mL of water, using sterile beakers for collection. Review the water-testing procedures found in the analysis kit prior to class. To measure grid paper for the bottom of a Petri dish, trace the outer edge of the Petri dish onto the paper. Cut out the circle of grid paper and tape it to the bottom of the Petri dish with double-sided invisible tape. Make sure the grid is facing up so it can be seen when looking into the Petri dish. NOTE: If time allows and source is available, you may want to organize an outing during which students collect the water samples themselves. The survey of macroinvertebrate indicator species requires a visit to the stream itself and collection of animal specimens.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>
Instruct students to read over the Stream Water Quality Standards chart and answer any questions they have. Next, demonstrate for students the basic procedures for observing a water sample for macroinvertebrates.

1. a. Use an eyedropper to extract water, and squeeze the water into the Petri dish. Repeat until the Petri dish is approximately half-filled with water.

b. Place the Petri dish under the compound microscope and adjust focus and light as needed.
b. Compare shapes seen on the illustration of Common Stream Macroinvertebrates (at the end of this Hands-On Lab) to those seen through the microscope.
d. Record the number of *different* macroinvertebrates observed, and make a sketch of each type. Then, observe the *number* of macroinvertebrates. This will be difficult with fast-moving organisms, so use a best estimate by counting the ones in each section of the graph paper and calculating an estimated total.

Next, show students how to test the water sample for pH, dissolved oxygen, nitrates, and phosphates. Follow the kit instructions for this.

Instruct students to record all data in their notebooks using an appropriate method (graphic organizer, table, etc.). Encourage students to compare their results with other groups.

After students have completed the procedure, have each group briefly share their observations and data (verbally and using charts). Next, have students compare their chemical data results to the Water Quality Standards chart and ask leading questions such as:

- Would you consider your results of the macroinvertebrates observation an indicator of high quality or poor quality stream water? Why?
- Were your chemical results similar to the Water Quality Standards?
- What might be the reason for elevated (or below average) levels of pH? Dissolved oxygen? Nitrates? Phosphates?
- What affect might increased nitrate levels have on the overall food chain of the stream?

<u>Guided Inquiry</u>

Lead the students in a brief discussion of the aquatic component of your local stream watershed. Discuss some of the different populations and their interactions. Next, instruct students to work in groups to develop a question that could be answered by conducting a quality analysis of samples of local steam water from different parts of the watershed. If possible organize a field trip to collect samples and observe the watershed features. This could be conducted as an after school activity with selected students. In the lab have students work in small teams of 4-6. Tell them they are working together as a team of

"ecologists". You may want to help them brainstorm by presenting some questions such as:

- Why would an ecologist test stream water? What could he or she be looking for?
- What sort of data could be collected when studying a sample of stream water?
- What organisms would an ecologist look for when surveying a stream? Why?

Have each group show its question to you and instruct them to revise as needed; make sure the question is testable. [Samples: *Are pH, nutrient and oxygen levels the same throughout the watershed? Are different aquatic species found in different parts of the watershed? If so why do these differences exist? What evidence is there of human impact?)]*

Instruct the student groups to use the materials provided to gather data about the water samples. If time is a concern, point out that they should divide tasks and responsibilities between members of their team. Also, you should monitor each group's progress as they work and help them interpret the water quality test results if necessary. Remind students to compare their data to the data in the Water Quality Standards chart. Finally, have students answer the question they developed in their ecologist groups.

Analysis and Conclusions

On 2 pieces of flip chart paper, have each team present their question and a short summary of their findings (in the form of tables, graphs, illustrations, maps etc.). This should form the basis of a short team presentation to the class. Encourage other teams to engage in challenging questioning of the data, its analysis and conclusions. Exhibit these charts, together with those of other classes. Use these to help students create an overview of water quality within the watershed. Among the questions to be addressed are the following:

1. Some stream macroinvertebrates are considered pollution-sensitive and others are considered pollution-tolerant. What could you infer about a stream that has a diverse population of organisms, but contains no pollution-sensitive organisms? *(They died or moved to another area.)*

2. Certain types of freshwater fish require water that is relatively low in temperature. How might the removal of shading trees around a freshwater pond affect these types of fish populations? *(Increase the water temperature so the fish that require water that has a*

low temperature would either die or need to move to a place with shade or a cooler water temperature.)

3. What pollution-sensitive species occur in the water that you sampled? What does this tell you? Hypothesize about the relationship between your data regarding pollution-sensitive species and the pollution levels in your water sample. *(Answers will vary.)*

4. Do you know of any *invasive* species that occurs in this water, but is not native to this area? If so, how do you think it got here? *Answers will vary.)*

5. In general how do you think communities respond to pollution? *The organisms may decrease in number, diversity may decrease, new pollution tolerant species may come into the community.*

Further Questions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. If your observations and chemical measurements indicate that your water sample is unhealthy, what factors might be contributing to the poor quality? If your data indicate a healthy stream, what factors could cause potential problems in the future? *[Run-off from nearby farms may be causing pollution and harm to the stream populations.]*

2. If you found elevated nitrates in your water sample, and you attributed these nitrates to run-off from crop fertilizers, which other chemical measurement likely would also be elevated, and why? *[Phosphates may be elevated because they also result from agricultural application of fertilizers for certain crops. Livestock also release phosphates in their urine and runoff from livestock might also reach the stream.]*

3. Some stream macroinvertebrates are considered pollution-sensitive and others are considered pollution-tolerant. What could you infer about a stream that has a diverse population of organisms, but contains no pollution-sensitive organisms? *[Pollution-sensitive organisms would only survive in a healthy, unpolluted stream. They would be an indicator that a stream is not healthy.]*

4. Algae thrive with adequate sunlight and nutrients. After a period of overgrowth (an algal bloom), algae die in large numbers and are decomposed by prokaryotes. Describe a sequence of events that could lead to an algal bloom and the results of the bloom on a

pond*. [Sample answer: Increases of nitrates and phosphates in the presence of sunlight could result in an algal bloom. Death of the algae would result in a reduction of dissolved oxygen in the pond.]*

5. Certain types of freshwater fish require water that is relatively low in temperature. How might the removal of shading trees around a freshwater pond affect these types of fish populations? *[Removal of the trees would likely increase water temperatures as more direct sunlight reaches the water. Therefore, the temperature-sensitive fish populations would likely decline.]*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship.
    - can be answered with a science investigation or observational study.
  - Develop predictions/hypotheses that
    - state what may happen in an investigation based on prior knowledge or experience (prediction)
- Design Investigations
  - Design and conduct investigations using:
    - Fair test - changing only one variable at a time makes comparisons valid
    - Independent variable - the one variable the investigator chooses to change
    - Dependent variables - what changes as a result of, or in response to, the change in the independent variable
    - Control (control group) - used for comparison in which the independent variable is not changed
- Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
- Gather Data
  - Uses the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
    - Sketch
    - Diagram
  - Use senses to observe

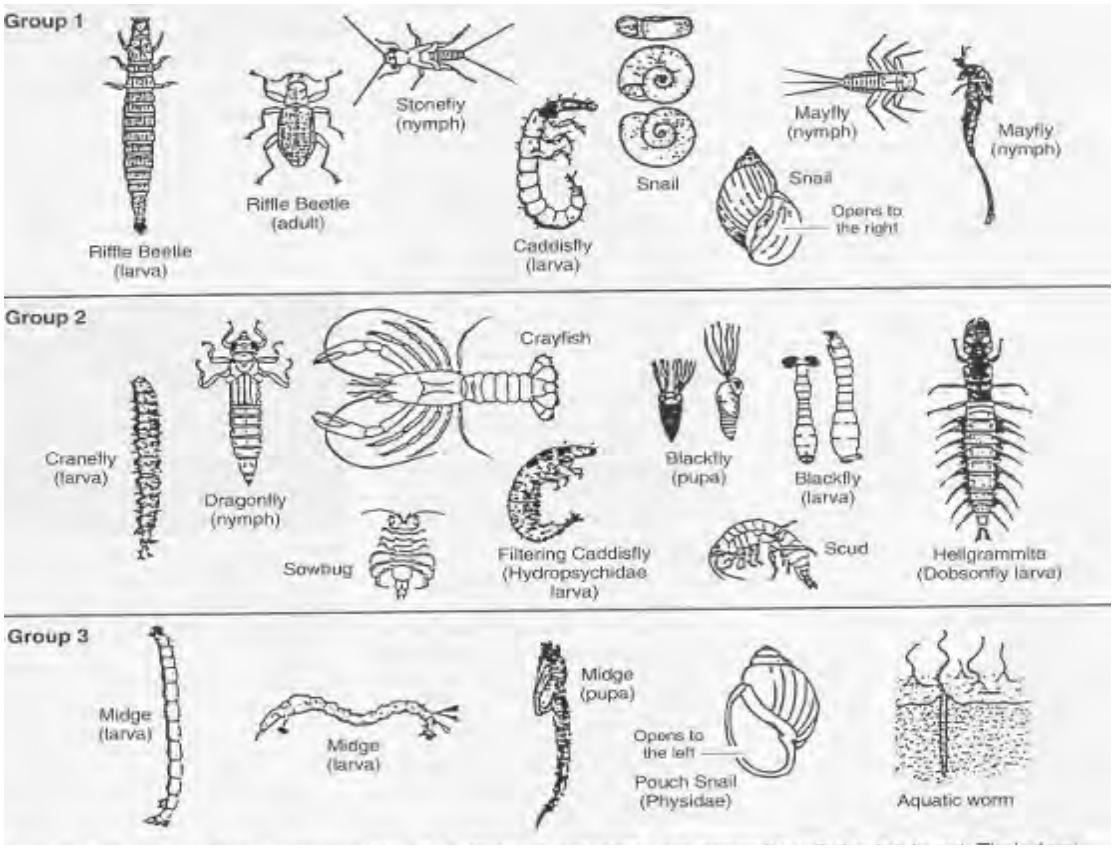
        - Seeing (color, shape, size, texture, motion)

- Evaluate Evidence
    - Drawing and supporting a conclusion by:
        - Using data to determine the cause effect relationship observed in the investigation
        - Extrapolating results beyond the investigation.
        - Formulating scientific explanations/arguments
        - Show the application of the scientific concept or process being investigated
- Communication in Science
    - Report results using:
        - Peer presentation
        - Formulating scientific explanations/arguments
- Analyze Scientific Results
    - Participate in critiquing/peer review by:
        - Evaluating a conclusion
        - Analyze scientific explanations

Stream Water Quality Standards

Chemical Measurement	Average Standard Measurement for Supporting Aquatic Life	Information
pH	6.5-8.5	Measures the degree of acidity or alkalinity. A pH level that is too low or too high can damage organs of aquatic animals.
dissolved oxygen	>5 mg/L	Needed by aquatic animals for metabolic processes. When sewage and other pollutants are high, microorganisms use it for decomposition causing availability to decline for other organisms.
nitrates	<2 mg/L	Found in synthetic fertilizers used on crops to improve plant growth; elevated levels may cause overgrowth of algae, which in turn may deplete dissolved oxygen levels once the algae decays. Overgrowth of algae also limits available sunlight for other organisms.
phosphates	<0.1 mg/L	Found in detergents and synthetic fertilizers used on crops to improve plant growth; elevated levels may cause overgrowth of algae, which in turn may deplete dissolved oxygen levels once the algae decays. Overgrowth of algae also limits available sunlight for other organisms.
salinity	<5 ppm	Caused by minerals dissolving in groundwater and being carried to the stream, or by incursion of seawater in coastal areas. Too much salinity is toxic for most freshwater organisms. Many human activities that cause other forms of water pollution also increase salinity.

Illustration of Common Stream Macroinvertebrates



Hands-On Activity

Carrying Capacity

In this activity, students will investigate a field ecosystem and its carrying capacity for a population of mice. They will model predation and determine its effects on the ecosystem and mouse population.

Suggested Materials

Per pair:

- poster board, 56 cm by 71 cm, 1
- construction paper, 2 sheets
- ruler
- scissors
- marker, pencil, or pen
- calculator
- meter stick

Procedure

Gather materials in advance, and provide calculators for students if not already available. Some students may prefer to calculate the carrying capacities through graphical means by creating a grid on their "island." In this case, a yardstick may make the process easier.

1. Have students measure and record the size of their irregularly shaped paper. Inform them that it represents an island ecosystem, with each square centimeter representing a square meter of land. Ask students to calculate the number of square meters of land in their ecosystem.
2. After students have finished this calculation, tell them that every square yard of land contains enough wheat to sustain 5 mice. Have students use the construction paper to create a model depicting the amount of wheat necessary to support 5 mice and compare it to the overall size of the island, noting any observations they make.
3. Ask students to calculate the island's current carrying capacity.
4. Tell students that the badger population in this ecosystem has a hunting territory of 400 square meters. Instruct students to use the construction paper to create a model depicting the hunting territory of a badger.
5. Ask students to calculate the island's population of mice if 2 badgers entered the ecosystem and hunted all of the mice in their territory.

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Analysis and Conclusions

1. What was the carrying capacity of the mouse population in this island ecosystem?
   Answers will vary for each ecosystem. For islands around 50 cm by 70 cm, approximately 17,500. The ecosystem contains 3,500 square meters of field, and every square meter supports 5 mice.

2. How did your estimate of the mouse population change after the predator population was factored in? Explain.
   Answers will vary for each ecosystem. It decreased to approximately 13,500. Predation meant that fewer mice survived.

3. What percentage of the mice survived after predators arrived?
   Approximately 77%

4. Suppose that a drought occurred one year, and much of the wheat died. Now it takes 2 square yards of island to produce enough wheat for 5 mice. Assuming that the badger population is still present in the ecosystem, what is the size of the mouse population now? Explain.
   6,750. There is less wheat available for the mice to eat, so fewer mice survive.

5. Suppose that during the next year the sea level rose and reduced your island size by half. What would the carrying capacity of the mouse population be if the badger population was still present?
   4,750

6. Name the factors that limited the carrying capacity of the mouse population. What other factors might you take into consideration if you were to calculate a more accurate estimate of the carrying capacity?
   The factors that limited the carrying capacity were the amount of wheat available and the presence of predators. Answers may vary, but students should cite at least two of the following as limiting factors:, interspecific competition, disease, environmental conditions such as temperature, and availability of other sources of food.

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In this activity, students will demonstrate the following Inquiry Skills:

- Identify
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship.
    - Require the changing of one variable at a time.

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated.

- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)

  - Uses the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
    - Table
    - Graph or chart

- Interpret Data
  - Identifies and interprets patterns
    - Trends in data
    - Repeating physical or data pattern
    - Graphed data points
    - Tables and graphs
    - Analyzes data collected during an investigation

- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause effect relationship observed in the investigation.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

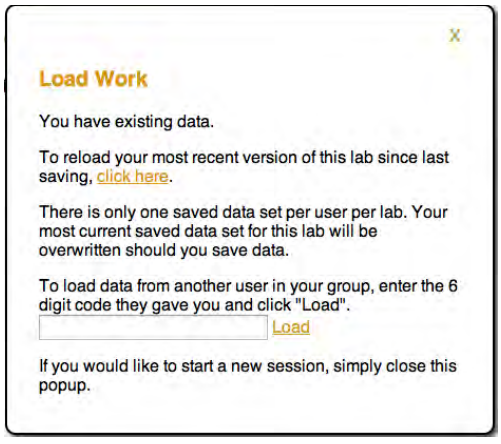
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

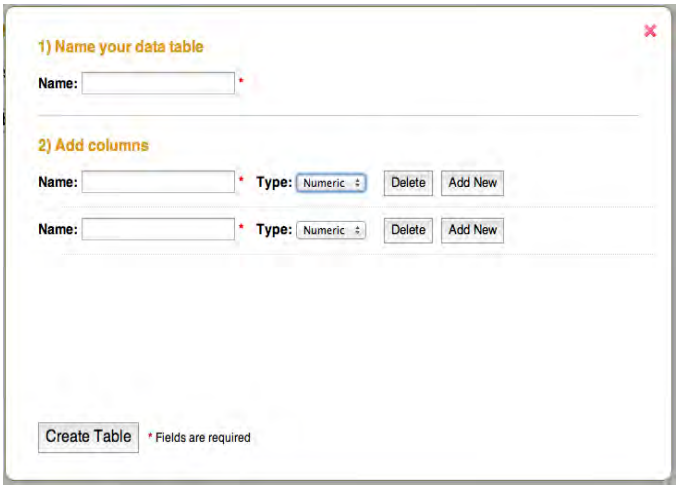
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



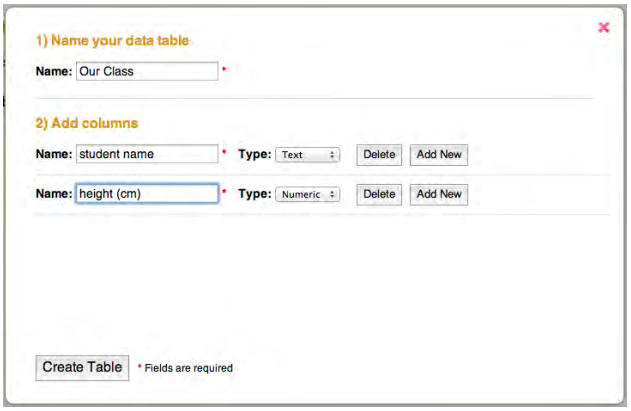
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

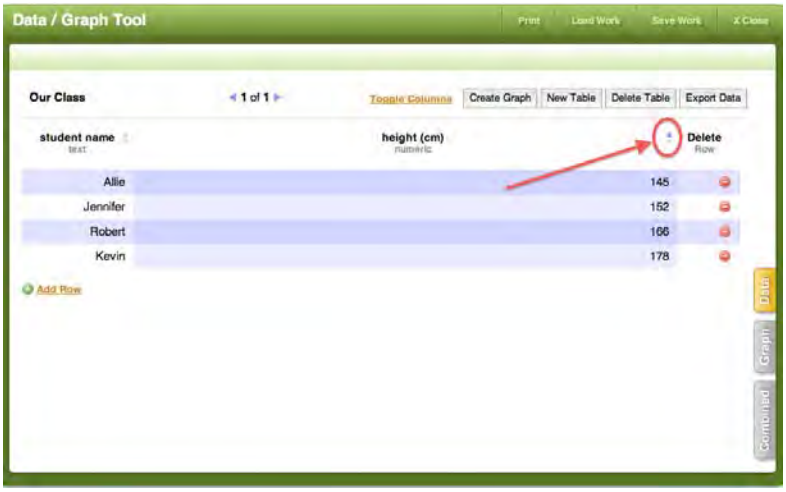
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

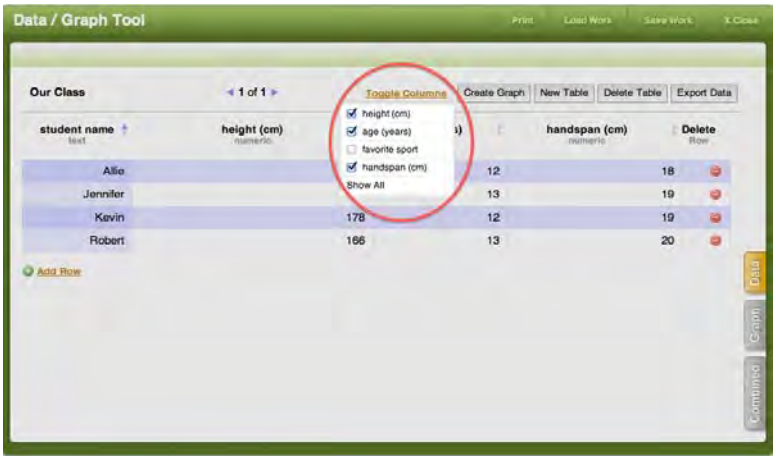


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

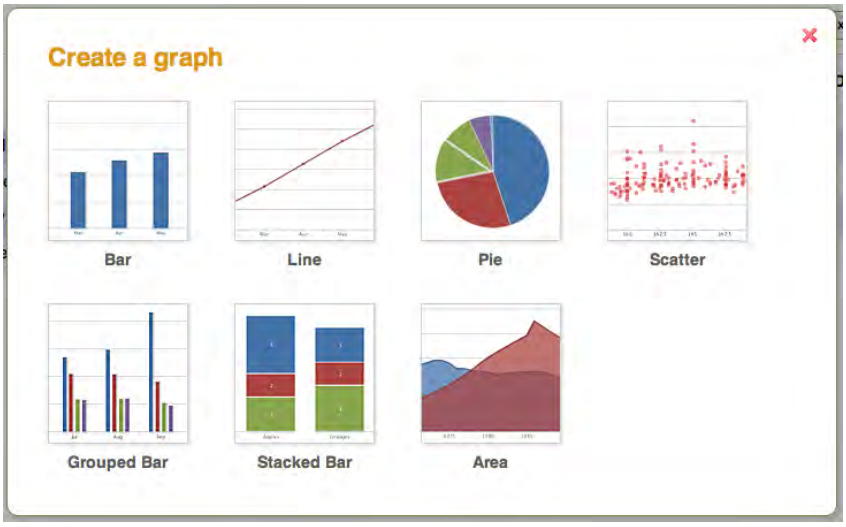
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

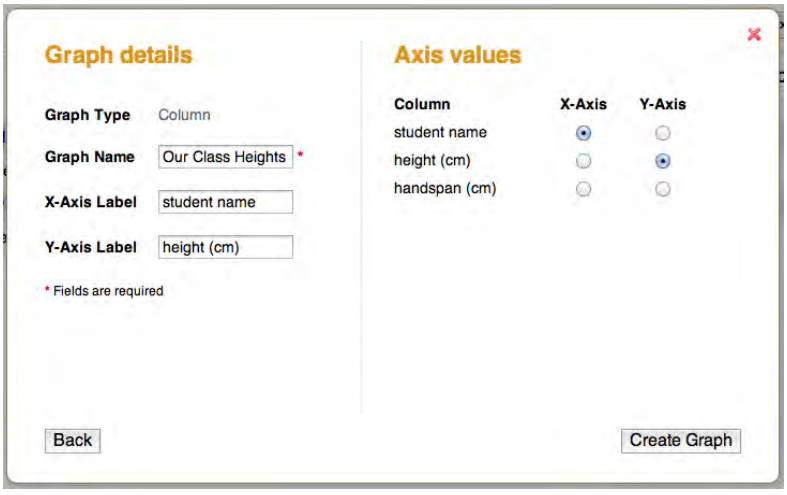
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

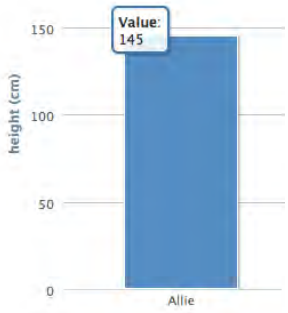


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

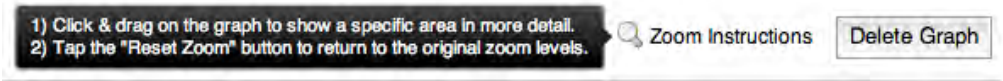
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Exploration Teacher Guide: Describing Populations

Overview

Populations are groups of organisms within the same species. In this Exploration, students examine the dynamics of population growth by varying initial population, birthrate, and death rate of primary consumers and secondary consumers. They are introduced to the concepts of logistic and exponential growth.

Student Learning Objectives

- Investigate the relationship between different trophic levels in an ecosystem.
- Observe the characteristics of logistic and exponential growth.
- Determine the role of birth and death rates on population growth.
- Understand the concept of carrying capacity as a limit on population.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students use the radio buttons for *Temperate Forest* and *Taiga Region* to toggle between the two ecosystems. The dropdowns for *Initial Population*, *Birthrate* and *Death Rate* of primary and secondary consumers are used to vary these values. Students click on the *Include Carrying Capacity* checkbox to observe the effects of carrying capacity. The *Simulate* button is clicked after selecting the desired values. This action begins plotting of the population graphs for the primary and secondary consumers. An image showing the dynamic change in population is presented. Both graphs are plotted for a maximum period of two hundred simulated years or until either of the two populations becomes constant. After both graphs are plotted, clicking the *Proceed* button shows a window with the characteristics of the graphs formed.

The *Data* tab summarizes the change in primary and secondary consumers over the years.

The growth curves for primary and secondary consumers are shown in the *Graph* tab.

The *Tracker* tab allows students to compare the birthrate, death rate, initial, and final population of the primary and secondary consumers for various runs of the Exploration.

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Answers to Questions in the Student Worksheet

1. List the differences between exponential and logistic growth. Describe the graphs obtained in both these growth patterns.

   Answer: Exponential growth is characterized by a J-shaped curve. On the other hand, logistic growth is represented by an S-shaped curve.

2. This Exploration illustrates the interdependence of primary and secondary consumers. Describe the role of other trophic levels in population dynamics.

   Answer: Primary producers are the basic trophic level upon which the other levels depend. Predators that comprise the tertiary consumer level are important in controlling the numbers of primary and secondary consumers.

3. Explain the role of carrying capacity in limiting the population of a particular organism in an ecosystem.

   Answer: Carrying capacity is the greatest number of individuals in a population that a given environment is capable of supporting, under a specific set of conditions.

4. Can the death rate of a population of organisms be greater than 1? Explain your answer.

   Answer: A population's death rate can never exceed 1. A death rate greater than 1 implies that more individuals died than were in the population to begin with. That is, it is impossible for 110 individuals to die out of a population of 100.

5. Explain the factors that lead to population explosion of a species in an ecosystem.

   Answer: Unchecked growth of a species in an ecosystem may be due to factors such as favorable climatic conditions and absence of disease or predators.

6. The human population increased gradually until the nineteenth century, after which it has increased dramatically due to the availability of better medicine and food production. Describe the kind of growth curve that human population has followed.

   Answer: This kind of growth is termed as exponential growth as it is characterized by a J-shaped curve.

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7. Explain the differences between the Malthusian theory of population growth and the Lotka-Volterra competition model.

   Answer: The Malthusian theory is based on a fixed set of parameters that were predefined by Thomas Robert Malthus. On the other hand, the Lotka-Volterra competition model gives specific formulae to calculate the changes in population.

8. Give examples of two ecosystems and the primary and secondary consumers in each, which are interdependent on each other.

   Answer: In the South Polar Region, the population of penguins (secondary consumers) depends on the population of their food fish (primary consumers). In desert regions, the population of reptiles (secondary consumers) is based on the population of insects and other prey (primary consumers).

9. Many species are considered to be endangered. List the measures that can be taken to save them from extinction.

   Answer: Preventing endangered species from being hunted by using laws to protect them, and providing reserves for necessary habitat are measures that can save endangered species from extinction.

10. The birth rate and death rate are mathematically related to an organism's population growth. Describe the mathematical equation used to quantify this relationship. Explain how the growth rate could be negative.

    Answer: Birth rates and death rates combine to give the population growth rate, which maybe negative if death rates exceed birth rates. The equation describing this relationship is

    r = b – d, where r = growth rate, b = birth rate and d = death rate.

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Activity Sheet

Name _____

Date _____

Describing Populations

Work with a partner. Read the text and watch videos in the Explore section of “Describing Populations.” Write important words in the chart below. Write the meanings, draw a picture, and write a sentence using each word. Share your chart with your teacher. Use the chart to help you understand “Describing Populations.”

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish? _____

Word	Meaning	Picture	Sentence

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Teacher Hands-On Lab

Population Demographics

Timing: one 90-minute class session

Objective(s):
Students will use a sampling technique to determine the size of a plant population in their environment.

Safety Precautions:
Students will be working outside. Remind students to use sunscreen and other protection as needed and to be careful of potential wildlife. Students should wear long pants, long sleeves, and close-toe shoes when working outside. Students should wear gloves when collecting samples. Students with plant allergies should be cautious and avoid contact with allergens.

Materials:
Per class:

- samples of plants being studied (optional)

Per student pair:

- stakes, 10
- string, at least 2 m
- meter stick
- scissors
- disposable gloves
- calculator, computer with spreadsheet program, or online standard deviation calculator (optional)

Teacher Preparation:
Collect materials one day prior to class. Find a suitable site for students to collect plant demographics. A site with grass, shrubs, and trees is ideal. Get permission from the land owner beforehand, and get permission for gathering samples. If it is required to leave the school campus for the fieldwork, make any necessary arrangements with the school administration and parents. Alternatively, students can survey landscaping plants at the school. If possible, provide students with samples of the target plants they will be studying prior to going outside to help them with identification. Alternatively, students can find images of the plants on the Internet or in a field guide. Make copies of the Student Investigation Sheets, one per student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic

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laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Students will work with a partner to conduct a sampling technique called plot sampling in order to determine the population density of target plants (a common groundcover/plant). Make sure students know how to identify the plant species they are studying by providing them with samples of the plants prior to going outside or by allowing them to find an image of the plant on the Internet.

Review the following procedure with the class prior to going outside. Also have students predict the outcome of the field study: How many target plants will they find in a 2 × 2–m area? Before conducting their study, have student to generate a hypothesis about the proportion of plant species they might find in the given area. Use a meter stick to demonstrate the size of a 2 × 2–m quadrat.

1. Choose an area, or quadrat, in the field to use as your plot sampling area. Try to choose the area randomly and not because it appears to contain more plants or more target plants than nearby areas. The area should by 2 × 2–m in size. Use stakes and string to mark off the area.
2. Randomly choose a smaller area within your quadrat from which you will count target. This area should be 20 × 20 cm. Use stakes and string to mark off the area.
3. Count the number of individual target plants in the 40 × 40–cm area and record it in a data table.
4. Estimate the average number of target plants in the 2 × 2–m quadrat by multiplying the number you recorded in Step 3 by 25 because there are 25 smaller areas within the larger quadrat. Record this number in the data table.

Once the field study has been completed, have students share their data by writing it on the board in a class data table. As a class, find the class average number of target plants and compare the average with the individual data set from each group. Discuss whether this was a good sample size.

Optional extension activity: As a class or in pairs (using calculators, spreadsheets, or an online standard deviation calculator), calculate the standard deviation of all the data sets. Discuss how

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closely or far apart the data seem to be grouped and whether knowing the standard deviation changes students' opinions of whether the sample size was sufficient or not.

Guided Inquiry

Students can develop their own plans for collecting data, based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry and make a hypothesis about the plant population before they begin their activity:

- How can you use a sampling technique to determine the population of a given plant species?
- How would your protocol vary if the plants you studied were grasses or if they were trees?
- What proportion of plant species might be found in this given area?

Before designing protocols for their sampling techniques, decide as a class what plant species students will be sampling so data can be shared and discussed after the fieldwork. If possible, provide students with real samples of the plants they will be studying, and have them draw sketches of an individual plant in their notes. Otherwise, allow students to find an image of the plant species on the Internet. Make sure all students receive approval of their protocols before going outside for the field study. Students should provide a description of their experimental design, which could be used by fellow scientists to conduct a similar study.

Analysis and Conclusions:

In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. Compare the experimental designs used by different groups if they differed from one another. Did a certain design result in an estimate that more closely matched the class average? *Answers will vary based on the selected site. Students may discover that larger samples provide more reliable data.*

2. When you surveyed the entire area, were there differences in plant density? Could you see any causes for differences—such as shade or sun for most of the day? *Students may have noticed systematic differences and could ascribe them to environmental variables such as light or other plant cover.*

3. If you arrange the class data from smallest count to largest count, how large is the range? Do you think the average (the mean) of the class data is a reasonable estimate of plant cover? Why or why not? (If you calculated standard deviation, reference those results as part of your justification). *Answers will vary. The mean of the class data is probably a reasonable estimate of true plant cover because many random samples were taken. (Standard deviation for the results indicated that the data were clustered fairly close together).*

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4. Imagine a situation in which a person took only a single 40 × 40–cm sample, and it happened to be the same as the largest sample from the class data taken today. How far off from average would that sample be? What statement can you make about the potential inaccuracy of a single sample representing a large population?
Answers will vary. If the plant data are fairly heterogeneous, the largest sample could be very much larger than the average. Students should understand that fewer samples are more inaccurate than many samples.

5. How well would this strategy work for sampling animal populations? *This strategy would work for animals that remain in a small, localized area (such as earthworms) but would not work well for animals that are more mobile.*

6. After completing the lab, share your explanation with someone from another group. Based on the data you collected, evaluate the explanation of the other person. How well did the other group's explanation fit their data? How are your data similar to or different than theirs? What issues or problems are there in the data? *Answers to this will vary.*

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Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - asks a question about a specific science concept or process
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
    - Require the changing of one variable at a time
    - Can be answered with a science investigation or observational study
  - Develop predictions/hypotheses that:
    - State what may happen in an investigation based on prior knowledge or experience (prediction)
    - State the expected cause and effect (if-then statement) in an investigation based on prior knowledge and experience (hypothesis)
- Design Investigations
  - Design and conduct field studies using:
    - Survey - collects multiple data points at one point in time
  - Design and conduct investigations using:
    - Fair test - changing only one variable at a time makes comparisons valid
    - Sampling - a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements
    - Multiple trials - repeated tests with the same variables to check for variability of results
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Properly citing all equipment and materials
    - Describing it so that it can be repeated easily by a fellow scientist
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
    - Incorporating laboratory safety practices into the investigation design
- Gather Data
  - Use tools and the SI (metric) system to measure accurately:
    - Length/distance/depth
  - Choose appropriate tools to conduct an investigation:
    - Meter stick
  - Use the appropriate format to record data:
    - Table
    - Graph
    - Chart

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        - Writing (journal, worksheet, electronic text)
- Interpret Data
    - Identify and interpret patterns using:
        - Trends in data
        - Tables and graphs
        - Analysis of data collected during an investigation
- Evaluate Evidence
    - Draw and support a conclusion by:
        - Using data to determine the cause-effect relationship observed in the investigation
        - Reporting trends and patterns in the data
        - Comparing results with hypothesis
        - Answering the testable question
        - Extrapolating results beyond the investigation
        - Examining how investigations can be improved
        - Formulating scientific explanations/arguments
- Communication in Science
    - Report results using:
        - Peer presentation
        - Written report
        - Scientific explanations/arguments
        - Table/graph showing data
- Scientific Investigation
    - Scientific investigation:
        - Science investigation begins with a testable question.
        - When a scientific investigation is repeated, a similar result is expected.
        - Science takes place in many locations including labs, offices, in the field, and under the ocean.
        - Scientific investigations lead to the development of scientific explanations.
    - Scientific data and outcomes:
        - Scientific claims are based on data and reliable scientific sources.
        - The best way to understand a changing pattern is by collecting and analyzing data.
        - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
        - It is important in science to keep honest, clear, and accurate records.
        - Arguments and conclusions are invalid if based on very small samples of data, biased samples, or samples for which there was no control sample.
- Scientific Endeavor
    - Characteristics of science:

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- Scientific claims can be substantiated using data and observation.
- An important part of science is the critical review and analysis of any idea or conclusion.

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Teacher Hands-On Lab

Population Demographics

Timing: one 90-minute class session

Objectives:

- Students will use a sampling technique to determine the size of a plant population in the environment.
- Students will determine the level of accuracy appropriate to measuring plant populations in this experiment.

Safety Precautions:
Students will be working outside. Remind students to use sunscreen and other protection as needed and to be careful of potential wildlife. Students should wear long pants, long sleeves, and close-toe shoes when working outside. Students should wear gloves when collecting samples. Students with plant allergies should be cautious and avoid contact with allergens.

Materials:
Per class:

- samples of plants being studied (optional)

Per student pair:

- stakes, 10
- string, at least 2 m
- meter stick
- scissors
- disposable gloves
- calculator, computer with spreadsheet program, or online standard deviation calculator (optional)

Teacher Preparation:
Collect materials one day prior to class. Find a suitable site for students to collect plant demographics. A site with grass, shrubs, and trees is ideal. Get permission from the land owner beforehand, and get permission for gathering samples. If it is required to leave the school campus for the fieldwork, make any necessary arrangements with the school administration and parents. Alternatively, students can survey landscaping plants at the school. If possible, provide students with samples of the target plants they will be studying prior to going outside to help them with identification. Alternatively, students can find images of the plants on the Internet or in a field guide. Make copies of the Student Investigation Sheets, one per student.

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Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Students will work with a partner to conduct a sampling technique called plot sampling to determine the population density of target plants (a common groundcover/plant). Make sure students know how to identify the plant species they are studying by providing them with samples of the plants before going outside or by allowing them to find an image of the plant on the Internet.

Review the following procedure with the class before going outside. Also have students predict the outcome of the field study: How many target plants will they find in a 2 m × 2 m area? Before conducting their study, have students generate a hypothesis about the proportion of plant species they might find in the given area.

Given that the sample area is 2 m × 2 m, ask students to discuss the appropriate level of accuracy, given limitations on measurement when reporting results. For example, students could count every single plant within the area, or they could use a smaller area for the sample. Ask students to consider how they could improve the accuracy of their counts. For example, if several students count the same plant species in the sample area, they would have a range of estimates. This range could then be used to determine the accuracy of a given count. Alternatively, all plants in the 2 m × 2 m area could be counted. However, sampling the entire area could take too long. Use this dilemma to explain the trade-off between measurement accuracy and the limitations of measurement.

Use a meter stick to demonstrate the size of a 2 m × 2 m quadrant.

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1. Choose an area, or quadrat, in the field to use as your plot sampling area. Try to choose the area randomly and not because it appears to contain more plants or more target plants than nearby areas. The area should by 2 m × 2 m in size. Use stakes and string to mark off the area.
2. Randomly choose a smaller area within your quadrat from which you will count target. This area should be 40 cm × 40 cm. Use stakes and string to mark off the area.
3. Count the number of individual target plants in the 40 cm × 40 cm area and record it in a data table.
4. Estimate the average number of target plants in the 2 m × 2 m quadrat by multiplying the number you recorded in Step 3 by 25 since there are 25 smaller areas within the larger quadrat. Record this number in the data table.

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- How can you use a sampling technique to determine the population of a given plant species?
- How would your protocol vary if the plants you studied were grasses or if they were trees?
- What differences in your sampling technique would be necessary to ensure a level of accuracy appropriate to limitations on measurement when reporting your results?

Before designing protocols for their sampling techniques, decide as a class what plant species students will be sampling so data can be shared and discussed after the fieldwork. If possible, provide students with real samples of the plants they will be studying and have them draw sketches of an individual plant in their notes. Otherwise, allow students to find an image of the plant species on the Internet. Make sure all students receive approval of their protocols before going outside for the field study. Students should provide a description of their experimental design, which could be used by fellow scientists to conduct a similar study.

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        - Writing (journal, worksheet, electronic text)
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    - Identify and interpret patterns using:
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- Scientific Endeavor
    - Characteristics of science:

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

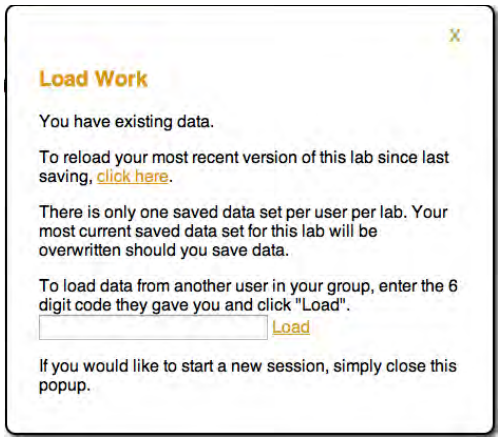
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

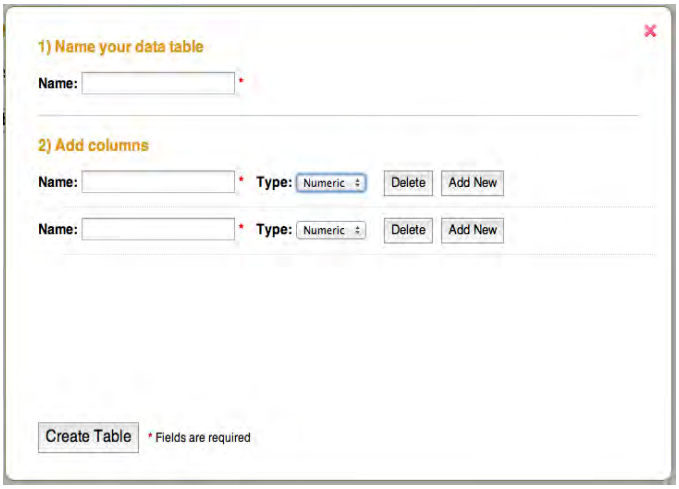
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



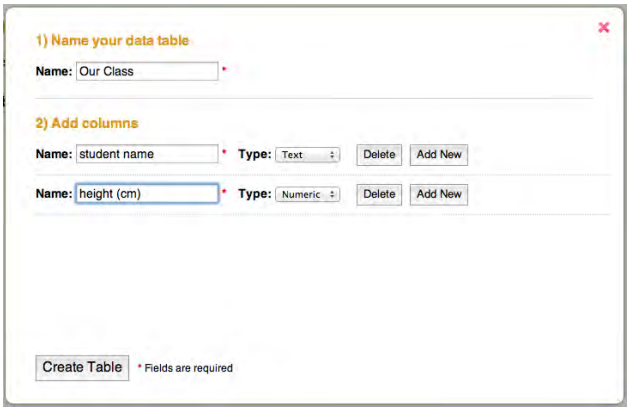
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

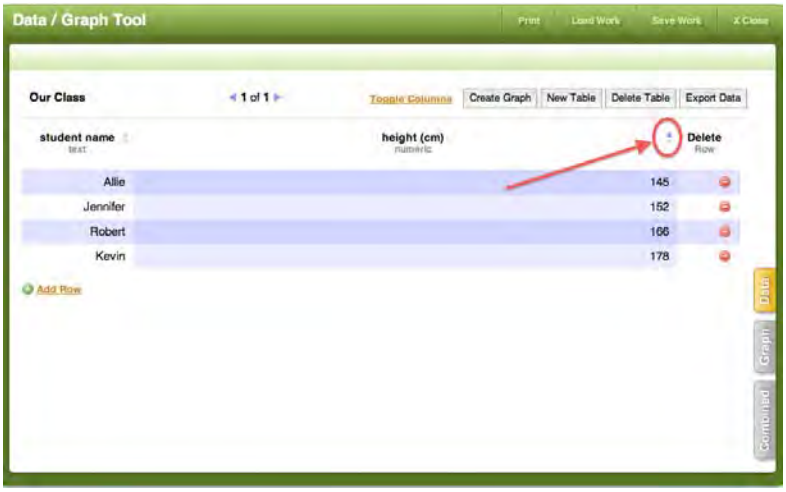
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

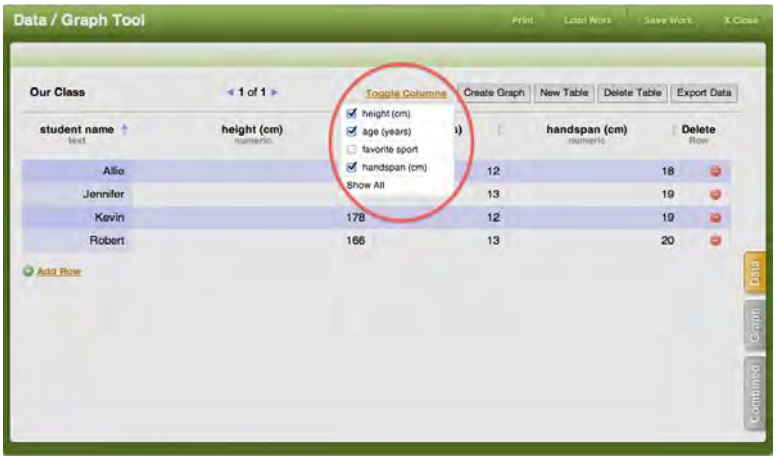


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

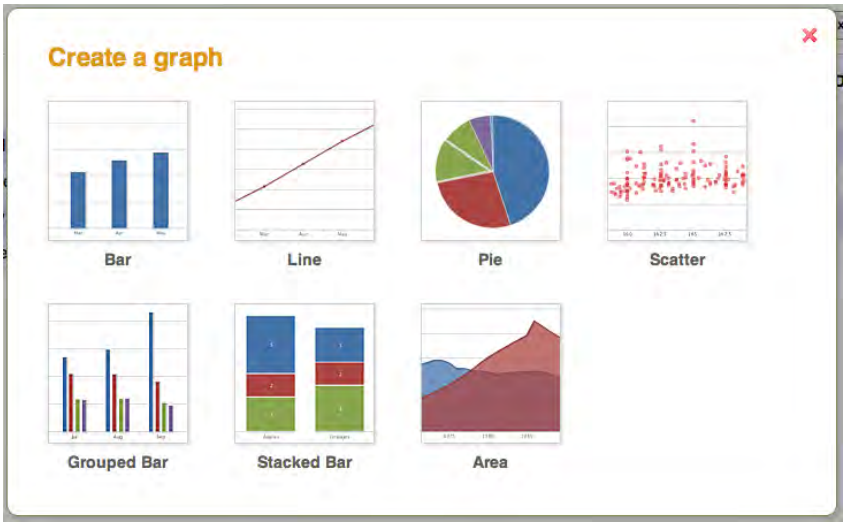
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

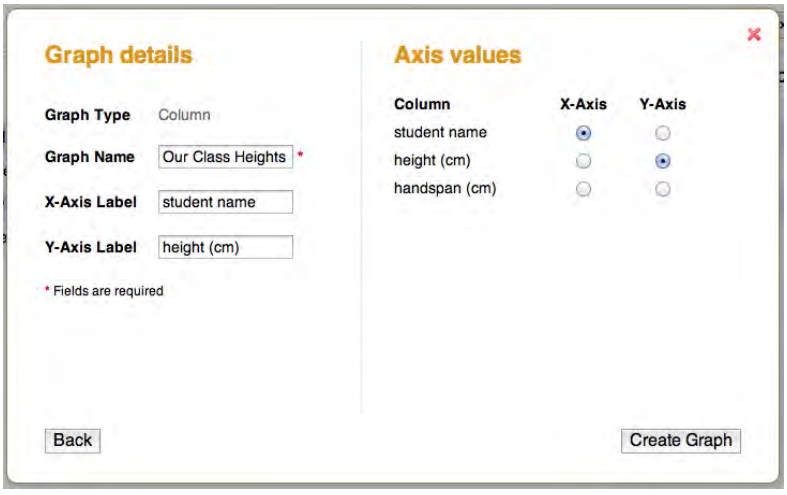
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

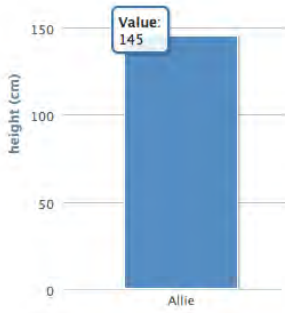


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

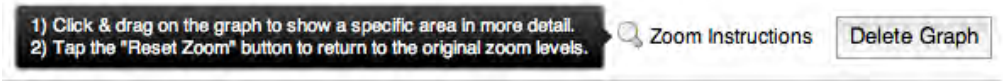
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Name _____

Date _____

Activity

Terrestrial Biomes

Overview: Work with a partner to read the Explore section of "Terrestrial Biomes." Highlight new words. Use the Interactive Glossary to help complete the chart below. Use your chart to create flashcards to help you learn the words.

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish? _____

	Meaning	Example or Picture

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Hands-On Lab

Experience Your Biome

Timing: one 90-minute class session

Objective(s):
In this investigation, students will conduct field investigations and Internet research to determine in which of Earth's major biomes they live. Students are expected to demonstrate an understanding of the use and conservation of resources, and to properly dispose of or recycle all consumable materials during this investigation.

Safety Precautions:
Students should follow general safety guidelines for fieldwork, including being careful of wild animal life, poisonous plants, and physical obstacles. Students should wear long pants, long sleeves, and close-toe shoes when working outside. Students should wear gloves when collecting samples. Students with plant allergies should be cautious and avoid contact with allergens. Students should not disrupt or remove any wild resources while in the field.

Materials:
Explain to your students the type of work they will be doing. Have each group select materials. Some typical materials are shown below:

- quart-sized self-sealing plastic bags, 4–5
- string, 4 meters
- computer with Internet access
- digital camera
- disposable gloves
- graph paper
- hand lens, one per student
- three-panel display board
- materials for three-panel visual presentation such as poster board, markers, colored pencils, scissors
- meter stick
- sticky notes

Teacher Preparation:
Research the local area around the school and determine the best areas for students to explore the characteristics of their biome. Be sure to find an area large enough so that several groups can mark off a 1 square meter observation zone. Get permission from the land owner beforehand, and get permission for gathering samples. If it is required to leave the school campus for the fieldwork, make any necessary arrangements with the school administration and parents. Prepare a copy of the Student Investigation Sheet found at the end of this lab for each student before the lab begins.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Review the following procedure with the class.

1. Use a meter stick and string to designate a 1 square meter area that will be your observation zone. Measure the area with the meter stick and lay the string on the ground to mark off the area.
2. Decide as a class what data you will collect from this area and make a corresponding data table. Suggestions for data include components of the soil, number and types of plant life, description of plants, number and type of animal life including insects, description of animal life, and description of terrain.
3. While making observations, use the digital camera to collect visual data.
4. If you have permission to, you may also use the plastic bags to carefully collect small samples of soil, rocks, or pieces of plants. Do not collect any animals or whole plants.
5. After returning to the classroom, research the temperatures and amounts of precipitation in your area for a one-year period within the last ten years.
6. Graph the data, using a computer if possible, for both average yearly temperature and precipitation in the form of a climograph. If students make their climographs by hand, remind them to consider the entire range of their data in order to choose an appropriate scale for the graph.
7. Use your research, field data, pictures, and samples to identify your terrestrial biome.
8. Gather all of your information to create a three-panel display of your biome. The display should include your data table, pictures from your fieldwork, any collected samples,

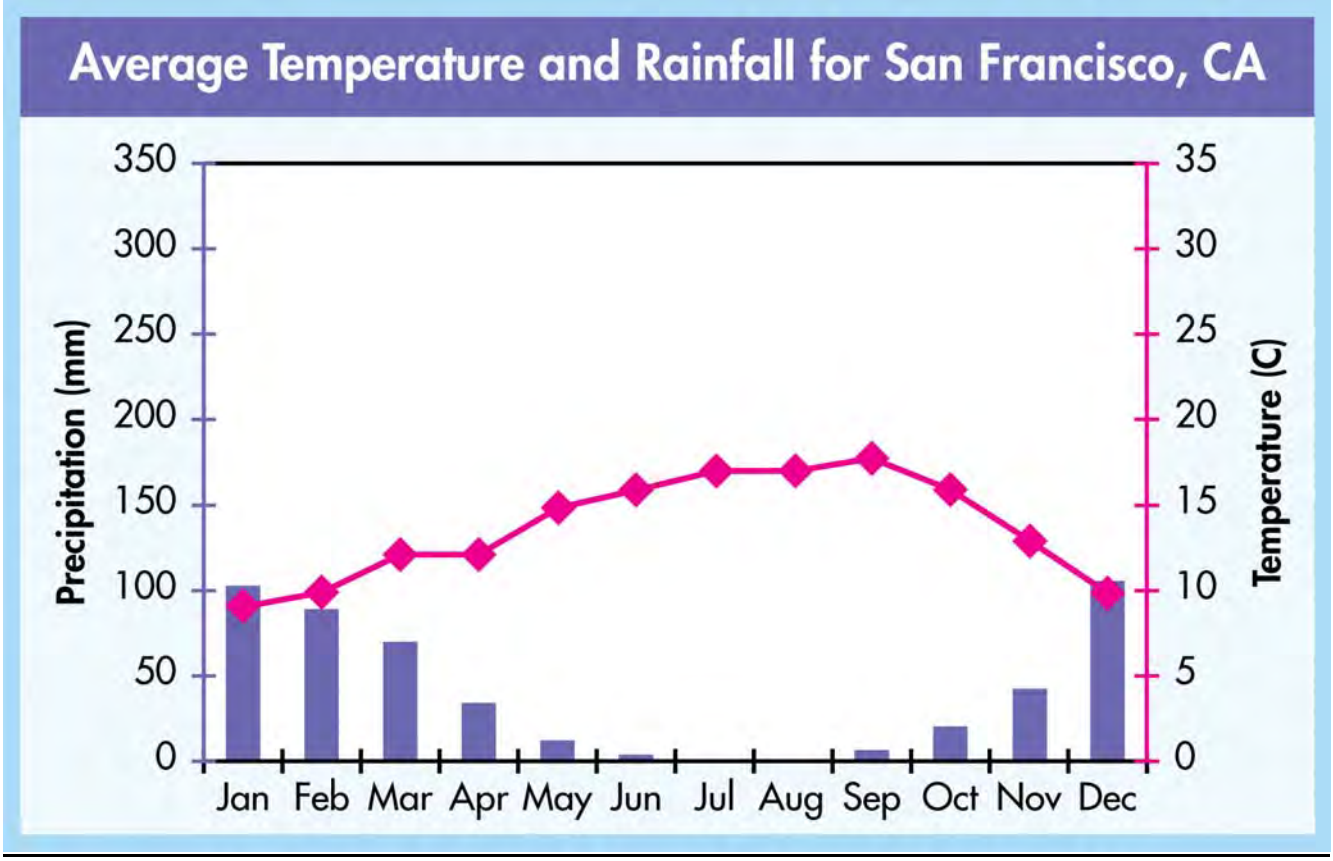
climograph, and a written summary of your findings including how you determined your biome.

Once all students have completed their three-panel displays, set the displays up in the classroom and have students go on a gallery walk to observe other groups' displays. Each student should write one question or constructive comment on a sticky note for the other groups' displays and place the sticky note near the display. When the gallery walk is over, allow groups to address any questions their classmates wrote on sticky notes.

Sample data table for field observations – Chaparral biome

Terrain	Soil	Plant life	Animal life	Other notes
*flat *nearby hills	*fairly dry *dusty *many pebbles *moist deeper down	*short shrubs *small leaves *light green color *prickly leaves *many bushes of this type *a few taller trees with skinny trunks *short grasses nearby	*squirrels *several insects including pill bugs, ants, and a few ladybugs	*spider webs but no spiders seen *the soil seems like it can be either dry or wet depending on time of year *these notes were taken in spring

Sample Climograph – Chaparral



Guided Inquiry

Students can develop their own plans for collecting data, based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry:

- What data will you collect?
- How will you record your observations to bring back to the classroom?
- What information do you need to determine the biome in which you live?

- What is a climograph?
- How will you present your findings?

Allow students to use the Internet to research the term “climograph” and how to create one. Make sure students receive approval about the type of data they will collect prior to conducting fieldwork. Students may work independently, but all groups should enter and exit the field together.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. How do your data compare with the data collected by other groups? If there are differences, are they because the plots are different, or did you notice things other groups did not (or vice versa)? *Student answers will vary. Both effects probably are in operation: the plots differed and the groups differed in the amount of data they recovered.*

2. How does this lab compare to the work of an environmental engineer or other biome scientist? How does it differ? *Sample answer: Like environmental scientists, this lab allowed us to do field work or perform an investigation in the real world. We gathered actual data about the biome from where it exists rather than in a classroom. It is different because we only examined a small area (1 sq. meter) of the biome. Scientists in the field would cover much more of the biome’s area in order to gather the most accurate data.*

3. If you were to repeat this experiment in five years and found drastically different data, what conclusions might you draw? *Sample answer: I would suspect that some sort of pollution, natural disaster, or other major event occurred that would have caused major changes to the biome in such a short period of time.*

4. Is it possible for a student in another part of the world to collect data nearly identical to yours? Explain. *Sample answer: Yes, because the same biomes are found in different parts of the world. Many of the same biomes exist at the same latitude on Earth but at different longitudes. So a student living across the world could easily collect the same the data I collected here about my biome.*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - asks a question about a specific science concept or process.
- Design Investigations
  - Design and conduct field studies using:
    - Survey - collects multiple data points at one point in time
  - Make or use models that:
    - Have as many details as possible replicated from the real thing.
    - Function exactly like or similarly to the real thing
  - Practice lab safety by:
    - Following lab safety procedures
- Gather Data
  - Chooses appropriate tools to conduct an investigation:
    - Meter stick
    - Magnifying glass
    - Other laboratory equipment
  - Uses senses to observe:
    - Seeing (color, shape, size, texture, motion)
    - Touching (temperature, texture, shape, size, vibration, motion)
  - Uses the appropriate format to record data:
    - Table
    - Graph
    - Writing (journal, worksheet, electronic text)
    - Photograph/image
- Interpret Data
  - Identifies and interprets patterns:
    - Trends in data
    - Graphed data points
    - Tables and graphs
    - Based on an analysis of data collected during an investigation
- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Reporting trends and patterns in the data.
    - Extrapolating results beyond the investigation
- Communication in Science
  - Report results using:
    - Peer presentation

        - Written report
        - Scientific illustration with proper labeling
        - Images or video
        - Table/graph showing data
- Patterns and Systems
    - Patterns and Change:
        - Patterns in nature may be simple repeating patterns or complex growing or changing patterns
- Scientific Investigation
    - Scientific Investigation
        - Science takes place in many locations including labs, offices, fields, and under the ocean.
        - Scientific investigations generally work the same way in different places.
    - Scientific Data and Outcomes
        - Scientific claims are based on data and reliable scientific sources.
        - Collecting and analyzing data is the best way to understand a changing pattern.
        - Some data can be collected in a short period of time (e.g. motion of a rolling ball) and some data takes much longer (e.g. the growth of a tree).
        - It is important in science to keep honest, clear, and accurate records.
- Scientific Endeavor
    - Characteristics of Science
        - Science is based on factual knowledge.
        - Scientists are curious about wanting to know how things work.
        - Scientific claims can be substantiated using data and observation

Exploration Teacher Guide: Terrestrial Biomes

Overview

Biomes consist of specific plant and animal communities. Every biome has a set of compatible environmental conditions and life forms specific to that biome. In this Exploration, students build different biomes and use an interactive key on a world map to distinguish between the various biomes.

Student Learning Objectives

- Distinguish among various terrestrial biomes and their diverse conditions, including the tundra, taiga, grassland, desert, temperate forest and tropical rain forest.
- Identify the climatic conditions of the different biomes.
- Determine the soil types in each biome.
- Compare the compatibility of the environmental conditions and life forms within a biome.
- Evaluate the pattern of temperature and precipitation in each biome.
- Identify the adaptations of certain plants and animals to their biome.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Build* tab, students select the biome they want to build from the *Biome* dropdown list. They then choose the most compatible environmental conditions and life forms for that biome. Students select the environmental conditions using the options in the *Mean Annual Temperature*, *Mean Annual Precipitation*, and *Soil* dropdown lists. They select the life forms using the options in the *Vegetation*, *Mammal*, and *Bird* dropdown lists. Students see an appropriate image for each selection. On clicking the *Check Compatibility* button, students receive feedback on the compatibility of each selection with the selected biome. Feedback indicates why a selection is not compatible with the biome. The *Compatibility Meter* shows the level of overall compatibility of the selections to the given biome. If all the selected elements are compatible with the biome, the students can use the *View Biome* button to see an integrated image of all the selections in the biome.

In the *Graph* tab, students view the biomes of the world on a map and observe how biomes change with latitude. The students use the interactive key to select a biome. A representative city is shown on the map. Students also view graphs for the annual temperature and precipitation of that city. They use the information in the text pane to compare the different biomes and the diverse conditions in them.

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In the *Tracker* tab, students observe the compatibility of each selection with the biome as well as the overall level of compatibility for each attempt. They use this information to improve upon each incorrect attempt and build every biome with perfectly compatible elements.

Answers to Questions in the Student Worksheet

1. If you were to travel around the globe, would you be more likely to come across different biomes by travelling from north to south, or from east to west? Explain.

   Answer: Since biomes depend largely on latitudes, you would be more likely to come across different biomes by travelling from north to south. Travelling east to west, you may not encounter as many different biomes.

2. Crossbills are birds whose upper and lower bills overlap or cross. The bill shape of different species of crossbills is optimized for opening specific species of conifers and extracting the seeds. Identify the biome you think this bird is most suited to.

   Answer: Since conifers grow in the taiga biome, this biome would be the most likely one to suit the crossbill.

3. Comment on the biome that receives the highest amount of precipitation. Explain the reason behind this.

   Answer: The tropical rain forest receives the highest amount of rainfall. Warm temperature in the tropics causes warm air to rise, since warm air is less dense. Near the equator, rising warm air carries moisture from the oceans. As the warm and moist air rises, it cools and the moisture condenses as rain. This is why tropical areas receive rainfall throughout the year.

4. Explain why the tundra biome has extremely cold and dry conditions.

   Answer: The tundra is located in the northernmost latitudes. Due to the tilt of the Earth's axis, it receives relatively little sunlight. The long winters are months of twilight and darkness, with the Sun remaining below the horizon. Since cold air cannot hold as much moisture as warm air, the tundra is dry, with very little precipitation, mostly in the form of snow.

5. Consider two soil samples, one from a tropical rain forest and the other from a temperate deciduous forest. Predict which sample would have a greater concentration of organic material. Explain your answer.

   Answer: Deciduous trees shed their leaves every fall and these fallen leaves decompose relatively slowly because of the cool conditions during winter. Therefore, leaf litter accumulates over time. On the other hand, decomposers on the rain forest floor rapidly break down dead plant and animal matter, which is then taken up by plants again. The leaf

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litter has little opportunity to accumulate. Therefore, the soil from the temperate deciduous forest would have a greater concentration of organic material.

6. Grasslands are the most productive farming regions. Explain how agriculture can have a negative impact on the ecology of the grassland biome.

   Answer: Grain crops have shallow roots and cannot hold the soil in place, eventually resulting in soil erosion. Using fertilizers and pesticides changes the soil chemistry and biota. If crops are not rotated properly, the nutrients in the soil are exhausted, leading to barren land. The native flora and fauna may not be able to survive.

7. Identify a biome with very little vegetation. Explain the absence of large plants and trees in that biome.

   Answer: In the tundra, harsh winters and strong winds, short summers, permafrost, and lack of adequate water hinder the growth of large plants and trees.

   Note: "Desert" would also be an appropriate answer, with lack of water and excessive heat as factors that hinder plant growth.

8. As with plants and animals, people have adapted to life in different biomes. Identify at least two physical adaptations that people have developed to survive in a particular biome.

   Answer: In tropical latitudes, where there is intense ultraviolet radiation from the sun, people have dark skin. The pigment melanin gives this dark color, acting as a protective biological shield against ultraviolet radiation. People who travel to hot climates have the ability to acclimatize physiologically. The salt concentration of sweat progressively decreases as the volume of sweat increases.

   Note: Answers may vary.

9. Consider the overall pattern of biomes from the equator to the North Pole. Would a similar pattern exist for regions along a mountain, from the base to the peak?

   Answer: Yes. Just as temperature decreases from lower latitudes towards the poles, a similar change occurs from the base to the peak of a mountain. These changes in temperatures are reflected in similar changes in characteristic vegetation and organisms.

10. Describe the biome you live in. Create a graph plotting average annual temperature and precipitation data for your area.

    Answers would vary depending on the geographical region of the student.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

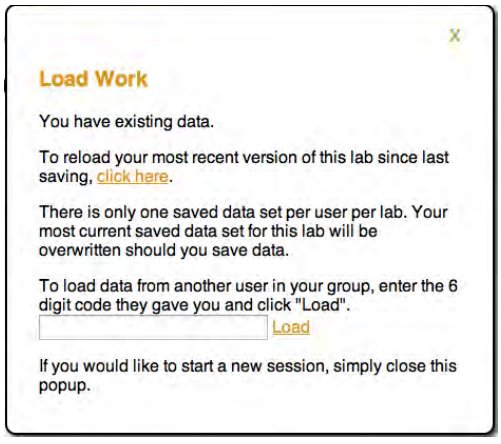
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

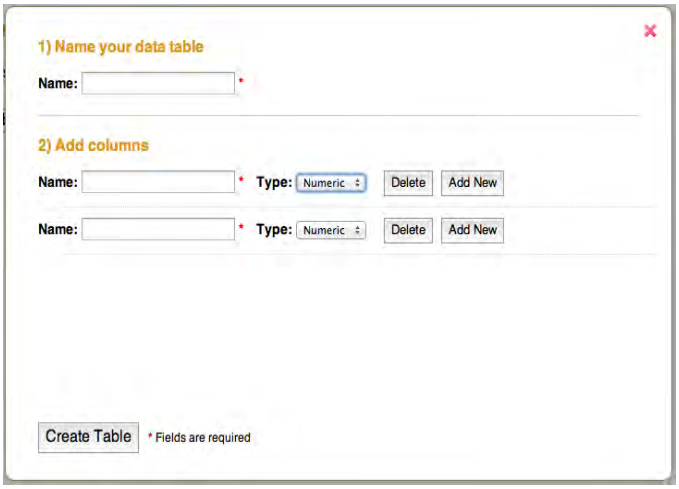
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



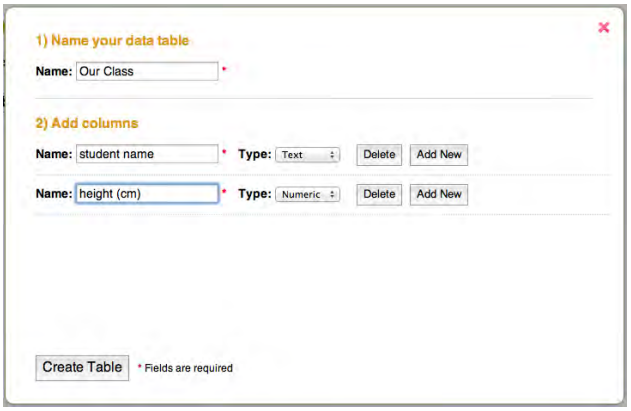
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

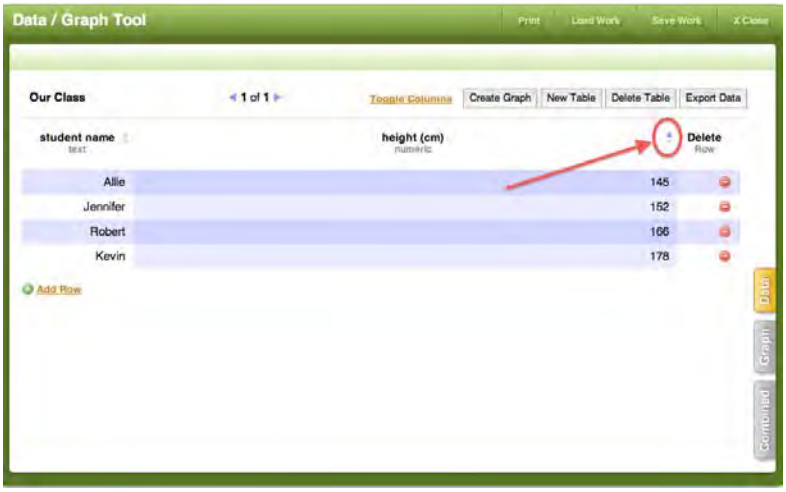
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

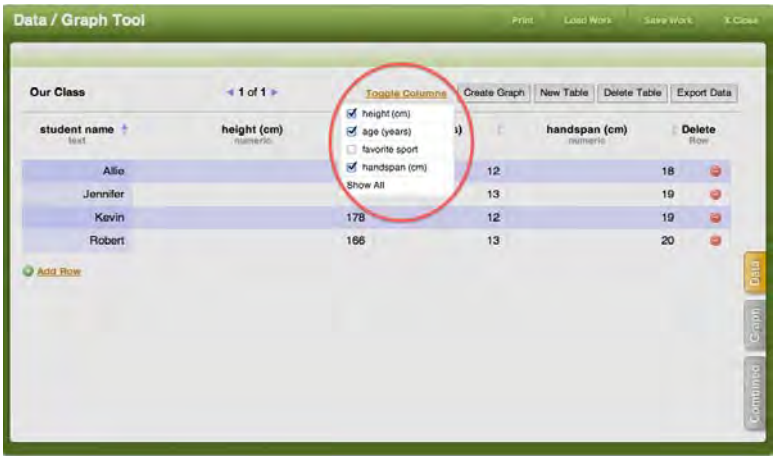


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

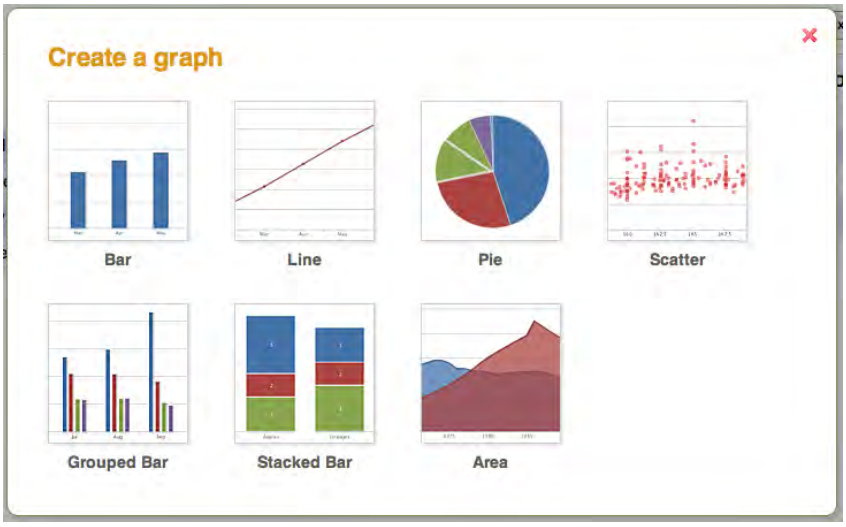
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

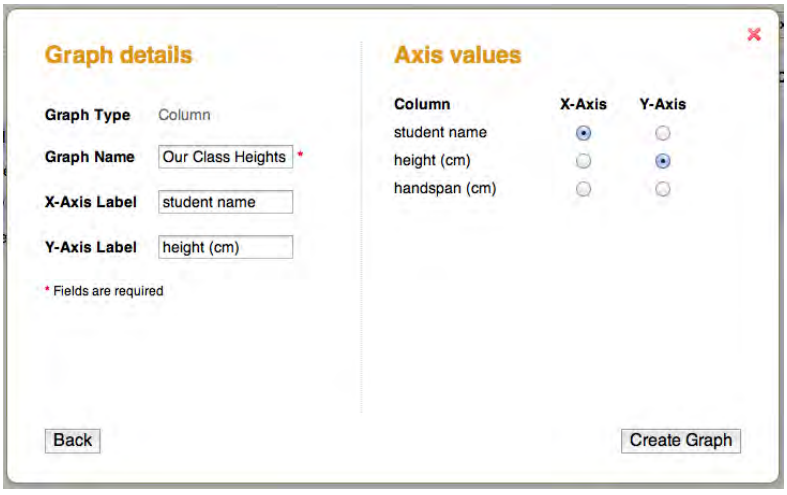
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

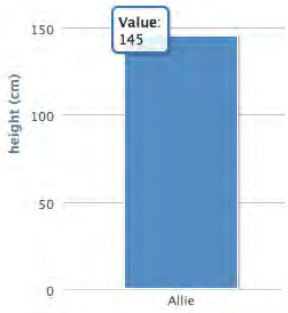


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

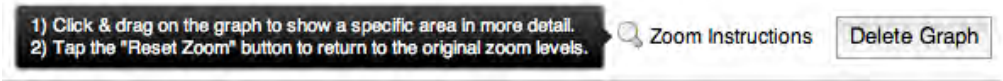
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Activity Sheet

Name _____

Date _____

Energy for Life

Work with a small group. Look at the words in the chart below. Talk about what you think they mean. Use your ideas and the Interactive Glossary to write the meanings of the words.

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish? _____

Add and improve your definitions using this table

Word	Meaning	Picture or Example
energy		
chemical energy		
thermal energy		
potential energy		

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Activity Sheet

Name _____

Date _____

	Our original definition	Our new definition
thermodynamics		
endergonic reactions		
exergonic reactions		
redox reactions		

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Hands-On Activity

Energy in Ecosystems

Timing:
One 30-minute class session

Objective(s):
Students will analyze mathematical representations of energy loss from one trophic level to another in an ecosystem in order to compare energy efficiencies.

Safety Precautions:
Remind students to follow all general lab safety rules and not to eat or drink anything in the lab.

Materials:
Per pair:

- data from study of the mass of organisms at different trophic levels in a hectare of grassland ecosystem (see below)
- calculator
- lab notebook and pencil

Data From Grassland Study		
Organism	**Number**	**Biomass (kg)**
Birds	2	0.05
Spiders	516	0.47
Grasshoppers	3603	5.12
Grass plants	12302	62.87

Teacher Preparation:

- Provide student pairs with a copy of the data table or copy it on the board or overhead projector for all students to review.
- Make sure students understand that only 10% of the energy is transferred from one trophic level to the next because organisms use the majority of energy for their metabolic functions.
- Remind students that the Sun is the initial source of energy input into the ecosystem and that this energy is later used to produce carbon molecules during photosynthesis.

Procedure:

1. Draw a trophic pyramid that represents a grassland ecosystem. As a class, determine where to place the organisms included in the table. Then add at least two more organisms to each trophic level.
2. Direct students to review the data table showing the numbers and biomasses of

3. producers (grasses), primary consumers (grasshoppers), secondary consumers (spiders), and tertiary consumers (birds) counted in a study of a grassland ecosystem.
4. Have students calculate the efficiency of energy transfer from producers and primary consumers using the energy efficiency equation shown below (0.8 = 8%).

$$\text{Energy Efficiency} = \frac{\text{Biomass of organisms at higher trophic level}}{\text{Biomass of organisms at lower trophic level}}$$

5. Now ask students to calculate the efficiency of energy transfer from primary consumers to secondary consumers (0.9 = 9%).
6. Finally, have students calculate the efficiency of energy transfer from secondary consumers to tertiary consumers (0.11 = 11%).
7. As a class, check the energy efficiencies that the students just calculated.

Analysis and Conclusions

1. The efficiency of energy transfer from spiders to birds was not 10%. Why do you think this answer did not match the others?

Answers may vary, but students should recognize that the efficiency will not be exactly 10% for every energy transfer between levels. The efficiency for any given ecosystem depends on the species of organisms present at each level. Some organisms may have more nutritional value than others. Some predators may have more or less energy efficient survival strategies than others. 11 percent is very close to 10 percent.

2. Most terrestrial food chains only have three to four levels. Why is this so?

Answers may vary. Students should recognize that because about 10% of the total energy is transferred from one trophic level to the next, there may not be enough energy to support more than a few trophic levels.

3. Which mass of organism can an area usually support more of: herbivores or carnivores? Explain your answer.

Herbivores; only 10% of the available energy is transferred from herbivores (generally, primary consumers) to carnivores (generally, secondary consumers). Thus, a general area can usually only support 10% the mass of carnivores as it can support herbivores.

In this lab, students will demonstrate the following Inquiry Skills:

Design Investigations

- Uses the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
        - Table
        - Graph or chart

Interpret Data

- Identifies and interprets patterns
    - Trends in data
    - Repeating physical or data pattern
    - Graphed data points
    - Tables and graphs
- Analyzes data collected during an investigation

Patterns and Systems

- Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.
    - Things that change may do so in steady, repetitive or irregular ways.
    - Many patterns in nature occur in cycles.
    - Cycles may be short, such as the second hand of a clock, or long such as the cycle of a year.

Hands-On Lab

Energy in Food

Timing: one 90-minute class session

Objective(s):
Students will measure the calories in sample food items. Students will then convert these measurements into different units of energy.

Safety Precautions:
Remind students to wear closed-toe shoes and not to eat or drink anything in the lab (including the experimental materials). Tell students to report any broken glass and not to try and clean it up by themselves. Students will be burning small quantities of food items, so remind students to take precautions when working around the fire. Make sure students wear safety goggles, a lab apron, and heat-resistant gloves.

Materials:
Per student group:

- scale for measuring mass
- ring stand
- wire mesh
- ring (large enough to hold wire mesh)
- 25 mL beaker
- thermometer
- clamp (to hold thermometer)
- rubber stopper with holes (to hold thermometer)
- probe (to hold food items)
- matches or lighter
- safety goggles, one pair per student
- lab apron, one per student
- heat resistant gloves, one pair per student
- various food items (in original packaging if possible)
  - ideas for foods to use:
    - marshmallows
    - pet food
    - bread
    - croutons
    - popcorn
    - candy bars, chocolate, etc. (hard candy will not work)
    - fruit

- vegetables
- hot dogs
- French fries

Teacher Preparation:
Purchase food items at least one day prior to the lab. Cut up food items so they are approximately 1 cm^3. Keep one piece of food aside to demonstrate the procedure. Make copies of the Student Investigation Sheet—one per student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>
Energy can be measured in joules, ergs, or calories. Write these units on the board and ask students which unit is most commonly used to measure the energy in foods.

Write sample Calorie counts from food labels on the board using a chart similar to the one below:

Calories in Various Foods

Food	Calories
1 medium apple	72
1 candy bar (Snickers)	280
1 slice cheese pizza	231
1 cup seedless grapes	104

Remind students that the Calorie measurement used on food labels is actually kilocalories.

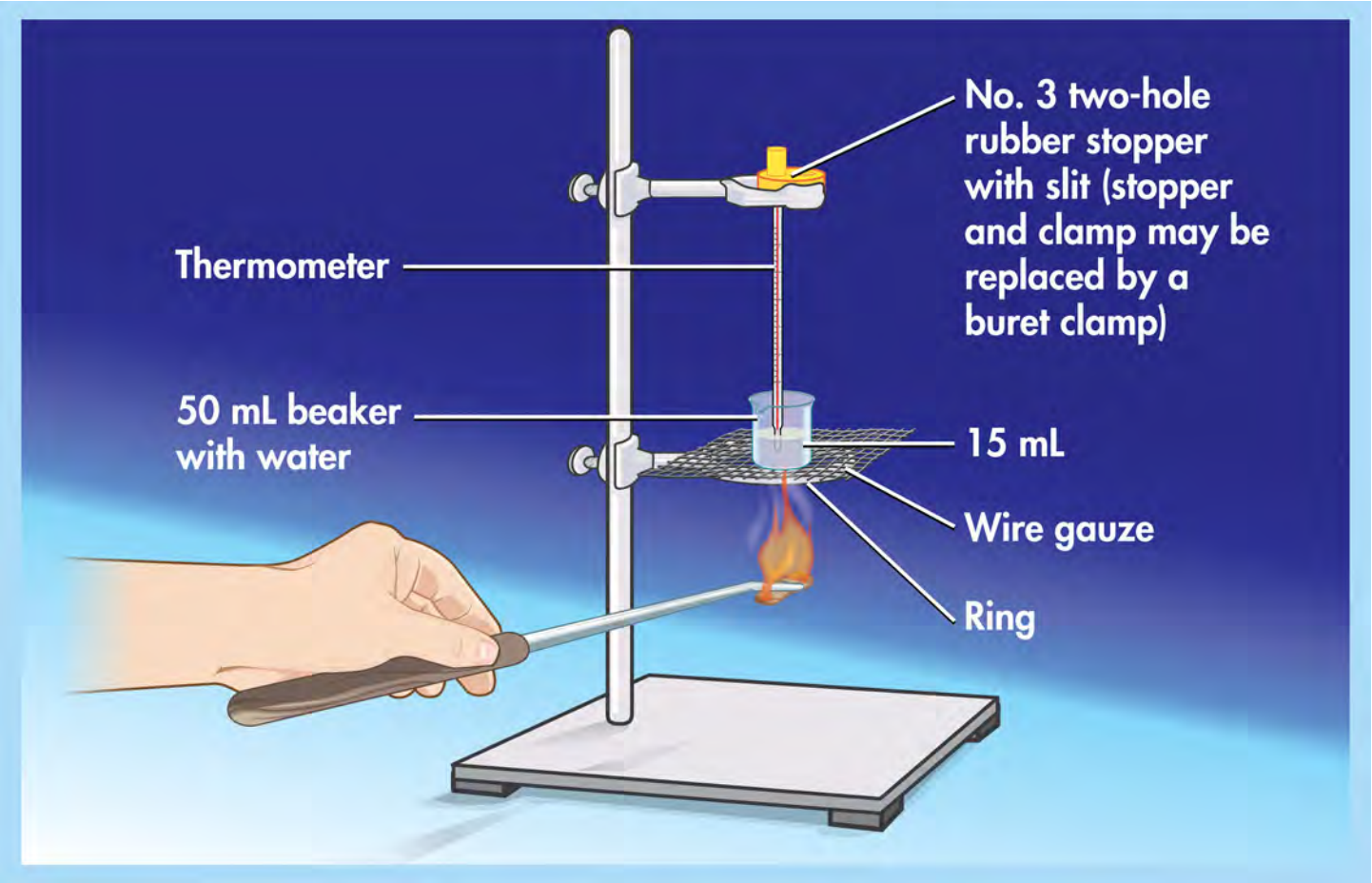
Write the following equation on the board for finding the calories in a food item. Tell students that the density of water is 1g/mL, which makes it easy to convert milliliters to grams. One mL of water is equal to one gram of water. This is important since students are using milliliters to measure water used in the experiment.

$$\text{Calories per gram} = \frac{\text{Change in temperature of water} \times \text{mL of water}}{\text{Average mass change of food}}$$

Demonstrate how to set up the experiment. Measure 15 mL water in the beaker. Place the ring one-third of the way up the ring stand. Put a metal mesh on the ring and place the beaker on the mesh. Put

a clamp two-thirds of the way up the ring stand. Put a thermometer into a rubber stopper and hold the rubber stopper with the clamp. Be sure that the end of the thermometer is in the water.

Setup



Demonstrate how to safely take the measurements. Make sure you are wearing all of the necessary personal protective equipment. Obtain a piece of food approximately 1 cm^3. Find the mass of the item and record the results in a table. Obtain and record the temperature of the water. Impale the food item on the end of the probe and use a match to light it on fire. Place it under the beaker of water and let the item burn out completely. Measure and record the highest temperature of the water; this may take a few seconds after the food item has burned out. Allow the food item to cool for at least one minute, then obtain and record its mass. Calculate the calories per gram of the food item.

Sample Data Table: Data for Calculating Calories of Food Items

Food item					
Mass of food item before (g)					
Mass of food item after (g)					
Change in mass (g)					
Temperature before (°C)					
Temperature after (°C)					
Change in temperature (°C)					
Calories per gram					

Students will now measure the calories in sample food items. Give each group the materials needed and sample food items. Student groups can measure different foods, but ensure that each food item is measured by at least two student groups or all student groups measure at least one like food item. This will provide repeated measurements and allows students to estimate the precision and accuracy of their results. Students groups should have time to measure three to five different food items. Circulate the room to make sure all students are following lab safety protocol.

Create a table on the board for listing the calories per gram of the sampled food items. Student groups should record their results on the board for all students to see. If multiple groups measured a given item, all group results should be recorded. As a class, compare the results of different groups and discuss the precision of this technique. Ask students to hypothesize about sources of error.

Find the average of replicated data and record the average. Erase all replicates so that the chart on the board has a single value for calories per gram for each food item.

Sample Data Table: Calories per gram Results

Food item	Calories per gram

Ask students to research the calories reported for these food items. If package information is available, students can use that. Otherwise, they can research the information on the Internet using a government website if possible. Use this information to discuss the accuracy of this technique. Remind students about the difference between calories, which they measured, and kilocalories, which is the unit on food labels: 1 kilocalorie = 1,000 calories.

Using dimensional analysis, ask students to convert their calorie data from the lab activity to joules and ergs.

1 cal = 4.184 J
1 erg = 10^{-7} J

Sample Data Table: Conversions

Food item	Calories per gram	Joules per gram	Ergs per gram

Guided Inquiry

Students can develop their own plans for collecting and displaying data, based on their knowledge of the materials used. Ask the students some guiding questions to help them focus their inquiry:

- What is a calorie?
- How will you measure the calories in the food items?
- How many milliliters of water are in 1 gram of water?

Tell the students that the task for this lab is to measure the calories in a given item of food. Students must first define the term calorie and determine a way to measure calories. The **Core Multimedia Reading Path** defines the term calorie in the **Explore** section; students will need to use this definition to construct a usable equation and experimental procedures.

You may wish to have student groups discuss the experimental designs as a class prior to beginning the experiment and decide on one design to be used by all lab groups. Alternatively, student groups

can use individual experimental designs and discuss the effectiveness of their design after the experiment. Make sure all procedures are approved before lab groups begin experimenting and remind students to follow all lab safety protocol, particularly when lighting the food items on fire.

Once students have determined the calories in their food items, have them research conversion factors for joules and ergs. Ask students to convert the calorie data to joules and ergs.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. Discuss the precision and accuracy of your results. *Students should include a comparison of their data to other group's data as well as a comparison of their data to the accepted calorie value for the food items.*

2. Discuss sources of error in this experiment. *This experiment is a rough measure of calories because it is in an open system; evaporation is an issue. Measurements (of water, of temperature, etc.) are also a source of error.*

3. Estimate and discuss the balance between the number of calories you consume in a day and the number of calories you burn in a day. Use the rough estimate that walking slowly burns approximately 120 calories. *Answers will vary. Students should discuss the energy balance between these numbers; if calories consumed is much higher than calories burned, students should mention that the excess calories add to weight gain.*

4. What form of energy is found in food molecules? To which form is the energy in food molecules transformed when animals use this energy to move? *The energy in food molecules is chemical potential energy, or chemical energy. It is transformed into kinetic energy when animals use the energy to move.*

5. In the experiment, the mass of each food item decreased after it was burned. Was the energy in some of this food destroyed? Explain. *Energy cannot be created nor destroyed. Instead, it can be transformed. The energy from some of the food was transformed into thermal energy.*

- **Inquiry and Nature of Science Skills in this Lab:**
- Identify Questions
    - Recognize and develop testable questions that:
        - Can be answered with a science investigation or observational study
- Design Investigations
    - Design and conduct investigations using:
        - Multiple trials - repeated tests with the same variables to check for variability of results
    - Practice lab safety by:
        - Following lab safety procedures
        - Recognizing safety equipment and materials and knowing their proper use
        - Incorporating laboratory safety practices into the investigation design
- Gather Data
    - Use tools and the SI (metric) system to accurately measure:
        - Mass
        - Temperature
    - Choose appropriate tools to conduct an investigation:
        - Glassware (beakers, flasks, watch glass, etc.)
        - Thermometer
        - Balance
        - Other Laboratory equipment
    - Use the appropriate format to record data:
        - Table
- Communication in Science
    - Report results using:
        - Table/graph showing data
- Analyze Scientific Results
    - Participate in critiquing/peer review by:
        - Evaluating data for accuracy
- Patterns and Systems
    - Patterns and Change:
        - Some small changes can be detected by taking measurements.
    - Systems:
        - No matter how substances within a closed system interact with one another, or how they combine or break apart, the total mass of the system remains the same.
- Scientific Investigation
    - Scientific Investigation:
        - When a scientific investigation is repeated, a similar result is expected.

- Scientific Data and Outcomes:
  - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
  - Comparisons of data are not accurate when some of the conditions are not kept the same.
  - Accurate record keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.

- Scientific Endeavor
  - Characteristics of Science:
    - Symbolic equations are used to show how the quantity of something changes over time or in response to changes in other quantities.
    - A law is a description of a specific relationship under given conditions in the natural world.

Activity Sheet

Name _____

Date _____

Photosynthesis

Read and watch the videos in the Explore section of “Photosynthesis.” Write 3 questions about photosynthesis. Trade your questions with a partner. Talk about the answers to the questions. Share your questions and answers with the whole class.

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish? _____

My Questions

1)_____

_____

2)_____

_____

3)_____

_____

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Hands-On Lab

Energy Conversions of ATP Production

Timing: one 90-minute class session

Objective(s):
In this investigation students will examine the budget of ATP production and resulting energy yields by calculating the amount of ATP created during cellular respiration and other processes. They will create flowcharts of photophosphorylation, glycolysis and cellular respiration and calculate the total energy yield of the ATP produced.

Safety Precautions:
This lab can be conducted in an ordinary classroom with computer access.

Materials:
Per pair:

- notebook
- computer access with internet
- writing implements

Background
ATP is considered to be the cell's energy "currency" because it carries chemical energy that is used for cellular metabolism. In plants, ATP is an end product of photophosphorylation in which light energy is converted into chemical potential energy at the cellular level. It is also the product of glycolysis and cellular respiration. When ATP is oxidized (by the addition of water) it is converted to ADP as shown in the following reaction:

$ATP + H2O \rightarrow ADP + P \quad \Delta G° = -30.5$ kJ/mol (−7.3 kcal/mol)

As indicated by the enthalpy value (Gibbs free energy), the hydrolysis of ATP yields energy. Given this value students can calculate the total energy yield of the processes of photophosphorylation, glycolysis and cellular respiration.

Procedure:

1. Have students research models that scientists have developed for photophosphorylation, glycolysis, and cellular respiration.
2. Use student questioning to review procedures for creating flowcharts.
3. Have students study the information, data, and images you found on the processes photophosphorylation, glycolysis and cellular respiration.
4. Have students simplify each process by creating a series of steps in a flow chart.
5. For each step in each process students should add the steps in the process to the flowchart.
6. For each step in each process, students should add annotations that describe energy conversions, including the energy yield of ATP for that step.
7. Have students calculate the budgets of energy conversion for each of the processes; photophosphorylation, glycolysis and cellular respiration.

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8. Have students compare and contrast the budgets of energy conversion for each of the processes photophosphorylation, glycolysis and cellular respiration.
9. Answer the Analysis and Conclusions questions.

Example websites
Photophosphorylation
http://academic.pgcc.edu/~kroberts/Lecture/Chapter%205/photosystems.html

Glycolysis and cellular respiration
http://www.uic.edu/classes/bios/bios100/lectures/respiration.htm

Flowcharts
http://www.eod.gvsu.edu/~blaucha/c2d2/Structured%20Design%20Using%20Flowcharts.pdf

Analysis and Conclusions

1. What new information did you learn about energy conversions of ATP production by calculating energy yields of the three cellular processes?

ATP can be used in processes that release energy and also as a form of energy storage. The same amount of energy is needed to synthesize a molecule of ATP from ADP+P (-7.3 kcal/mole) as is released when ATP is decomposed into ADP and P (7.3 kcal/mole). Organisms use a variety of different processes to make ATP. The processes that make ATP vary in their efficiency. For example glycolysis is about 2% efficient. Glycolysis is less efficient than aerobic cellular respiration Glycolysis produces a net 2 ATP molecules per molecule of glucose compared with a net of 36 for the entire process of aerobic respiration (an efficiency of about 26%).

2. How does by calculating energy yields of the three cellular processes, rather than reading about it or looking at pictures about it, provide you with a better idea about the role of ATP in energy conversions?

You become aware of the complexity of these chemical processes. When you do the calculations you discover how inefficient organisms are at changing the chemical energy of foods into the chemical energy in ATP. Other "high energy" compounds are produced (NADPH in these processes).

3. Scientific research suggests that the cause of increased blood pressure in chronic arterial hypertension could be compensation for lower rates ATP synthesis in mitochondria. How could further research into energy conversion of ATP help researchers develop new treatments for increased blood pressure?

Drugs could be developed that could increase the efficiency of ATP production in mitochondria. Another possibility would be to examine the efficacy of ATP supplements in reducing blood pressure in patients with chronic arterial hypertension. (It is currently given for controlling blood pressure during anesthesia and surgery.)

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Hands-On Lab

How Does Light Wavelength Affect Photosynthesis?

Timing: one 90-minute class session, then observation over one week

Objective(s):
Students will conduct an investigation to determine whether or not the wavelength of light affects photosynthesis in plants. Students will compare their results to make a final determination. Students will also compare their findings with those of classic experiments on light wavelength and photosynthesis.

Safety Precautions:
Remind students to follow all general lab safety rules, wear safety goggles and closed-toe shoes, and not to eat or drink anything in the lab. Students should use caution when working with sharp objects such as scissors. Students should follow all instructions for proper handling of plants.

Materials:
Per group:

- houseplant
- transparency film
- marker, colored (green, blue, yellow, or black)
- stapler
- tape
- safety goggles, one pair per student
- latex gloves, one pair per student
- Internet and/or library access

Teacher Preparation:

- Designate which color of marker to give each group of students. If possible, at least two groups should experiment with each color of marker.
- Use a variety of houseplants as an added variable for students to consider. All houseplants should have green leaves. Do not include cacti or succulents.
- If class time is short, you may wish to have a student assistant help you make the colored "sleeves" ahead of time.

Procedure

Part 1: Experimenting with Wavelengths

1. Direct students to make two to three "sleeves" for their plant using transparency film, a colored marker, and a stapler. Students will cut pieces of transparency film that are large enough to wrap around the plant's leaves. They will then use the marker (color designated by you) to color the transparency film. Students should then staple their sleeves around the plant's leaves. They should then secure the sleeve by taping it to the stem.
2. Have students create one clear sleeve to put on another of the leaves.
3. Tell students to place their plant in direct sunlight.
4. Ask students, "Which color do you predict will best promote photosynthesis the most? Which color will hinder photosynthesis the most?" Direct students to record their predictions.
5. Tell students to water their plants regularly and rotate them so that all leaves get plenty of sunlight.
6. After a week, students should remove the sleeves from their plant leaves and record their observations.
7. As a class, compile the results for each color of sleeve. Determine which color best promoted photosynthesis, and which color most hindered photosynthesis.

Part 2: Reviewing Classic Experiments

1. Have students conduct Internet or library research to review "classic" experiments that tested how light wavelength affects photosynthesis. Encourage students to look up the research of Theodor Engelmann in the 1800s.
2. Direct students to record relevant information found in their research.

Analysis and Conclusions

1. What was the purpose of placing the colored sleeves on the leaves?
   The colored sleeves filtered out all colors of light except the sleeve's color. The leaves absorb only light the color of the sleeve.

2. What was the purpose of placing a clear sleeve on one of the leaves?
   This allowed for a control in order to verify that there was not some other factor at play besides color of light.

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3. Which color of light best promoted photosynthesis? How can you tell?
Leaves that were covered by blue sleeves appeared the greenest after the sleeves were removed. The green color is a result of the presence of chlorophyll, where photosynthesis occurs. So a greener leaf means that more photosynthesis took place.

4. What happened to the leaves that were covered with black sleeves? Explain the results.
Leaves that were covered by black sleeves looked the least healthy; they may have been discolored or withered. The black sleeve prohibited light of any color to be absorbed by the leaf, so photosynthesis could not occur.

5. Explain why the green sleeve was not the best promoter of photosynthesis.
Chlorophyll, where photosynthesis takes place, is a green pigment. As such, it reflects rather than absorbs green light.

6. How did your results compare to those you reviewed in "classic" experiments?
Answers will vary but students should recognize that research has long shown blue light best promotes photosynthesis.

7. How did Theodor Engelmann's experiments establish that blue light promotes photosynthesis?
Engelmann shone light of different wavelengths (that is, different colors) on Spirogyra, which are photosynthetic algae. Spirogyra are motile, and Engelmann observed that the algal filaments moved toward blue light and produced more oxygen there, signaling that photosynthesis was occurring.

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Design and conduct field studies using:
    - Observational Study - compares changes in data points over time
  - Explain the investigative processes by:
    - describing the logical sequence that was used to conduct the investigation
- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)
  - Uses the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
    - Table
    - Graph or chart
- Interpret Data
  - Identifies and interprets patterns
    - Trends in data
    - Repeating physical or data pattern
    - Graphed data points
    - Tables and graphs
    - Analyzes data collected during an investigation
- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause effect relationship observed in the investigation
    - reporting out trends and patterns in the data.

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Hands-On Lab

Measuring Plant Respiration and Photosynthesis

Timing: Two 30-minute class sessions

Objective(s)
In this activity, students will use probes to measure changes in the net production of carbon dioxide by a plant over a twenty-four hour period.

Safety Precautions
Remind students:

- To wear safety goggles.
- Not to eat or drink anything in the lab (including the experimental materials).
- To report any broken glass; they not to try to clean it up themselves.

Materials
Per group:

- pH probe
- Probe graphing calculator interface or computer interface
- Graphing calculator or computer (with software for probes)
- pH probe
- Water plant (elodea, hydrilla, milfoil, or similar)
- Bottled water
- beaker, 250 ml

Teacher Preparation
Obtain enough of the aquatic plant for two to three strands per group. If using hydrilla, please dispose of it on a compost heap. It is a common invasive plant and should not be introduced into additional bodies of water. This experiment will be left running overnight. Be sure to arrange appropriate security for the probes, computes, and/or calculators.

Procedure

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Explain the relationship between the level of dissolved carbon dioxide and pH. Provide an outline of how the materials are to be set up. A typical set-up is:

1. Making a correct connection of the probe to the computer or calculator.
2. Understanding how to use the probe software.
3. Placing 100 ml of bottled (non-chlorinated) water into the beaker.
4. Measuring the pH of the water.
5. Setting up the probe software to measure the pH at a set interval (ten minutes usually works).
6. Placing the water plant specimens into the beaker.
7. Creating a class control (the set-up without the plant).
8. Placing the whole set-up in an illuminated area (preferably near a source of natural sunlight).
9. Starting the measurements.
10. Leaving the equipment in place for at least twenty-four hours.
11. Reviewing and graphing the results.

Guided Inquiry

Students can develop their own protocols based on their knowledge of the processes of photosynthesis and respiration. Use questions to help them develop the procedure:

- *How could you use pH to determine whether an aquatic plant is undergoing photosynthesis or respiration?*
- *How could you set up an experiment to find out patterns of these two processes over a twenty-four hour period?*
- *How frequently will you have your probe and recording device collect data?*
- *What would be an adequate control for this experiment?*

Visit the groups once they have decided upon their procedures. Approve each approach or ask additional questions to hone the procedure. Have students run the experiment and tabulate and graph their results.

Analysis and Conclusions

In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. What is the relationship between pH and dissolved carbon dioxide concentration? *Carbon dioxide dissolves in water to form a weak acid, carbonic acid. As dissolved carbon dioxide levels increase, the pH will decrease.*

2. Describe what happened to the pH over the twenty-four hour period. Account for these changes in terms of the physiological activity of the plant and the external environmental conditions*. A description should refer to the data collected. Typically it will show any fluctuations of pH with the pH lowest during the night and highest during the day. A description should refer to the data collected. Typically it will*

show any fluctuations of pH with the pH lowest during the night and highest during the day. Students should relate this to the production of carbon dioxide during darker periods when respiration exceeds photosynthesis and its consumption during illuminated periods, when photosynthesis exceeds respiration and carbon dioxide concentrations are lowered.

Further Questions

1. Is it correct to state that plants photosynthesize during the day and respire at night? Explain your answer. *No. Plants, like all organisms, respire all the time. However, in the light the rate at which photosynthesis produces oxygen often exceeds the rate at which the plant consumes it in the process of respiration, so there is a net production of oxygen.*

2. In a deep lake, the concentration of carbon dioxide was found to be low in the surface layers but increasing with depth. Explain this observation. *Phytoplankton in the upper water layers are undergoing photosynthesis during the day and using up dissolved carbon dioxide. In the deeper layers, there is less (or no) light, so carbon dioxide from respiration of organisms is higher.*

Inquiry and Nature of Science Skills in This Lab

- Identify Questions
  - Develop a question that:
    - Asks about a specific science concept or process
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
- Design Investigations
  - Design and conduct investigations using:
    - Fair test—changing only one variable at a time makes comparisons valid
    - Independent variable—the one variable the investigator chooses to change
    - Dependent variables—what changes as a result of, or in response to, the change in the independent variable
    - Control (control group)—used for comparison in which the independent variable is not changed
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Properly citing all equipment and materials
    - Describing it so that it can be easily repeated by a fellow scientist
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
- Gather Data
  - Choose appropriate tools to conduct an investigation
    - Glassware
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Reporting trends and patterns in the data
    - Comparing results to hypothesis
- Communication in Science
  - Report results using:
    - Peer presentation
- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating an investigative design
    - Evaluating a conclusion
- Scientific Investigation
  - Scientific Data and Outcomes
    - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
    - It is important in science to keep honest, clear, and accurate records.

- Scientific Endeavor
    - Characteristics of Science
        - One way to make sense of something is to think of how it relates to something more familiar.

Hands-On Activity

Modeling the Carbon Cycle

In this activity, students will model the carbon cycle by building and observing a terrarium. Students will then compare their model to a larger ecosystem where the carbon cycle happens on a very different scale.

Suggested Materials
Per group:

- glass container, large, or aquarium
- potting soil, moist with nutrients
- pebbles
- plants, small enough for container
- snail
- earthworms
- latex gloves, one pair per student

Safety Precautions:
Remind students to follow all general lab safety rules and not to eat or drink anything in the lab. Live organisms should be handled with care.

Teacher Preparation:

- Because of the time and materials involved, you may wish for each class to just create one terrarium together. In this case, you might want to use a glass aquarium so that the model is large enough for all students to see clearly.
- Potting soil with added nutrients is usually available at nurseries, hardware stores, and home-improvement stores,

Procedure

1. Direct students to place a layer of pebbles in the bottom of the glass container.
2. Then, students (wearing latex gloves) should add a layer of soil about 2 to 3 inches deep.
3. Tell students to place two to four (depending on the container size) plants in the soil, leaving some space between plants. The plant roots should be fully covered by soil. Students should add more soil if required to provide root coverage.
4. Check each container for optimal plant spacing and root coverage.
5. Direct students to place the snail and earthworms into the container.
6. Have students place their finished terrariums in a location that receives indirect sunlight.
7. Over the course of one to two weeks, students should observe their model and write down their observations.
8. Direct students to add water as needed if the soil becomes dry.

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Analysis and Conclusions

1. What role do the plants play in this model of the carbon cycle?
   The plants use carbon dioxide from the air, along with water from the soil and sunlight, to produce carbohydrates.

2. What role does the snail play in this model of the carbon cycle?
   The snail eats plant material, consuming carbon in the carbohydrates. The carbohydrates are then broken down through cellular respiration. This releases carbon back into the air.

3. What role do the earthworms play in this model of the carbon cycle?
   Earthworms are decomposers. They break down organic compounds, releasing carbon dioxide into the air.

4. How is the carbon cycle happening in your model similar to the processes that occur in a larger ecosystem?
   In the model, plants cycle carbon through the process of photosynthesis. This represents the action of all plants in an ecosystem. Snails cycle carbon through the process of cellular respiration. This represents the action of all consumers in an ecosystem. The earthworms cycle carbon by breaking down organic compounds, just as all decomposers do in an ecosystem.

5. How is the carbon cycle happening in your model different to the processes that occur in a larger ecosystem?
   There are fewer organisms represented in our model. In a larger ecosystem, there would be many plants, including grasses and trees. There would be far more primary consumers, such as grasshoppers and rabbits. A larger ecosystem would also include secondary and tertiary consumers that would also be cycling carbon through the process of respiration. There would also be more decomposers present, including fungi and scavengers.

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.
- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.
  - Practice lab safety by:
    - Following lab safety procedures

- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)

  - Uses the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)

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Exploration Teacher Guide: Photosynthesis

Overview

Students will observe a change in the rate of photosynthesis using an oxygen sensor and a carbon dioxide sensor. They will explore the process of production and consumption of carbon dioxide and oxygen in the light and in the dark. They will analyze graphs and observe the relationship between the concentration of carbon dioxide and the rate of photosynthesis.

Student Learning Objectives

- Explore how a carbon dioxide sensor and an oxygen sensor can be used to observe photosynthesis.
- Observe the production and consumption of carbon dioxide and oxygen by plants, in the light and in the dark.
- Analyze how the rate of photosynthesis changes with a change in the concentration of carbon dioxide.
- Examine the structure of a plant leaf.
- Investigate the light dependent and the light-independent reactions of the photosynthetic process.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Apparatus* tab, students will understand the experimental setup used when this experiment is done in real-life. Information is also provided about the oxygen and carbon dioxide sensors used in the setup.

In the *Explore* tab, students start the experiment with the 'In the Dark' reaction. They select the initial oxygen and carbon dioxide concentration levels using the *Oxygen Concentration* and *Carbon dioxide Concentration* sliders. Data collection starts when the *Start* button is clicked. A digital clock shows the time for which data is collected. Data collected includes time, oxygen concentration and carbon dioxide concentration. The *Stop* button becomes active after some time and is used to stop collecting data. Data collection stops after 10 minutes if the *Stop* button is not used. The *Proceed* button is active once data collection stops. A graph of time versus oxygen concentration is shown and the rate of this reaction is displayed. Students use the *Continue* button to observe a graph of time versus carbon dioxide concentration and the rate of this reaction is also displayed. The students may use the *Back* button to go back or the *Continue* button to explore the same process 'In the Light'. Students observe the graphs of time versus oxygen concentration and time versus carbon dioxide concentration for the 'In the Light' reaction. The rate of these reactions is also displayed. Students now use the *Continue* button to answer a question on the rate of photosynthesis. Students analyze the graph and answer this

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question to learn that the rate of photosynthesis is higher 'In the Light. The students use the *Continue* button to examine the relationship between the rate of photosynthesis and the concentration of carbon dioxide.

In the *Tracker* tab, students observe the initial concentrations of oxygen and carbon dioxide that they select for the experiment. They also observe the rate of photosynthesis obtained 'In the Light' and 'In the Dark'.

Answers to Questions asked in the Student Worksheet

1. Explain what photosynthesis is. Describe the process using a chemical equation.

   Answer: Photosynthesis is a chemical reaction in which light energy is used to convert carbon dioxide and water into oxygen, sugar and other organic compounds. It is the means by which the energy in sunlight becomes usable to living things. This process can be described using the following chemical reaction:

   $$6\ H_2O + 6\ CO_2 + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

2. List three organisms that can perform photosynthesis.

   Answer: Plants, algae, and some bacteria can perform photosynthesis.

3. Describe what will happen to the rate of photosynthesis if the size of the stomata is increased.

   Answer: Stomata are the pores found in the leaves and are used for the exchange of gases. The exchange of carbon dioxide and oxygen will become easier if the size of the stomata is increased. Hence, increasing the size of the stomata will increase the rate of photosynthesis.

4. Explain if photosynthesis can occur under water. Comment on the factors required for photosynthesis to occur under water.

   Answer: Yes, photosynthesis can occur under water if the water is clear and shallow enough for sunlight to travel through the water to plants like algae.

5. Use this Exploration to identify whether either of the rate values for carbon dioxide observed 'In the Light' and 'In the Dark' was a positive number? If so, explain the biological significance of this.

   Answer: The carbon dioxide rate value 'In the Dark' was a positive number. The biological significance of this is that carbon dioxide is produced during respiration. This means that the concentration of carbon dioxide increases, as sugar is oxidized and broken into carbon dioxide, water, and energy.

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6. Use this Exploration to identify whether either of the rate values for oxygen observed 'In the Light' and 'In the Dark' was a positive number? If so, explain the biological significance of this.

   Answer: The oxygen rate value 'In the Dark' was a negative number. The biological significance of this is that oxygen is consumed during cellular respiration. This means that the concentration of O_2 decreases as glucose is oxidized for energy.

7. Explain how you can prove that cellular respiration occurs in leaves.

   Answer: It can be observed that the concentration of oxygen decreased when leaves were in the dark. Hence, photosynthesis was not possible. This proves that cellular respiration occurred in leaves.

8. Explain how you can prove that photosynthesis occurs in leaves.

   Answer: The concentration of oxygen increased when leaves were exposed to light. This proves that photosynthesis occurs in leaves.

9. Name the pigment required for photosynthesis. Identify if carotenoids help in the process of photosynthesis.

   Answer: The most important pigment required for photosynthesis is chlorophyll. Carotenoid is an accessory pigment used to capture more light.

10. Name the stages of photosynthesis and explain them in brief.

    Answer: Photosynthesis has two stages. The first stage is the photochemical stage known as the light reaction. The second stage is the light-independent stage known as the Calvin cycle.
    In the light reaction, the energy of the light is captured and used to produce ATP and NADPH. This reaction occurs in the thylakoid membrane of chloroplasts. In the Calvin cycle, carbon dioxide and water are converted into organic compounds through a series of redox reactions. This reaction occurs in the stroma of chloroplasts.

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Hands-On Lab

Photosynthesis

Timing: one 90-minute class session

Objectives
In this lab, students collaborate in groups to conduct an experiment to investigate photosynthesis. In the Guided Inquiry option for this investigation, students will plan an experimental investigation and select equipment and technology to implement their plan.

Safety Precautions
Have students use caution when handling glassware and other sharp objects. Remind students not to eat or drink in the lab and to wear safety goggles and aprons when working with substances.

Materials
Per group:

- graduated cylinder
- hole puncher
- 2 or more leaves
- light source
- liquid soap, diluted
- plastic cups, transparent
- plastic syringe (10 cc or larger) without a needle
- scale
- scissors
- sodium bicarbonate (baking soda), 0.6 mL
- stopwatch
- water, 300 mL
- safety goggles, one pair per student
- disposable gloves
- lab aprons, one per student

Teacher Preparation
Leaf suggestions include: spinach, pokeweed, ivy, or any other readily available kinds. Avoid hairy, overly veined, or thick leaves. Prepare the diluted soap in advance by adding water to the liquid soap. You do not need to use exact measurements, but suds should not appear in the solution. Prepare a copy of the Student Investigation Sheet for each student.

Procedure

The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Review the formula for photosynthesis as a class by asking individual students to name each reactant and product, one at a time. Write the equation on the board.

Next, review the following procedure with the class. You do not have to complete each step. However, you may want to use one lab group's set of materials and point out each material that is being used in each step.

1. Select the equipment and technology you will need for this investigation from the available supplies.
2. Prepare a sodium bicarbonate solution by mixing the water and sodium bicarbonate in a plastic cup.
3. Add one drop of the diluted liquid soap to the solution. If suds appear, add more sodium bicarbonate solution.
4. Use the hole puncher to punch out approximately 10 circles from the leaf. Avoid the veins when making the punches.
5. Remove the plunger from the syringe and place the leaf circles into the syringe. Then, put the plunger back on.
6. Push on the plunger to remove as much air as possible, but be careful not to crush the leaf circles.
7. Draw a small amount of sodium bicarbonate solution into the syringe.

8. Place your finger over the opening of the syringe. Then, pull back on the plunger of the syringe to create a partial vacuum.
9. Hold the plunger in its pulled back position for about 10 seconds and swirl the leaf circles so they become suspended in the solution.
10. Remove your finger from the opening and release the plunger. The bicarbonate solution should cause the leaf circles to sink. If not, repeat the procedure 2–3 more times until the circles sink. If they still do not sink, add a few more drops of the diluted soap to the solution.
11. Remove the plunger from the syringe, and pour the leaf circles and solution into a clear plastic cup.
12. Add more bicarbonate solution until the cup is filled up about 3 centimeters. Use the same depth for each trial.
13. Place the light source over the cup and start the stopwatch. At the end of each minute, record the number of floating circles in your data table. Continue timing and recording until all of the circles are floating. (Hint: If any circles become stuck to the side of the cup or to each other, gently swirl the solution to dislodge them.)
14. Repeat the experiment by moving the light source farther away from the cup. Measure and record the distance the light source is away from the cup. The intensity of the light reaching the circles varies by the inverse square of the distance. Calculate the new relative intensity of the light reaching the circles.
15. You may decide to have different groups conduct this experiment with the light placed at a variety of different distances, and pool the class results.

Before starting the procedure, instruct students to write an experimental question that they will be answering during the procedure. (Sample: *How does light intensity affect the rate of photosynthesis?*)

Sample data:

Elapsed Time	*Total Floating Circles*
0	*0*
1	*0*
2	*0*
3	*0*
4	*0*
5	*0*
6	*1*
7	*1*
8	*2*

9	*6*
10	*8*
11	*9*
12	*10*

Guided Inquiry

Students can develop their own protocols for setting up a photosynthesis simulation based on their knowledge of the procedure and available materials. Ask the students some guiding questions to help them focus their inquiry:

- Have student groups conduct steps 1-12 as outlined in the directed inquiry.
- Ask students how they could use this procedure to investigate variables that could impact the rate of photosynthesis
- Groups should develop a testable question. (Groups may choose to investigate variables such as brightness/distance from light source, temperature, light color/wavelength, bicarbonate concentration, leaf area etc. Be prepared to have materials available to meet these different options.)
- Each group should create a modified procedure to answer their testable question. Have groups report to the teacher once they have decided on a possible procedure.
- Each group should decide upon its data collection protocols.
- Students should prepare reports that should include details of their procedure, the data they have obtained and their interpretation of the data.
- Each group should provide a three minute report out of their investigation.

Analysis and Conclusions

In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. What are the reactants of photosynthesis? What served those purposes in the lab? *The reactants of photosynthesis* are *water, carbon dioxide, and energy from sunlight. In this lab, we used water, baking soda solution ($NaHCO_3$, sodium bicarbonate), which was a source of carbon dioxide, and lamp light, which took the place of sunlight.*

2. What change took place over the course of the experiment? *The small circles cut from the leaf began to float.*

3; Did photosynthesis take place? Did you directly observe photosynthesis, or did you infer it from other data that you observed? *Sample answer: We can infer photosynthesis did occur. The leaf circles began to float because of gas—bubbles—forming in their tissues. We assume that these bubbles are oxygen, and oxygen is a product of photosynthesis.*

4. What were the independent variable and the dependent variable? What variations occurred in the dependent variable when you adjusted the independent variable? How do your results relate to the reactions of photosynthesis? *Sample answer: The independent variable was the intensity of the light (changed by moving the light closer or further away. The dependent variable was the time it took for the leaf circles to float It took much longer for the leaf circles to float when we moved the light source away from the leaf circles. This makes sense because light is the energy source that powers the reactions in photosynthesis.*

- **Inquiry and Nature of Science Skills in this Lab:**
- Identify Questions
    - Recognize and develop testable questions that:
        - Specify a cause-effect relationship.
        - Require the changing of one variable at a time.
        - Can be answered with a science investigation or observational study.
- Design Investigations
    - Design and conduct investigations using:
        - Dependent variables-what changes as a result of, or in response to, the change in the independent variable.
- Design Investigations
    - Make or use models that:
        - Simulate a real thing that cannot easily be studied or manipulated.
        - Have as many details as possible replicated from the real thing.
        - Function exactly like or similarly to the real thing.
- Design Investigations
    - Practice lab safety by:
        - Following lab safety procedures
- Gather Data
    - Chooses appropriate tools to conduct an investigation:
        - Clock/stopwatch
        - Scale
        - Graduated cylinder
- Evaluate Evidence
    - Drawing and supporting a conclusion by:
        - Using data to determine the cause effect relationship observed in the investigation
- Communication in Science
    - Report results using:
        - Written report
- Patterns and Systems
    - Systems
        - No matter how substances within a closed system interact with one another, or how they combine or break apart, the total mass of the system remains the same.
- Scientific Investigation
    - Scientific Data and Outcomes
        - It is important in science to keep honest, clear, and accurate records.
- Scientific Endeavor
    - Characteristics of Science
        - Science is base on factual knowledge.
        - Scientists are curious about wanting to know how things work.
        - Scientific claims can be substantiated using data and observation

Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

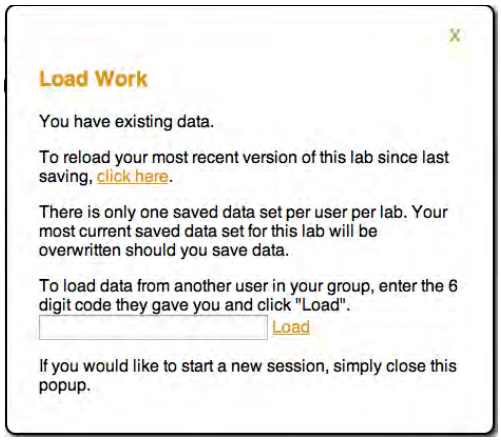
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

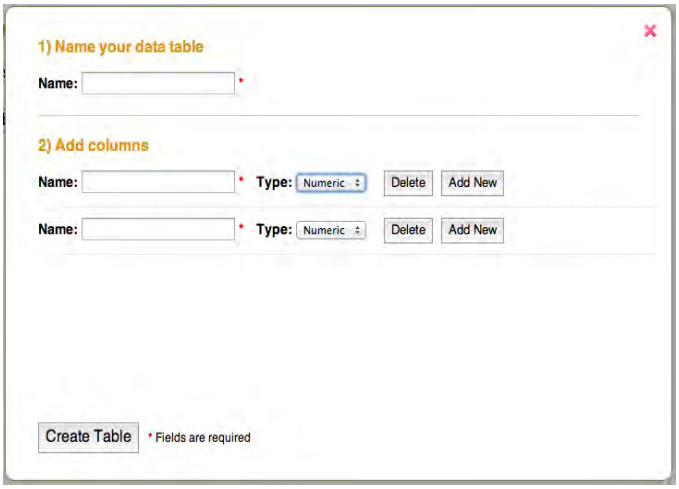
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



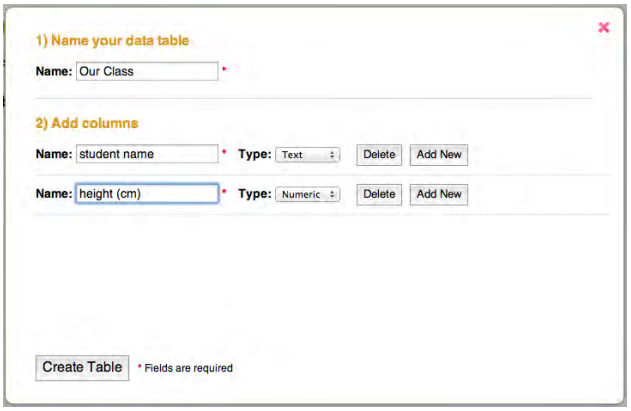
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

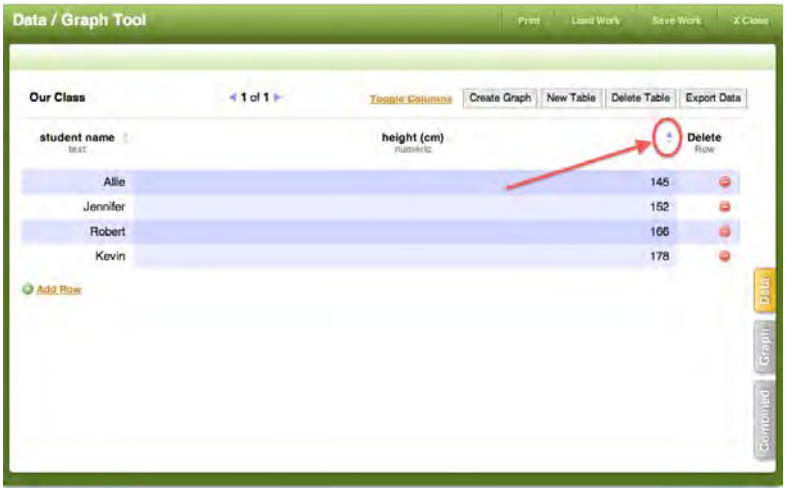
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

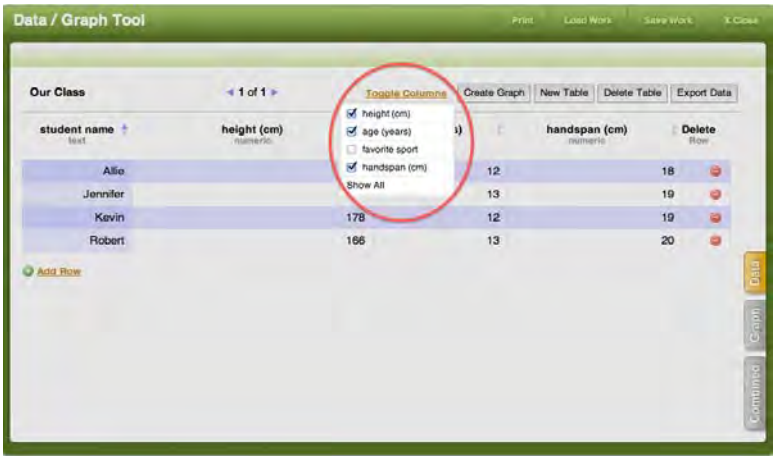


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

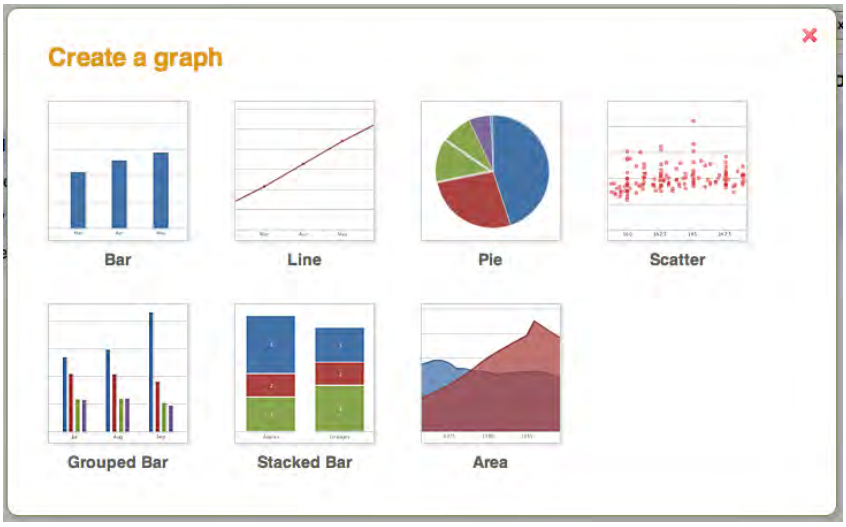
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

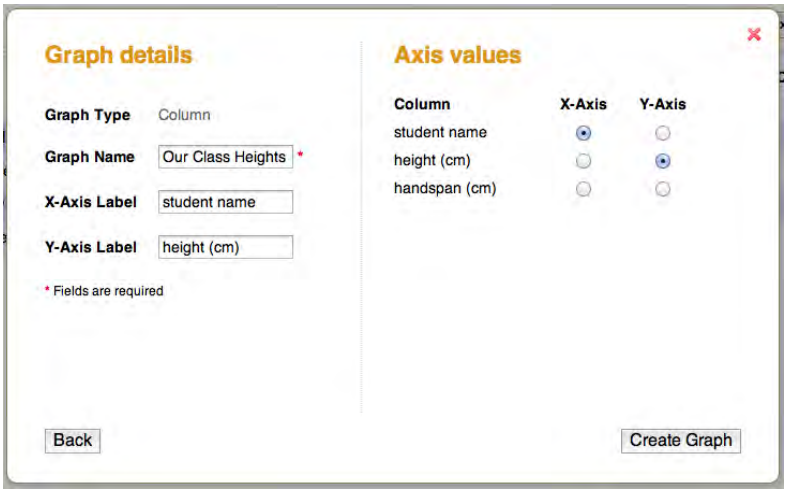
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

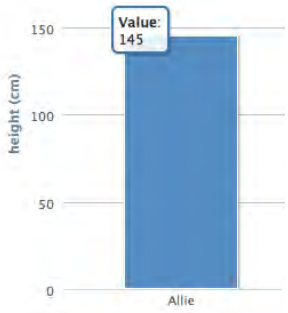


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

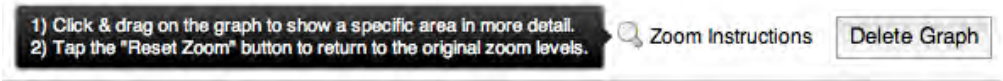
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Aerobic vs. Anaerobic Respiration

Timing: one 40-minute class session

Objective(s):
Students will investigate the effect of aerobic and anaerobic respiration on their muscle cells, as well as the possible physiological effects of lactic acid.

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should use the lab equipment only for its intended purposes.

Materials:
Per pair:

- tennis ball
- timer or stopwatch

Teacher Preparation:

- Gather materials in advance of students performing the lab.
- Explain to students not to overexert themselves during the lab; if movements cause pain rather than mild discomfort, immediately discontinue the activity.

Procedure

1. Give one student a tennis ball and one student a stopwatch. Working in pairs, students count how many times they can squeeze a tennis ball in 30 seconds *without stopping.* If muscle fatigue becomes apparent, students should note the number of squeezes at which it occurs. Record the number in the table below.

# of consecutive squeezes in 30 seconds	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10
Partner 1										
Partner 2										

2. Switch the tennis ball and timer between partners and have them repeat step 1. Continue until pairs have 10 measurements for each partner.

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3. Direct student to rest for 2 minutes, then repeat steps 1 and 2 with a 1-second pause between squeezes. If muscle fatigue becomes apparent, students should note the number of squeezes at which it occurs. Record the results in the table below.

# of squeezes with pause in 30 seconds	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10
Partner 1										
Partner 2										

4. Graph the results for each partner with trial number on the *x*-axis and number of squeezes on the *y*-axis. Repeat for both tables.

Analysis and Conclusions

1. Describe your graphs for both experiments. Did you observe any trends? If so, hypothesize why they developed.
   The first graph showed a declining slope as trials progressed. The second graph showed a decline as well, but it was not as drastic Students may propose that the body made more energy in the second experiment, or the muscle got stronger.

2. What type of cellular respiration do you think was occurring at the beginning of the trials and the end of the trials? Why?
   Aerobic respiration was used; the ATP in muscles gave the muscles energy to contract. Once the ATP from aerobic respiration was exhausted, anaerobic respiration was used. Anaerobic respiration produced much less ATP.

3. Graph data points when you noted muscle fatigue during your experiments. Did you observe any trends? Explain.
   Students should note that muscle fatigue occurred earlier as trials progressed.

4. Lactic acid, a byproduct of anaerobic respiration, is widely thought to contribute to muscle soreness and fatigue. Does this evidence support your answer to Question 2? Explain.
   Yes. Because lactic acid is the result of anaerobic respiration, its buildup in muscles (and resultant fatigue) can be seen as evidence that anaerobic respiration is occurring.

5. Given this new evidence, look again at your graph for the second experiment and your answer to Question 3. How would you revise your explanation?
   Students may note that pausing between squeezes may have given the body time to disperse lactic acid, or for anaerobic respiration to produce more ATP to be used for further squeezes.

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In this lab, students will demonstrate the following Inquiry Skills:

- Identify
  - Develop a question that:
    - asks a question about a specific science concept or process.
  - Recognize and develop testable questions that:
    - specify a cause-effect relationship.
    - can be answered with a science investigation or observational study.
  - Develop:
    - state what may happen in an investigation based on prior knowledge or experience

- Design Investigations
  - Practice lab safety by:
    - Following lab safety procedures

- Gather Data
  - Uses the appropriate format to record data:
    - Graph or chart

- Interpret Data
  - Identifies and interprets:
    - Analyzes data collected during an investigation

- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause effect relationship observed in the investigation

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Exploration Teacher Guide: Cellular Respiration

Overview

Students will observe a change in the amount of carbon dioxide exhaled, with increasing exercise levels using a carbon dioxide sensor.They will explore the process of cellular respiration and production of carbon dioxide. They will analyze graphs and observe the relationship between exercise levels and the concentration of carbon dioxide.

Student Learning Objectives

- Understand how a carbon dioxide sensor can be used to observecellular respiration.
- Analyze how the amount of carbon dioxide produced changes with a change in exercise levels.
- Examine the role of glycolysis, the citric acid cycle, and the electron transport chain in respiration.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Apparatus* tab, students understand the experimental setup used when this experiment is done in real-life. Information is also provided about the carbon dioxide sensor used in the setup.

In the *Explore* tab, students start the experiment by selecting an exercise level from the *Select Exercise Level Section*. Data collection starts when the *Start* button is clicked. A digital clock shows the time for which data is collected. Data that is collected includes time (in minutes) and carbon dioxide concentration (in parts per million). The data is recorded in the table and on the graph. The *Stop* button becomes active after six data values are recorded. It can be used to stop the data collection. Data collection automatically stops after 10 minutes if the *Stop* button is not used. The *Proceed* button is active once data collection stops. When the student clicks the *Proceed* button, a graph of time versus carbon dioxide concentration for the selected exercise level is shown and the amount of carbon dioxide recorded is displayed. Students use the *Continue* button to observe the same reaction for the next exercise level.

When students use the *Start* button, data begins recording for the next exercise level. All buttons work in the same way as the previous exercise level. Students can examine the graph of time versus carbon dioxide concentration for this exercise leveland the amount of carbon dioxide recorded. Similarly, students can use the *Continue* button and then the *Start* button to observe the amount of carbon dioxide recorded for the third, and last, exercise level.

After data for all three exercise levels is recorded, with the last graph students can use the *Continue* button to analyze the graph and the exercise level for which the maximum amount of

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carbon dioxide is produced. They will learn that the amount of carbon dioxide produced increases with increasing exercise levels.

Students can use the *Start Over* button at any time during the Exploration to begin again.

In the *Tracker* tab, students examine the initial and final concentrations of carbon dioxide recorded for different exercise levels for every run of the experiment.

Answers to Questions in Student Worksheet

1. Explain what cellular respiration is. Describe the process using a chemical equation.

   Answer: Cellular respiration is a process in which energy is released by breaking the bonds of food molecules, such as glucose. This energy is used to make ATP from ADP. The other products of this reaction are carbon dioxide and water.
   This process can be described using the following chemical reaction:

   $$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ H_2O + 6\ CO_2 + \text{energy}$$

2. Name the compound that is phosphorylated for the formation ATP. Also name the compound formed after energy is liberated from ATP.

   Answer: The compound ADP (adenosine diphosphate) is phosphorylated to give ATP (adenosine diphosphate). This process stores energy in the produced ATP molecule.
   When an ATP molecule liberates energy to cellular metabolism, it loses one of its phosphates and ADP reforms.

3. List two types of cell respiration. Explain how they are different from each other.

   Answer: The two types of cell respiration are aerobic cell respiration and anaerobic respiration. Aerobic respiration involves the participation of molecular oxygen (O_2) whereas in anaerobic cell respiration other inorganic molecules are used as oxidants.

4. List two differences between cellular respiration and photosynthesis.

   Answer: Cellular respiration occurs in all living organisms but photosynthesis occurs only in plants and some bacteria.
   The products of cellular respiration are carbon dioxide, water, and energy and those of photosynthesis are oxygen and organic molecules like glucose.

5. Name the organelle in which cellular respiration occurs. Also, describe this organelle briefly.

   Answer: Cellular respiration occurs in the mitochondria. Mitochondria have two lipid membranes. The inner membrane extends to the interior of the organelle forming cristae and also forms an internal space known as the mitochondrial matrix.

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6. Name the three phases of aerobicrespiration.

   Answer: The three phases of aerobic respiration are glycolysis, Krebs cycle and the electron transport chain.

7. Select all three activity levels available in the Exploration and note the amount of carbon dioxide level recorded for each. Comment on your observation.

   Answer: The highest level of carbon dioxide is recorded for the exercise level 'running'. Following 'running', the exercise level 'walking' would have the second highest level of carbon dioxide production. The exercise level 'at rest' would have the least. This is because when we exercise, the cells consume oxygen faster to produce more energy. This, in turn, creates more carbon dioxide.

8. Explain where the processes of glycolysis, citric acid cycle, and electron transport occur in a cell.

   Answer: Glycolysis occurs in the cytosol. The citric acid cycle occurs in the mitochondria and electron transport occurs in the inner mitochondrial membrane.

9. Explain whether anaerobic respiration occurs in humans. What is its significance?

   Answer: Anaerobic respiration occurs in humans when cells do not get sufficient oxygen. In this case, the end product is lactic acid. Anaerobic respiration occurs during very high exercise levels like sprinting. This is because energy is used up rapidly during such high levels of exercise and the cells don't have oxygen coming in fast enough to perform aerobic respiration. However, anaerobic respiration is not a significant energy source because it only gives the body 2 ATP unlike aerobic respiration which gives around 20 times that amount.

10. Identify how many ATP molecules are made after aerobic respiration. Also explain the net energetic gain of the process.

    Answer: One glucose molecule is consumed and 38 ATP molecules are made after aerobic respiration. However, two of these ATP are consumed by glycolysis. Hence, the net gain of the process is 36 ATP molecules.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

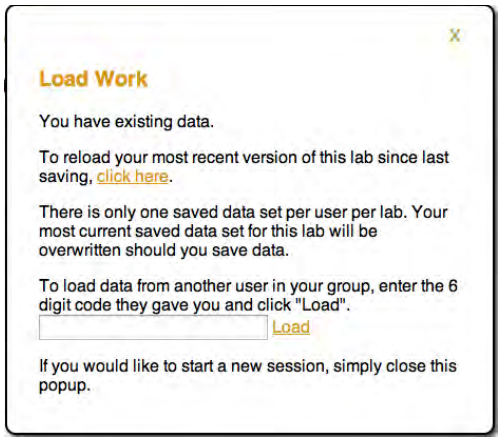
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

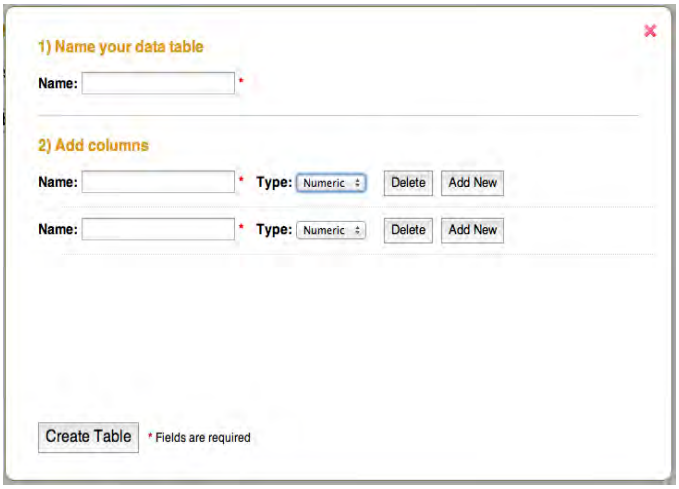
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



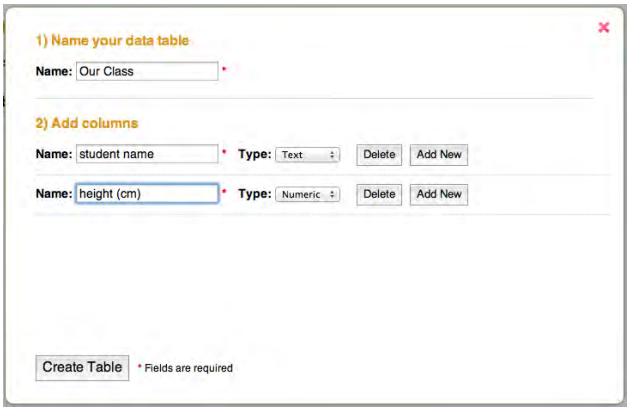
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.



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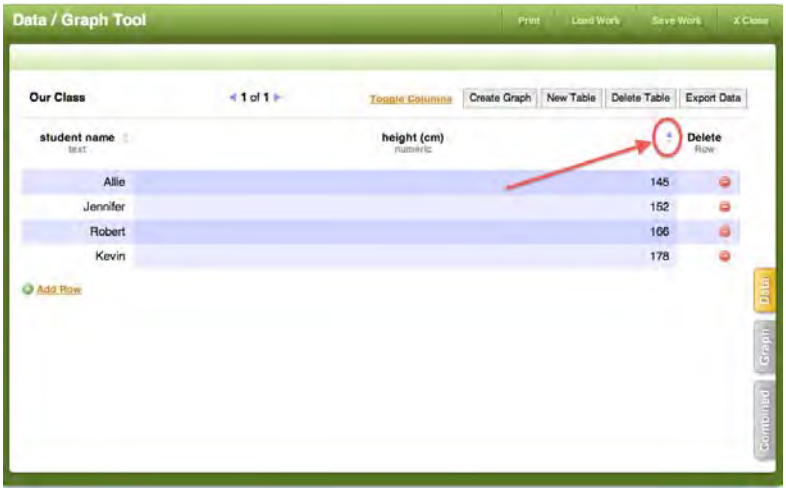

In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

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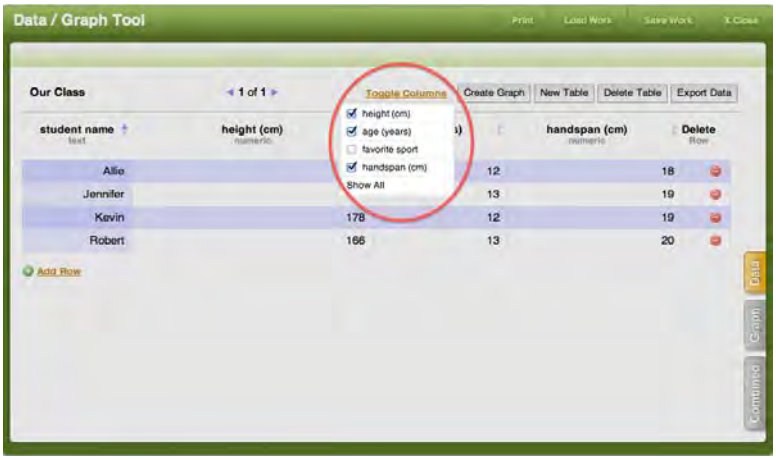

The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
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Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

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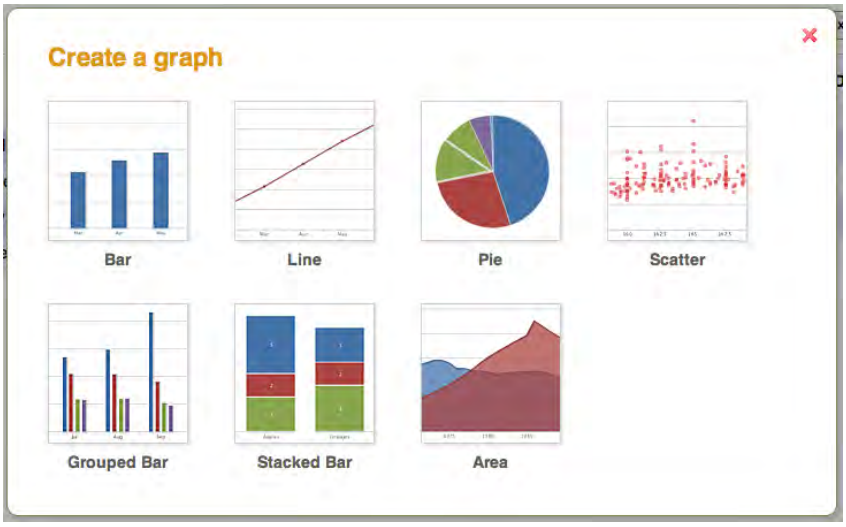
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

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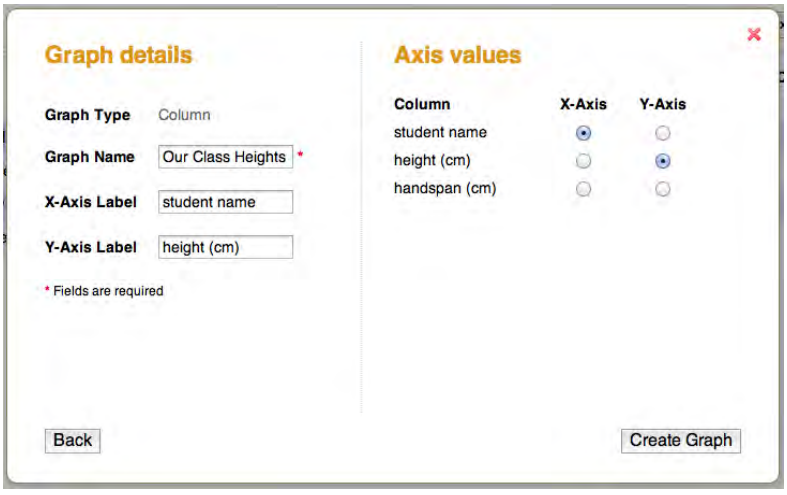

Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

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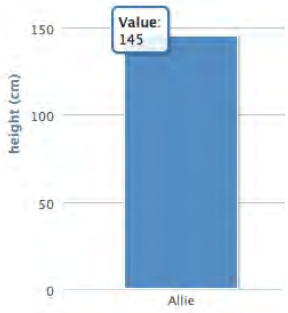

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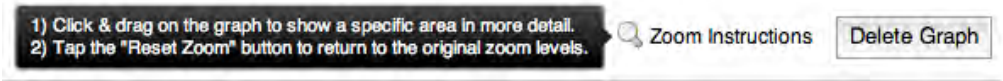


When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Explaining Cellular Respiration in Plants

Timing: one 90-minute class session

Objective(s):
Students will investigate the results of cellular respiration by measuring the oxygen consumption of germinating pea seeds.

Safety Precautions:
This lab utilizes potassium hydroxide, a very strong base. Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should never leave the lab area unattended with chemicals sitting out. Remind students to wear safety equipment including goggles, gloves, and lab aprons. Students should follow all instructions for disposal and cleaning of the chemicals and their containers. Students should report any chemical spills or broken glass immediately and should not try to clean up any spills or glass by themselves. Ensure that students are familiar with the locations of all spill kits, chemical showers, and eyewashes in case of accident.

Materials:
Per group:

- 3 test tubes, 3
- wads of cotton, small, 6
- dropper bottle of 15% KOH
- clean aquarium gravel, plastic beads, or other non-germinating material
- graduated cylinder, 100-mL
- water
- germinated pea seeds, 20
- 20 ungerminated pea seeds, 20
- rubber test-tube stoppers with calibrated pipettes, 3
- masking tape
- paper towels
- water bath, room-temperature
- thermometer
- heavy ruler or other small weight
- safety goggles, one pair per student
- lab apron, one per student
- disposable gloves, one pair per student

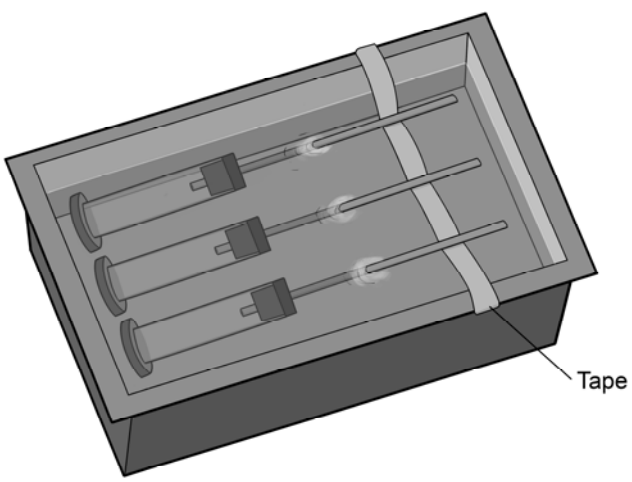
Teacher Preparation:

- Gather materials in advance of students performing the lab.
- Germinate pea seeds by placing them inside a dampened, folded paper towel inside a perforated plastic bag. Keep the bag at 65–75 degrees Fahrenheit (14–18 degrees Celsius) for 1 to 2 days until you see small roots forming. Moisten the paper towel periodically if it becomes too dry.
- It may help to assemble one respirometer ahead of time for students to refer to while building theirs.
- Explain to students that during aerobic cellular respiration, oxygen is consumed and carbon dioxide is released. An intake of oxygen is an indicator of active cellular respiration. Note that carbon dioxide gas can react with potassium hydroxide to form potassium carbonate (a solid) and water. The equation for this reaction is written as $CO_2 + 2KOH \rightarrow K_2CO_3 + H_2O$
- A small change in the amount of water in the pipette is expected during the equilibration period. A greater change is likely due to a break in the pipette or stopper seal.

Procedure

1. Direct students to fill the water bath and set it aside to reach room temperature while they prepare the rest of the experiment.

2. Then, students should place a piece of masking tape across the top of the water bath as shown below. This will help hold the test tubes while the air pressure equalizes.



3. Next, students should fill a 100-mL graduated cylinder with 50 mL of water. They should then place 20 germinated pea seeds in the water and record the final volume. Next, students should remove the seeds and allow them to dry on a paper towel. They should subtract 50 mL from the final volume to find the volume of the seeds.

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4. Direct students to construct a respirometer by placing a small wad of cotton in the bottom of a test tube. Students should saturate the cotton with the dropper bottle of KOH, counting the number of drops used. Remind students to be careful to keep the sides of the test tube dry. If students accidentally moisten the side of the test tube, they should replace it with a clean tube. Have students place a small wad of cotton on top of the KOH-saturated cotton and place the pea seeds on top of that. Then they should insert the stopper with a calibrated pipette.

5. Students should repeat steps 3 and 4 to create two more respirometers with the ungerminated seeds and gravel. Remind students to use the same amount of KOH in each test tube. The volume of ungerminated seeds will be smaller than that of germinated seeds; students should add gravel to the graduated cylinder until the same volume is reached. Include that same volume of gravel in the 3rd respirometer. Student groups should now have three respirometers: one with germinated seeds, one with ungerminated seeds and gravel, and one with only gravel.

6. Using test tube tongs, students should place all three respirometers on the masking tape "sling" so that the ends of the pipettes are above the water. Then they should weigh the respirometers down with a ruler or other item if necessary to keep the tips from sinking. Tell students to allow the respirometers to sit for 8 minutes so that they reach the same temperature as the water. Students should record the temperature of the water bath.

7. Gently remove the sling and lower the respirometers into the water until they are completely submerged. Position them in the water bath so that the measurements on the pipettes are easy to read. Place the weight on the test tubes to prevent them from floating to the surface.

8. A small amount of water will have entered the pipette tubes. Tell students to allow the tubes to equilibrate for 5 minutes and then record the reading on the pipette to the nearest 0.01 mL. (Remind them to measure the bottom of the meniscus.) This is the initial reading. Students should enter the results in the table and complete by taking readings at 10 minutes, 20 minutes, and 30 minutes. Direct students to subtract the initial reading from the 30-minute reading to find the net change.

Tube	Initial Reading	10 Minute Reading	20 Minute Reading	30 Minute Reading	Net Change
Germinated seeds					
Ungerminated seeds					
Gravel					

9. At the conclusion of the experiment, students should carefully disassemble the respirometer and dispose of the beans in the trash. Direct students to remove the cotton using forceps and place it in a sealed container for disposal. All glassware should be washed and dried.

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Analysis and Conclusions

1. Why do you think the water levels in the pipettes changed? What does this indicate?
   The oxygen in the tube was used up, so the internal pressure of the test tube changed and the water was drawn into the pipette. The use of oxygen is an indication of active cellular respiration.

2. How did the net change measurements differ between respirometers?
   The germinated seeds had the greatest net change. The ungerminated seeds had less, and the gravel had the least.

3. What was the scientific significance of the respirometer filled with gravel? Why might the water level in its pipette have changed? Determine the significance to your net change and revise if necessary.
   Gravel does not undergo cellular respiration, so it functions as a control. Any change in the pipette water levels is due to atmospheric changes that affect all 3 respirometers equally. The change in volume of the gravel-filled respirometer should be subtracted from the net changes of the other respirometers.

4. Oxygen consumption can be calculated by dividing the change in volume by the change in time. Determine the oxygen consumption of the germinated and ungerminated seeds at all data points.
   Answers will vary but should indicate that the oxygen consumption of the germinated seeds is higher than ungerminated seeds.

5. Many factors can affect the rate of oxygen consumption in organisms. Experimental data has shown that a cricket at room temperature consumes oxygen at a rate of 0.08 ml O_2 per gram of body weight per minute. At 30 degrees Celsius, the same cricket consumes oxygen at a rate of 0.10 ml O_2/g/min. Construct an explanation for this change in rate, and predict how your experimental rates would change if the water bath were heated to 30 degrees Celsius.
   The oxygen consumption rate increases as the temperature increases. Heat can speed up reactions and consequently increase the body's need for oxygen. If the temperature of the bath were increased, the oxygen consumption rate of both the germinated and ungerminated seeds should increase as well. The germinated seeds would increase more in rate because there are more cells using energy.

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In this lab, students will demonstrate the following Inquiry Skills:

- Identify
  - Develop a question that:
    - asks a question about a specific science concept or process.
  - Recognize and develop testable questions that:
    - specify a cause-effect relationship.
    - can be answered with a science investigation or observational study.
  - Develop:
    - state what may happen in an investigation based on prior knowledge or experience

- Design Investigations
  - Practice lab safety by:
    - Following lab safety procedures

- Gather Data
  - Use Tools to accurately measure:
    - Volume
  - Uses the appropriate format to record data:
    - Graph or chart

- Interpret Data
  - Identifies and interprets:
    - Analyzes data collected during an investigation

- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause effect relationship observed in the investigation

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Hands-On Lab

Yeast Fermentation

Timing: one 90-minute class session

Objective(s):
In this lab, students will investigate cellular processes, and discuss the chemical process and the energy conversions that occur during cellular respiration. Students will collect qualitative and quantitative data using laboratory glassware and a metric ruler. Students analyze and evaluate their data, make inferences, and use trends in their data to predict the effect of sucrose concentration on the rate of alcohol fermentation in yeast.

Safety Precautions:
Remind students to wear a lab apron, gloves, goggles, and closed-toe shoes. Remind students not to eat or drink anything in the lab (including the experimental materials). Tell students to report any broken glass to the teacher. They should not attempt to clean it up themselves.

Materials:

Per student group:

- 15 mL test tubes, 4
- test tube rack
- individually labeled test tubes (4): 0%, 1%, 5%, 10%
- 1 tsp. fast-rising highly active baker's yeast
- 1/8 teaspoon measure for yeast
- water balloons that fit snugly on test tubes (4)
- centimeter ruler
- warm sucrose solutions, 1%, 5%, 10%, 10 mL of each concentration
- warm tap water (approximately 20 mL)
- timer or stopwatch
- safety goggles, one pair per student
- lab apron, one per student
- optional: tub of hot water to keep your sucrose solutions and water warm

Teacher Preparation: Prepare the water and sucrose solutions before the lab. For 1% add 1 g of sugar to every 99 mL of warm water, for 5% add 5 g of sugar to every 95 mL of warm water, and for 10% add 10 g of sugar to every 90 mL of warm water. Use warm water, which helps speed up yeast metabolism. Make sure the baker's yeast has not expired. Do not leave the test tubes with balloons overnight since the pressure of CO_2 as it accumulates may cause the balloons to pop off the test tubes. Prepare copies of the Student Investigation Sheet.

Background:
Students will use their knowledge of cellular respiration to formulate a testable hypothesis about the energy conversions that occur during yeast fermentation. They will observe yeast fermentation under various levels of sucrose concentration. In order to determine the effect of sucrose concentration, they will measure the amount of CO_2 gas that the yeast produces. Yeast undergoes alcoholic fermentation to release energy. In this process, pyruvate from glycolysis is broken down to acetaldehyde, which accepts electrons from NADH. It thereby becomes ethanol. CO_2 is a gaseous product of the reactions. Students will collect qualitative and quantitative data using laboratory glassware and a metric ruler. Students analyze and evaluate their data, make inferences, and use trends in their data to predict the effect of sucrose concentration on the rate of alcohol fermentation in yeast.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>
Begin class with a discussion of anaerobic respiration. Remind them that yeast commonly undergo alcohol fermentation, and ask the students to name some commonly used products that require alcohol fermentation by yeast. Ask the students the following questions, guiding and correcting answers as needed:

1. What are the two different types of fermentation, and how are they similar/different? *(alcohol and lactic acid; they both produce small amounts of ATP and neither process requires oxygen, they yield different waste products)*
2. Explain fermentation in terms of its function in energy conversion in the cell. *(yeast perform fermentation to get energy by turning sugar into alcohol)*
3. Why do yeast need ATP? (*for energy to perform cellular functions)*
4. What are the reactants and products of ethanol fermentation? (*glucose, carbon dioxide + ethanol*)
5. What is sucrose? (*a common form of sugar; more specifically, a combination of glucose and*

fructose)

6. How might you measure the rate of fermentation in yeast? (*Answers will vary. Reinforce all reasonable answers.)*
7. What equation could you use to show the chemical reactions taking place? *If you students provide the second reaction only they should still receive full points. However two reactions are taking place. The first, with the help of the enzyme zymase converts sucrose to glucose: Sucrose + Water → Glucose + Fructose. The second reaction, with the help of the enzyme invertase, converts Glucose (or Fructose)→ Ethyl alcohol + Carbon dioxide.*

Introduce the objective of the lab to the students. In order to determine the effect of sucrose concentration, students will measure the amount of CO_2 gas that the yeast produce and compare this amount from varying sucrose concentration solutions. CO_2 production can be measured by measuring the depth of the layer of bubbles trapped in foam on top of the yeast solution and also by observing the balloons, which get bigger as they catch the CO_2 produced by the yeast. Before this lab, you can review the parts of a traditional scientific investigation. Students will make a hypothesis about how the sucrose concentration will affect the rate of fermentation in yeast. They will test this hypothesis and analyze their results.

The procedure to measure alcoholic fermentation is:

1. Label each test tube, 0%, 1%, 5%, or 10%.
2. Add 10 mL of the appropriate water or sucrose solution to each tube.
3. For each tube, add 0.5 mL (or 1/8 tsp) of yeast and put a balloon firmly over the top.
4. With your thumb sealing the top, shake each tube until the yeast is dissolved.
5. With a ruler to millimeter precision, measure the depth of bubbles that are produced and observe the balloons as soon as the test tubes are prepared.
6. Perform additional depth and balloon measurements after 10 minutes and 20 minutes.
7. Students should record their observations and measurements in the following two tables:

Sucrose Concentration	Depth of CO_2 bubbles at:		
	0 min	10 min	20 min
0% (plain water)			
1% sucrose			
5% sucrose			
10% sucrose			

Sucrose Concentration	Balloon Description		
	0 minutes	10 minutes	20 minutes
0% (plain water)			
1% sucrose			
5% sucrose			
10% sucrose			

For students to see the general trends and variability in the results in different replications, you may want to collect the data on the depth of CO_2 bubbles at 20 minutes from each student group and display these data in a graph with sucrose concentration (0%, 1%, 5%, and 10%) on

the *x*-axis and depth of bubbles in millimeters on the *y*-axis; use a different symbol for the data from each group and for the class average at each sucrose concentration. Remind students to choose a level of accuracy appropriate to the limitations of their measurements as they produce their graphs. In a class discussion of these data, you may want to ask students if they are aware of any differences in

methods that could have resulted in points that deviate from the general trend; this may help students realize the importance of precision in experimental methods to achieve accurate results.

Guided Inquiry

Students can work more independently with less discussion and direction from the teacher. You can hand out the materials, and give students a step-by-step detailed procedure list. Students can develop their own plans for collecting data, based on their knowledge of the procedure and materials used. Ask the students any or all of the following questions to guide them and focus their study:

1. What are the two different types of fermentation, and how are they similar/different?
2. What do yeast need ATP for?
3. What is the ultimate purpose of performing fermentation for the yeast cell?
4. What are the reactants and products of glycolysis and ethanol fermentation?
5. Approximately how much ATP does ethanol fermentation produce, and how does this compare to aerobic cellular respiration?
6. What is sucrose?
7. In this lab procedure, what are the dependent and independent variables?

Analysis and Conclusions

In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. Based on your knowledge about sugar's role in cellular respiration, what was your hypothesis and how did your results compare with your hypothesis? *Answers will vary.*

2. What technology did you choose to obtain your results? Suggest ways in which you could modify your method to collect data with a higher level of precision. *Answers will depend upon how the students approached the method. However most will measure the depth of bubbles in the tube using a ruler marked in mm. One way to improve precision they could measure the volume of gas actually produced by, possibly by using a delivery tube to transfer the gas displaced to an inverted water filled graduated tube.*

3. Discuss your results with your group. What conclusions concerning the relationship between sucrose concentration and the rate of alcoholic fermentation are supported by your results? *As the concentration of sucrose increases, the rate of alcohol fermentation also increases.*

4. Compare your results with the class results or with the results of the group next to you. Are your results generally similar? If there are any significant differences in results, what could be the reason for these differences? *Answers will vary.*

5. What were the dependent and independent variables in this procedure? Name another variable that you could change, and predict how the results might change with this other variable. *The dependent variable was the rate of yeast fermentation, and the independent variable was the*

sucrose concentration. Other variables that could be altered are the yeast concentration or temperature.

6. What do you predict would happen if you added a great deal more sugar to the solution?. Would fermentation rate continue to rise? What limits (other than sugar concentration) are there on fermentation rate? *The fermentation rate might rise with additional sugar, but only up to a point. Adding more sugar at some point will not increase fermentation. One large limitation is the number of yeast organisms available to perform anaerobic respiration.*

Further Questions

7. Compare the products of aerobic and anaerobic respiration. From what you know about chemical reactions, which is likely to produce the most energy? *Aerobic respiration fully oxidizes glucose to carbon dioxide and water. Fermentation produces carbon dioxide and alcohol, only partially oxidizies the glucose. Aerobic respiration will therefore produce the most energy.*

8. What is the primary advantage of aerobic respiration? What about anaerobic fermentation? *Aerobic respiration is capable of producing more ATP for cellular processes. Anaerobic fermentation is advantageous under poor oxygen conditions to allow glycolysis to proceed.*

9. Why do you think yeast is important for baking bread? *The carbon dioxide produced is the purpose of adding yeast to bread dough, this gas makes the bread fluffy and full of gas pockets.*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - Asks a question about a specific science concept or process
  - Recognize and develop testable questions that
    - Specify a cause-effect relationship
  - Develop predictions/hypotheses that:
    - State the expected cause and effect (if-then statement) in an investigation based on prior knowledge and experience (hypothesis)
- Design Investigations
  - Design and conduct investigations using
    - Independent variable - the one variable the investigator chooses to change
    - Dependent variables - what changes as a result of, or in response to, the change in the independent variable
    - Constant- identify variables that must remain unchanged
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Describing it so that it can be easily repeated by a fellow scientist
- Gather Data
  - Use tools and the SI (metric) system to accurately measure
    - Length/distance/depth
  - Chooses appropriate tools to conduct an investigation
    - Test tubes, rulers, clock, measuring flask, scale
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
  - Use the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
    - Tables
    - Graphs
- Interpret Data
  - Identify and interpret patterns using:
    - Analysis of data collected during an investigation
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Reporting trends and patterns in the data
    - Comparing results to a hypothesis
    - Answer the testable question

        - Formulating scientific explanations/arguments

- Communication in Science
    - Report results using:
        - Peer presentation
        - Scientific explanations/arguments
        - Table/graph showing data
- Analyze Scientific Results
    - Participate in critiquing/peer review by:
        - Evaluating data for accuracy
        - Evaluating a conclusion
- Scientific Investigation
    - Scientific Investigation:
        - Scientific investigation begins with a testable question
        - When a scientific investigation is repeated, a similar result is expected.
        - Science takes place in many locations including labs, offices, fields, and under the ocean.
        - Scientific investigation results in things we know and things we don't know.
        - Scientific investigation leads to more questions.
        - Scientific investigations lead to the development of scientific explanations.
    - Scientific Data and Outcomes:
        - Scientific claims are based on data and reliable scientific sources.
        - Collecting and analyzing data is the best way to understand a changing pattern.
        - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
        - Comparisons of data are not accurate when some of the conditions are not kept the same.
        - It is important in science to keep honest, clear, and accurate records.

Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

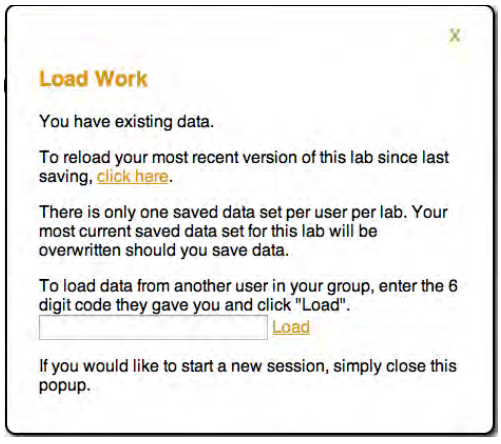
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

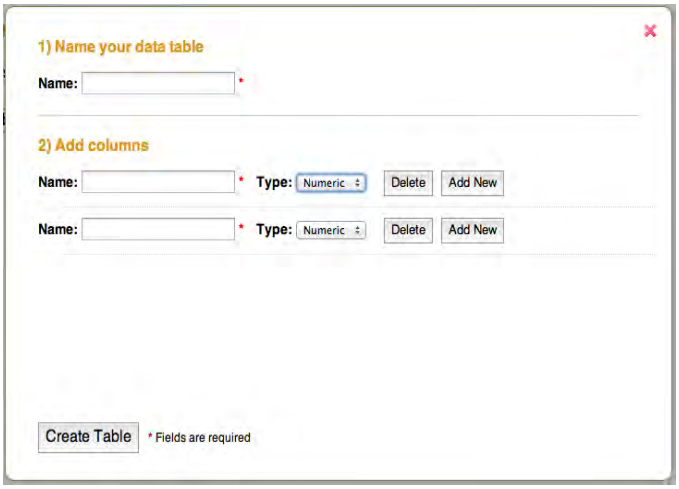
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



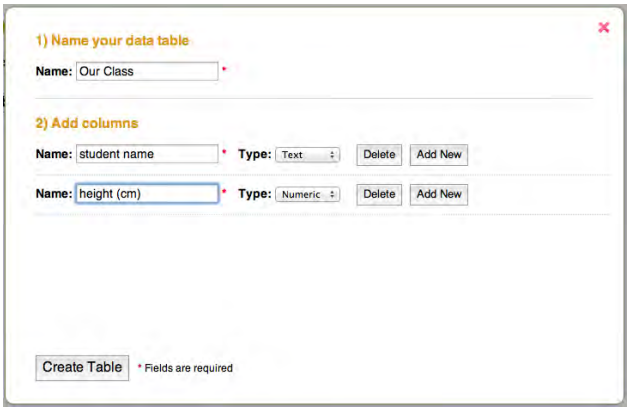
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

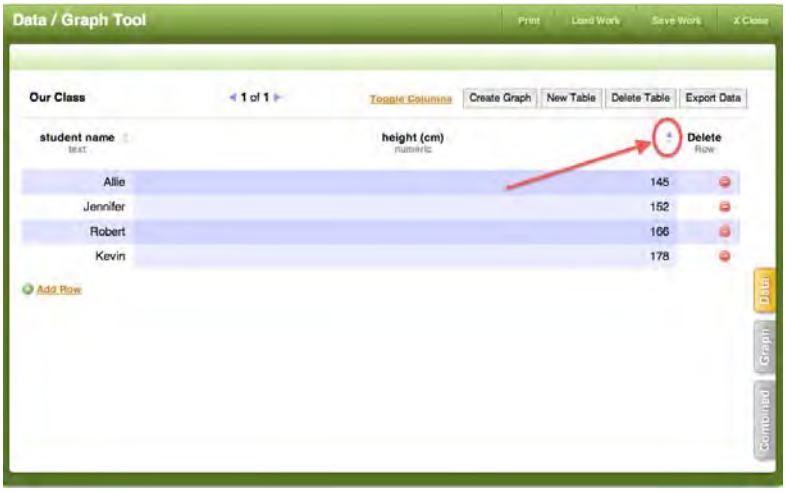
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

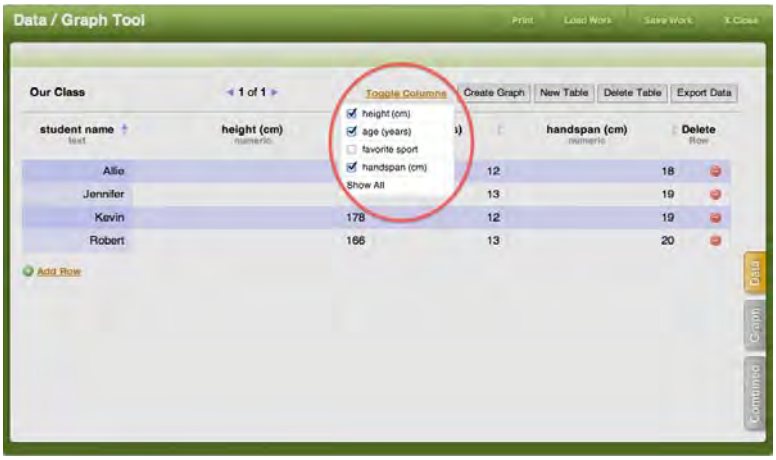


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

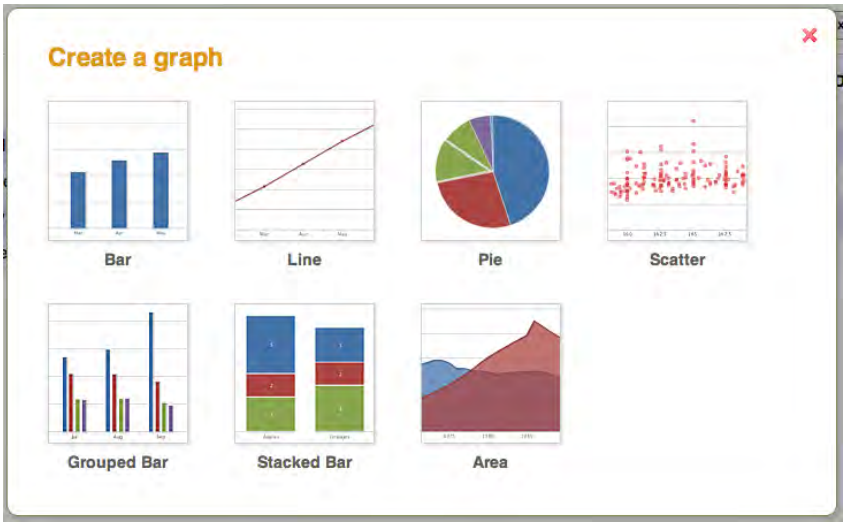
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

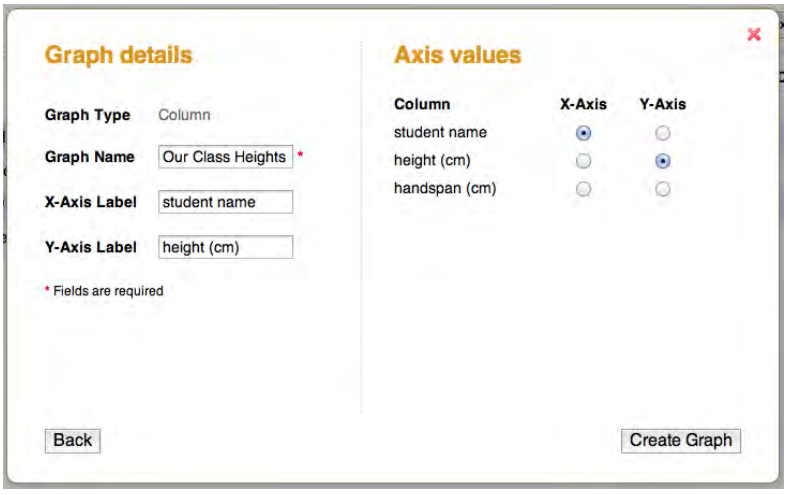
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

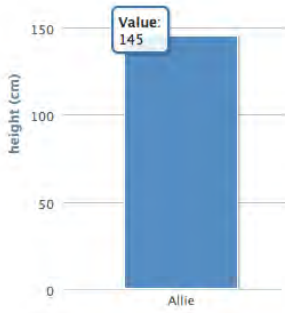


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

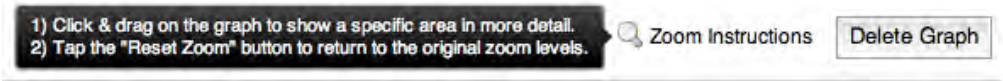
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Activity Sheet

Name _____

Date _____

The Water Cycle

Work with a partner. Watch and listen to the video, "The Constantly Flowing Water Cycle." Take notes that will help you write or draw a summary of the video.

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish?

Use the questions to help you write or draw a summary. If you draw, use labels.

What are the steps in the water cycle?

_____

_____

_____

What are some key words about the water cycle? _____

_____

Write or draw a summary of the water cycle.

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Exploration Teacher Guide: Nutrient Cycles

Overview

Nutrient cycles are complex biogeochemical cycles in which elements are transformed from their inorganic to organic compounds. In this Exploration, students identify the different forms of nitrogen and phosphorus in their respective cycles. They also determine the processes involved in the conversion of these elements from one form to the other.

Student Learning Objectives

- Identify the different compounds as nitrogen and phosphorus move through their respective cycles.
- Identify the different processes involved in the two cycles.
- Examine the exchange of matter between living systems and their environment.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students select the nutrient cycle they want to explore using the radio button options, *Nitrogen* or *Phosphorus*. This is a two-step activity. In Step 1, an image of the selected cycle with empty slots to label the different compounds is available on the activity area. Students drag the compound labels from the *Select Compound* section and drop them to their corresponding locations in the respective cycles. After all compound labels are dropped correctly, students use the *Proceed* button to move on to Step 2.Students may use the *Reset* button to undo what they have done and identify the parts again.

In Step 2, students identify the different processes of the selected cycle. An image of the selected cycle with empty slots to label the processes is available on the activity area. The students drag the process labels from the *Select Process* section and drop them into their corresponding slots. After all processes are dropped correctly, students use the *View Cycle* button to view an animation of the complete cycle. Students may use the *Reset* button to undo what they have done and identify the processes again or use the *Start Over* button to go back to Step 1.

In the *Tracker* tab, students can track the correctly identified compounds and processes of the nitrogen and phosphorus cycles. Students select a cycle from the *Select Cycle* dropdown list to view its data.

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Answers to Questions in the Student Worksheet

1. List the various forms of nitrogen present in the nitrogen cycle.

   Answer: Nitrogen is present in the following forms in the nitrogen cycle:
   a. Ammonia
   b. Ammonium
   c. Nitric oxide
   d. Nitrous oxide
   e. Nitrate

2. List the various forms of phosphorus in the phosphorus cycle.

   Answer: Phosphorus is present in the following forms in the phosphorus cycle.
   a. Minerals such as apatite.
   b. Phosphate and dissolved phosphates
   c. Inorganic phosphate
   d. ATP

3. Identify and name the different ways in which atmospheric nitrogen is made available for plants and animals.

   Answer: Atmospheric nitrogen is made available for plants and animals by the processes of biological fixation by microorganisms and industrial fixation.

4. Name the process in the nitrogen cycle that releases nitrogen gas (N_2) back into the atmosphere.

   Answer: Denitrification releases nitrogen gas (N_2) back into the atmosphere.

5. Identify the processes that convert phosphorus in rocks to usable forms of phosphorus.

   Answer: Phosphorus in rocks is converted to usable forms of phosphorus by weathering of rocks and phosphate mining.

6. Explain the significance of phosphorus uptake by plants in the phosphorus cycle.

   Answer: Plants absorb inorganic phosphorus from the soil and convert it to ATP. This ATP is used as energy for growth and repair. ATP is also transferred to animals when they eat plants.

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7. Explain the significance of phosphate mining.

   Answer: Phosphate mining converts phosphorus in rocks to phosphorus in fertilizers for use in agriculture and industry.

8. List the different forms of nitrogen found in the atmosphere.

   Answer: Nitrogen is present in the atmosphere in the form of atmospheric nitrogen (N_2), nitrous oxide (N_2O) and nitric oxide (NO).

9. Describe the role played by microorganisms in the nitrogen cycle.

   Answer: Microorganisms, primarily nitrogen fixing bacteria convert atmospheric nitrogen to ammonia and make it available for plants and animals. Microorganisms also convert ammonia to nitrates and nitrites, which are used as nutrients for plant growth.

10. Use this Exploration and identify which nutrient cycle which does not have a gaseous phase.

    Answer: The phosphorus cycle does not have a gaseous phase.

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Hands-On Lab

Soil Testing

Timing: one 90-minute class session

Objective(s):
Students will develop and test predictions about the relative levels of nitrogen and phosphorous in soil samples from a variety of locations.

Safety Precautions:
Remind students to wear closed-toe shoes and not to eat or drink anything in the lab (including experiment materials.) Students should wear a lab apron, gloves, and safety goggles when working with chemicals. Tell students to report any broken glass immediately and not to try cleaning it up by themselves.

Materials:
Per student group (3–4 students)

- camera
- pre-collected soil samples in small bags or containers, 2 samples per group
- soil test kit, and any materials required to complete the soil test. These may include, but are not limited to:
  - graduated cylinder, 50 mL
  - graduated cylinder, 100 mL
  - beaker, 250 mL
  - test tubes
  - test tube rack
  - filter paper
  - funnels
  - electronic balance
  - distilled water (>200 mL)
  - plastic pipettes
- gloves, one pair per student
- safety goggles, one pair per student
- lab apron, one per student

Teacher Preparation:
For this experiment you will need to obtain soil testing kits and have students follow the instructions of the particular kit. Students should collect soil samples prior to the lab. A few scoops from a hand shovel should be sufficient for all required testing. It is recommended that soil collection takes place at least one or two days before the lab, especially if any students are collecting samples from a location at home. Provide students with the necessary supplies to collect the samples, such as a hand shovel and

small bag or container. Students should obtain their samples from approximately six inches below the surface. They should collect two soil samples from similar, nearby sample spots within one location in order to obtain a more accurate sampling of that location. Each group should test from a different area, if possible. Ideas for collection locations include: a student's back or front yard, a home garden, a nearby field or dirt lot, the school playground, etc. Try to choose locations that vary significantly in soil color, composition, and degree of vegetation. If possible, have students take pictures of the general area from which they take their samples. They should also take pictures of the soil. If cameras are not available, sketches and detailed verbal descriptions may be used.

Prepare a copy of the Student Investigation sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>
Have students answer the following questions in their notes, and then discuss the answers as a class. Allow students to refer to their notes or the Discovery Education digital resources if needed.

1. Nitrogen gas (N_2) is extremely abundant in the atmosphere (approximately 80% of air). Can plants use gaseous nitrogen? Why or why not?
2. How is nitrogen cycled between the atmosphere, soil, plants, and animals?
3. From what sources does the soil receive phosphorous?
4. How do plants obtain both nitrogen and phosphorous?
5. What are some negative effects that over-fertilization may have on soil, water, and general nutrient cycling?

In this experiment, each group of students will test two soil samples from a specific location and compare their results with other groups. In class, students will use their soil test kits to test for phosphorous and nitrogen levels. This will involve a simple extraction procedure that might vary slightly depending on the particular soil test kit that is used. If the extraction procedure uses results in a color-matching system (with a nutrient "color chart"), have students take pictures of (and/or note) the resulting color of their nitrogen and phosphorous test solutions. Most test kits use qualitative results to indicate nitrogen and phosphorus levels such as "low," "medium," and "high."

Before conducting the soil tests, discuss all of the locations that are being used and have student groups share their pictures or sketches and descriptions of the area. Have students make predictions about the relative levels of nitrogen and phosphorous they expect from their location compared to their peers' locations and the reason for their predictions. (Guide students to understand that soil from residential lots or cultivated fields might have high levels of nitrogen and phosphorus because the soils have been treated by fertilizers.)

Using the soil testing kits as a guide, review the soil testing procedures with the class. You may wish to have soil samples on hand to demonstrate each test and how to interpret the results using a color chart.

Once students have finished determining their soil nitrogen and phosphorous content, have students record their results in a data table. Then have one student from the group make a copy of their data on the board so that all group data is listed together. Students should compile the group data and represent it graphically using a separate double-bar graph for each of the two nutrients. If results are qualitative (low, medium, or high), use predetermined increments for these concentrations. For example, the bar for low concentrations might be one centimeter above the x-axis, the bar for medium concentrations might be two centimeters above the x-axis, and the bar for high concentrations might be three centimeters above the x-axis.

Have students analyze the data in their notes to determine if there is any correlation between nitrogen and phosphorous soil content. Students should also discuss reasons for any discrepancies in data. For example, why might one sample test low for phosphorus and the other sample test medium for the same nutrient? *(Sample answer: The phosphorus concentration might be very close to medium, but since the data is qualitative, it could test low.)*

Sample Data Table: Nitrogen Test

Soil Sample	Nitrogen Concentration	Notes about Coloration
Sample 1	*medium*	*Moderately dark purple*
Sample 2	*medium*	*Moderately dark purple*

Sample Data Table: Phosphorus Test

Soil Sample	Phosphorus Concentration	Notes about Coloration
Sample 1	*low*	*Very light blue*
Sample 2	*medium*	*Moderately light blue*

Guided Inquiry

Have students conduct independent research to answer the following questions. They should then share their answers with their lab partners, discussing any differences in their answers and asking you questions as needed.

1. Nitrogen gas (N_2) is extremely abundant in the atmosphere (approximately 80% of air). Can plants use gaseous nitrogen? Why or why not?
2. How is nitrogen cycled between the atmosphere, soil, plants, and animals?
3. From what sources does the soil receive phosphorous?
4. How do plants obtain both nitrogen and phosphorous?
5. What are some negative effects that over-fertilization may have on soil, water, and general nutrient cycling?

Students can develop their own plans for collecting and displaying data, based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry:

1. How can you use a graph to represent qualitative data?
2. When testing soil samples for nutrients, what are your controls? What are the dependent and independent variables?
3. How can you increase the accuracy of your test results?

Before performing the experiment, have students review the procedures on the soil test kits within their lab groups. After performing the experiment, students should record their data in a table and then represent it using the graph of their choice. Have student groups share and compare their results with the class.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. Soil samples from which location(s) contained the most nitrogen? Phosphorous? *Answer depends on experimental results.*

2. What facts about the soil samples did you consider when you predicted the amounts of nitrogen and phosphorus you would find? What facts did you consider before selecting the technology? How did your predictions compare with your results? How did your results compare to the results of other groups? *Answer depends on experimental results.*

3. If you recovered soil from a field or garden where legumes such as soybeans were planted, what would you expect to find when your tested the soil for nitrogen and phosphorus? Why? *Sample answer: I would expect to find higher levels of nitrogen than in other soil samples because legumes fix nitrogen in the soil in which they grow.*

4. What sources of error could have been present in your experiment? *Our soil sample might not have accurately represented the soil in our collection location, we may have used too little or too much soil, and we may have lost some product or made mistakes during the extraction process (such as waiting too long, or not long enough for the color to appear).*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - Asks a question about a specific science concept or process
  - Develop predictions/hypotheses that
    - State what may happen in an investigation based on prior knowledge or experience (prediction)
  - Design and conduct field studies using:
    - Survey- collects multiple data points at one point in time
  - Recognize and develop testable questions that
    - Specify a cause-effect relationship.
    - Require the changing of one variable at a time.
    - Can be answered with a science investigation or observational study.
- Design Investigations
  - Design and conduct investigations using
    - Fair test - changing only one variable at a time makes comparisons valid
    - Independent variable - the one variable the investigator chooses to change
    - Dependent variables - what changes as a result of, or in response to, the change in the independent variable
    - Sample (if needed) - a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements
- Gather Data
  - Chooses appropriate tools to conduct an investigation
    - Other laboratory equipment
  - Uses senses to observe
    - Seeing (color)
  - Uses the appropriate format to record data
    - Writing (journal, worksheet, electronic text)
    - Graph
    - Photograph
- Interpret Data
  - Sorts and classifies using scientific reasoning
    - Develop a classification scheme for objects, substances or organisms
  - Identify and interpret patterns using:
    - Trends in data
    - Tables and graphs
    - Based on an analysis of data collected during an investigation
- Evaluate Evidence
  - Draw and support a conclusion by:

        - Reporting trends and patterns in the data
        - Comparing results to hypothesis
        - Answer the testable question
- Communication in Science
    - Report results using:
        - Table/graph showing data
- Scientific Investigation
    - Scientific Investigation:
        - Science investigation begins with a testable question
        - Science takes place in many locations including labs, offices, in the field, and under the ocean.
        - When a scientific investigation is repeated, a similar result is expected.
        - Hypotheses are valuable, even if they turn out not to be true, because they lead to further investigation.
        - Scientific investigation leads to more questions.
        - Scientific investigations lead to the development of scientific explanations.
    - Scientific Data and Outcomes:
        - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
        - Comparisons of data are not accurate when some of the conditions are not kept the same.

Hands-On Lab

Chemical Weathering

Timing: one 90-minute class session

Objective(s):
Students will design and conduct an experiment to investigate how when gases from the air dissolve into water, they contribute to the dissolving (chemical weathering) of carbonate rocks.

Safety Precautions:
1.0 M hydrochloric acid (HCl) is corrosive. Have students wear safety goggles, gloves, and a lab apron during this investigation. Remind students to tie back long hair, to pour acids carefully, and to clean up any spills immediately. If students are diluting HCl, remind students to add acid to water, rather than the other way around. Use baking soda (sodium bicarbonate) to neutralize any spills. Review the use of safety equipment, including the emergency eyewash. Remind students of proper procedures for lighting Bunsen burners, if applicable.

Materials:
Per group:

- 10 mL 1.0 M hydrochloric acid (HCl)
- 50 mL white vinegar
- 50 g baking soda
- distilled water
- several 50 mL or 100 mL beakers or flasks
- dropper
- pH meter or pH indicator paper
- several samples of calcite and/or limestone
- hammer
- cloth rag or towel
- Bunsen burner or hot plate
- thermometer
- safety goggles
- apron or lab coat
- protective gloves

Teacher Preparation:
Before the lab, gather several samples of calcite and/or limestone per group. Each sample should be small enough that students can pick it up and carry it easily, but large enough that most of the rock will not be affected by the drop of acid. (This will make the contrast between the weathered rock and the non-weathered rock easier to see.) Check your supply of laboratory materials. Purchase vinegar if necessary. The measurements specified in the materials list, above, are approximate; slightly more or less of each substance is acceptable. Students should be encouraged to suggest appropriate quantities of the materials being used. Gather enough supplies so that no group consists of more than four students. If necessary, several groups may share the final four supplies listed: hammer, rag/towel, Bunsen burner/hot plate, thermometer.

Print a copy of the Student Investigation Sheet for each student.

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Procedure

The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process also will be included. In some cases, students then may be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It also will be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Divide students into small groups of three or four. Explain that the goal of the lab is to investigate the chemical weathering of carbonate rocks by acids and identify the carbonate rocks with which students will be working (most likely calcite or limestone). Remind students of all safety procedures for the lab. Distribute materials and have students set up a table like the one below. (Each student should take notes in his or her own table, adding rows as necessary.)

Acid	pH	Observations

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Each group should complete the following procedure:

1. Use the pH meter or indicator paper to test the pH of 1.0 M HCl. Record the pH in the table.
2. Place a small sample of carbonate rock in a beaker.
3. Add 2–3 drops of 1.0 M HCl to the rock.
4. Record your observations in the table.

Sample response:

Acid	pH	Observations
1.0 M HCl	*1*	*The surface of the rock where the acid landed fizzed instantly and crackled; sediment formed at the bottom of the beaker.*

Bring the class together to discuss the results of the Directed Inquiry. Call on students to share their observations; if any groups do not report observations similar to the sample response above, discuss possible sources of error (e.g., perhaps the acid or the rock that group used was misidentified). Then, continue to the Guided Inquiry portion of the lab.

Guided Inquiry

Remind students that a pH of 1 indicates a strong acid. Explain that the pH of rainwater typically is 5.5 to 6.0. (Pure water has a neutral pH of 7.) Acid deposition can lower the pH of rainwater below that range. In extreme cases, the pH of water contaminated by acid deposition can dip below 2, but on average, the pH of acid rain falling in the United States is about 4.3. Explain that the weak acid in vinegar falls in the pH range of acid deposition.

Based on their experiences in Directed Inquiry, have groups hypothesize the effect of acid deposition on carbonate rocks. *(Students should infer that acid deposition can wear away—or weather—carbonate rocks, though probably not as quickly as hydrochloric acid does.)* Then, have groups brainstorm factors

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that may affect the rate at which exposure to acid weathers rocks—that is, why might some carbonate rocks be worn away more quickly by acids? *(sample responses: temperature, surface area)*

Discuss students' ideas; then, instruct each group to come up with a scientific (i.e., testable) question about the chemical weathering of carbonate rocks that it would like to investigate. Each group should write its question on a piece of paper, along with the following:

- A hypothesis that poses an answer to the question
- A procedure for an experiment using the available materials to test the hypothesis
- Tables for recording observations and other data during the experiment
- A plan for analyzing data obtained during the experiment

For example, groups might want to answer the following question: *How does the strength of an acid affect the rate at which it weathers rock?*

- A hypothesis for this question might be: *Stronger acids will wear away carbonate rocks more quickly than weaker acids.*
- To test this hypothesis, groups would need to expose the same type of rock to a variety of acids, including hydrochloric acid, diluted hydrochloric acid, and vinegar.

Or, groups may want to answer the following question: *How does the temperature of an acid affect the rate at which it weathers rock?*

- A hypothesis for this question might be: *Acids at higher temperatures will wear away carbonate rocks more quickly than acids at lower temperatures will.*
- To test this hypothesis, groups would need to expose the same type of rock to the same strength acid, using the hot plate or Bunsen burner to heat the acid to different temperatures.

If necessary, ask students guiding questions, such as:

- What variables could you investigate in your experiment? *(pH, temperature, surface area)*
- How many variables should you investigate at one time? *(one)*
- What else can you do to increase the validity of your results? *(use controls, repeat experiments)*
- Why is accuracy of the data you recorded important? *(If data is not recorded with accuracy, conclusions cannot be made regarding the reliability of the measurements that were taken.)*

Have groups submit their questions, hypotheses, procedures, and plans to you for approval. Check to be sure students have included safety precautions in their procedures. Once you approve, have students carry out their investigations. Remind students to write conclusions once they are finished analyzing their data.

When all groups have finished their investigations, invite each group to present its investigations to the class. Encourage classmates to ask questions and offer critiques. Remind students that critiques should focus on whether the data supports the conclusions. Ask them to consider the limitations on the precision of the data they collected, such as cost of materials and time, and how that may have affected repeat measurements. After presentations, have students write brief descriptions of how they could refine their procedure or design to improve their experiments.

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Analysis and Conclusions:

To help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. What was the independent variable in your experiment? *Sample response: pH*

2. What was the dependent variable in your experiment? *Sample response: amount of sediment produced*

3. How did you control variables in your experiment? *Sample response: To test only the effects of pH, we used the hammer to break rock samples into pieces with similar surface areas, and we ran each test for the same amount of time.*

4. Did your data support your hypothesis? Describe why it did or did not and explain possible reasons for this result. *Sample response: Partly. We found about the same amount of sediment after 10 minutes at both pH 5 and pH 4. However, we found noticeably more sediment after 10 minutes at pH 1 than at pH 5. This probably is because a substance with a pH of 1 is highly acidic and will weather the type of rock we tested more quickly than will less acidic substances.*

5. How could you improve your experiment? *Sample responses: We could run the experiment for a longer time to see whether the effects might be more noticeable. We could weigh the original rock and compare the ratios of sediment to rock rather than just comparing the mass of sediments.*

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In this lab, students will demonstrate the following Inquiry Skills:

- Identify Questions
  - Develop a question that:
    - Asks a question about a specific science concept or process
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
    - Require the changing of one variable at a time
    - Can be answered with a science investigation or observational study
  - Develop predictions/hypotheses that:
    - State what may happen in an investigation based on prior knowledge or experience (prediction)
    - State the expected cause and effect (if-then statement) in an investigation based on prior knowledge and experience (hypothesis)
- Design Investigations
  - Design and conduct field studies using:
    - Survey - collects multiple data points at one point in time
    - Interventional Study - adjusts one or more elements and observes resulting changes over time
  - Design and conduct investigations using:
    - Fair test - changing only one variable at a time makes comparisons valid
    - Independent variable - the one variable the investigator chooses to change
    - Dependent variables - what changes as a result of, or in response to, the change in the independent variable
    - Constant- identify variables that must remain unchanged
    - Control (control group) - used for comparison in which the independent variable is not changed
    - Sample (if needed) - a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements
    - Multiple trials - repeated tests with the same variables to check for variability of results
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Properly citing all equipment and materials
    - Describing it so that it can be easily repeated by a fellow scientist
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
    - Incorporating laboratory safety practices into the investigation design
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Volume
    - Mass
    - Temperature
    - Time
  - Choose appropriate tools to conduct an investigation:
    - Glassware (beakers, flasks, watch glass, etc.)

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        - Bunsen burner
        - Thermometer
        - Clock/stopwatch
        - Balance
        - Erlenmeyer flask
        - Other Laboratory equipment
        - Hot plates
    - Use senses to observe:
        - Seeing (size, texture)
        - Touching (temperature, size)
    - Use the appropriate format to record data:
        - Table
        - Chart
        - Writing (journal, worksheet, electronic text)
- Interpret Data
    - Identify and interpret patterns using:
        - Trends in data
        - Repeating physical or data patterns
        - Tables and graphs
        - Analysis of data collected during an investigation
- Evaluate Evidence
    - Draw and support a conclusion by:
        - Using data to determine the cause-effect relationship observed in the investigation
        - Reporting trends and patterns in the data
        - Comparing results to hypothesis
        - Answering the testable question
        - Extrapolating results beyond the investigation
        - Identifying alternative explanations
        - Examining how investigations can be improved
        - Formulating scientific explanations/arguments
        - Showing the application of the scientific concept or process being investigated
- Communication in Science
    - Report results using:
        - Peer presentation
        - Scientific explanations/arguments
        - Table/graph showing data
- Analyze Scientific Results
    - Participate in critiquing/peer review by:
        - Evaluating an investigative design
        - Evaluating data for accuracy
        - Evaluating a conclusion
        - Identifying alternative explanations
        - Analyzing scientific explanations
        - Analyzing scientific arguments
- Scientific Investigation

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- Scientific Investigation:
  - Science investigation begins with a testable question.
  - New observations should be made when there is disagreement among initial observations.
  - Scientific investigation results in things we know and things we don't know.
  - Hypotheses are valuable, even if they turn out not to be true, because they lead to further investigation.
  - Scientific investigation leads to more questions.
  - Different explanations can be given for the same evidence, and it is not always possible to tell which one is correct without further inquiry.
  - Scientific investigations lead to the development of scientific explanations.
- Scientific Data and Outcomes:
  - People are more likely to believe ideas if good reasons are given for them.
  - Scientific claims are based on data and reliable scientific sources.
  - Collecting and analyzing data is the best way to understand a changing pattern.
  - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
  - Comparisons of data are not accurate when some of the conditions are not kept the same.
  - Accurate record keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.
  - It is important in science to keep honest, clear, and accurate records.
  - When similar investigations give different results, it often takes further studies to decide what is right.
  - Arguments and conclusions are invalid if based on very small samples of data, biased samples, or samples for which there was no control sample.

- Scientific Endeavor
  - Characteristics of Science:
    - Science is based on factual knowledge.
    - Scientific claims can be substantiated using data and observation.
    - An important part of science is the critical review and analysis of any idea or conclusion.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

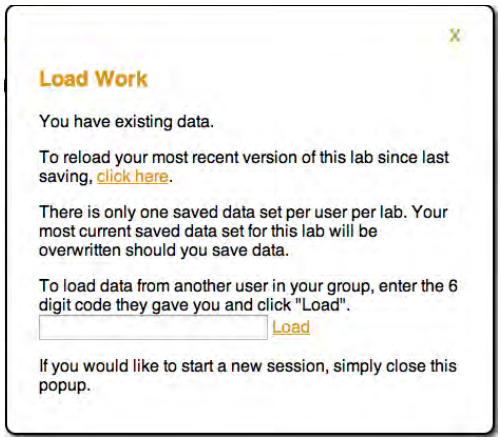
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

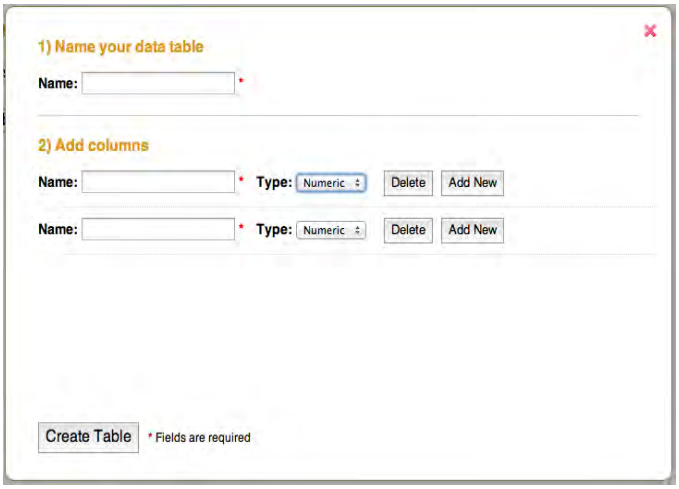
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



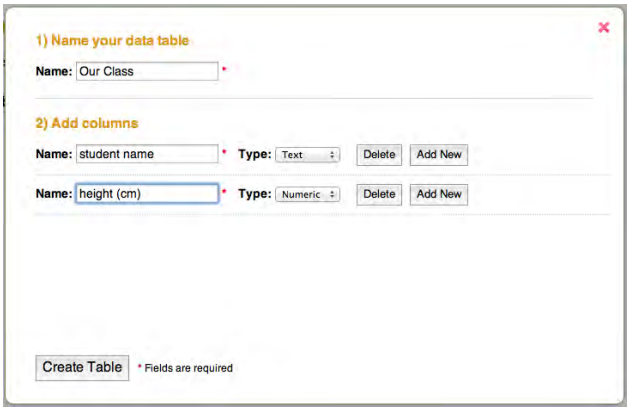
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

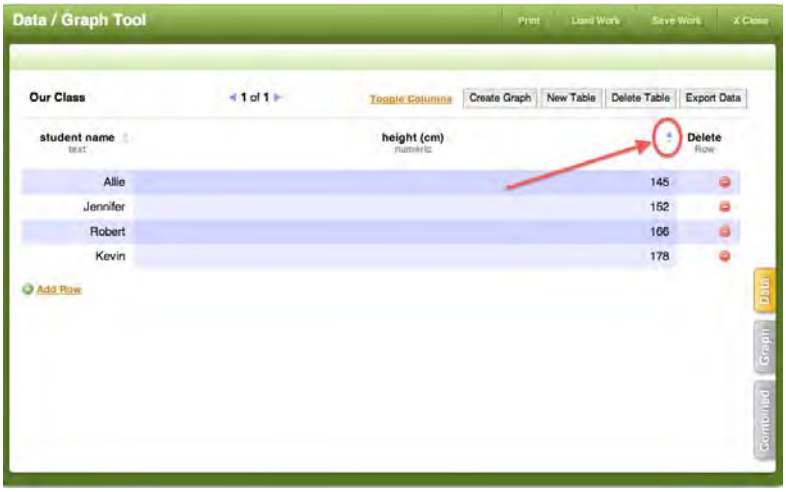
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

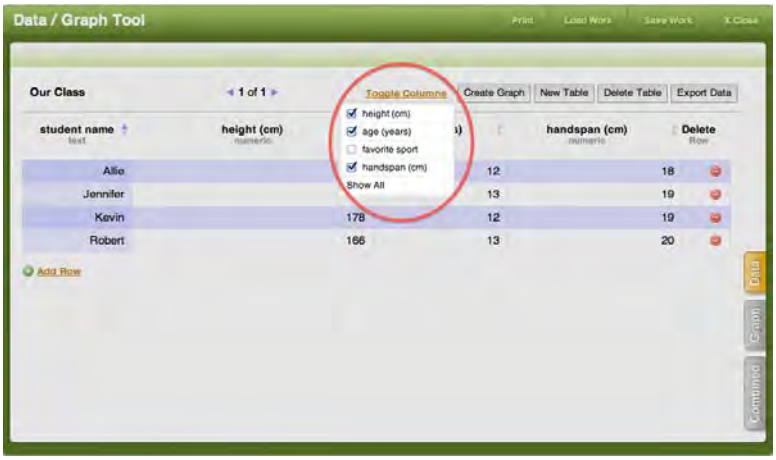


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

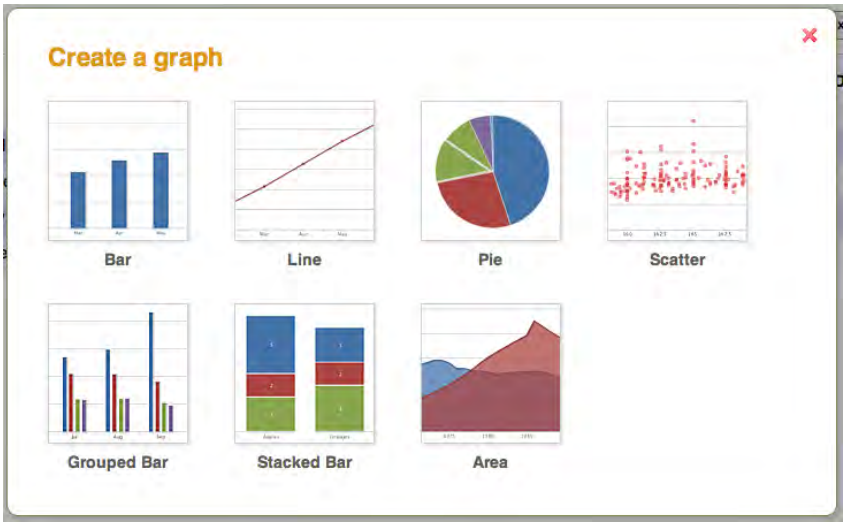
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

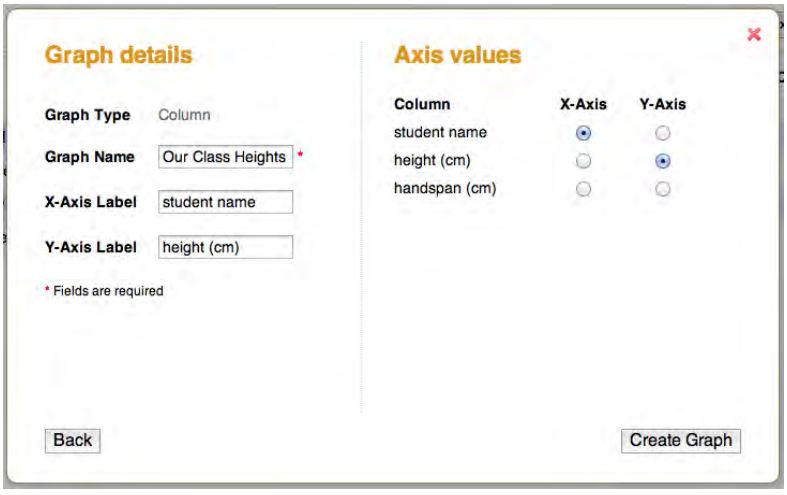
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

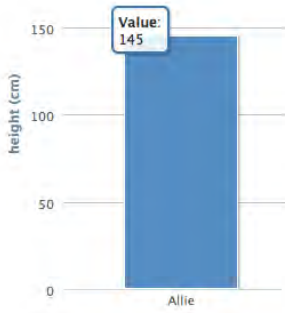


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

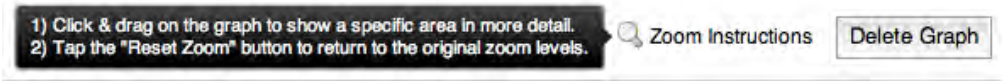
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Gravity Flow

Timing: one 90-minute class session

Objective(s):
Students will examine how sediment size affects a gravity flow.

Safety Precautions:
Students should not eat or drink anything in the science lab. Students should clean up spills immediately, and nobody should walk through a spill until it has been cleaned up.

Materials:
Per group:

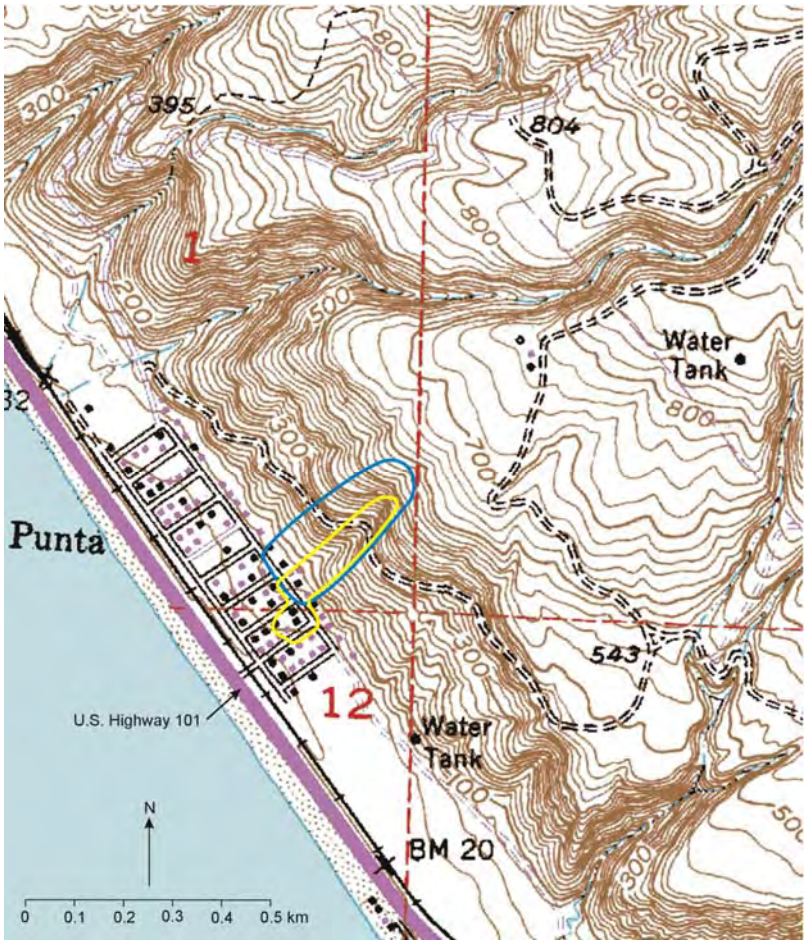
- Plastic tray or wooden board (about 1' × 1')
- Protractor
- 10 cups coarse sand
- 10 cups silt
- 10 cups clay
- ¼-cup dry measure
- ½-cup dry measure
- 1-cup dry measure
- Liquid measure (with tick marks identifying quarter-, third-, half-, and full cups)
- 1 gallon of water
- 4–6 mixing bowls
- Spoon
- Paper towels or rags
- Bucket or large pan

Teacher Preparation:
Prepare a copy of the Student Investigation Sheet for each student.

The bucket or pan should be wider than the board to ensure that the mixtures land completely in the bucket after they slide off the board. Regardless, have rags or paper towels available so that students can clean up spills and splatters immediately.

You may wish to preface this lab by discussing with students regions that have experienced destructive gravity flows throughout their history, such as La Conchita, a town in California. You can learn more about the history of gravity flows in La Conchita by reading a report prepared for the United States Geological Survey (USGS) by geologist Randall W. Jibson; the report may be downloaded here: http://pubs.usgs.gov/of/2005/1067/

This report includes a topographical map of the La Conchita region:



Students can review this map and infer why La Conchita is particularly vulnerable to gravity flows. *(The map shows that La Conchita is located on a narrow strip of land at the foot of a bluff that descends steeply from a height of approximately 180 m to sea level. According to the USGS report, the rocks that make up this bluff are "very weakly cemented.")*

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Before completing this lab, students should know the different ways that sediment is transported through erosion, and they should be familiar with the hazards associated with gravity flows. Students will work in groups of 3 or 4 to simulate mudslides consisting of three different sediment types: clay/silt, sand, and gravel. Groups will mix different ratios of sediment with different amounts of water, recording these data in tables (a sample table is provided below). Groups will then use a board or plastic tray to determine the angle at which the material becomes unstable.

Distribute the materials to students, pointing out the three different sediment types, each consisting of different grain sizes. Explain to groups that they are going to mix the different sediments to determine which ratios of grain sizes are most likely to produce a gravity flow. Each group should begin by hypothesizing an answer to the following guiding question:

1. How does sediment size affect a gravity flow?
2. How does water content affect a gravity flow?
3. How does angle of repose affect a gravity flow?

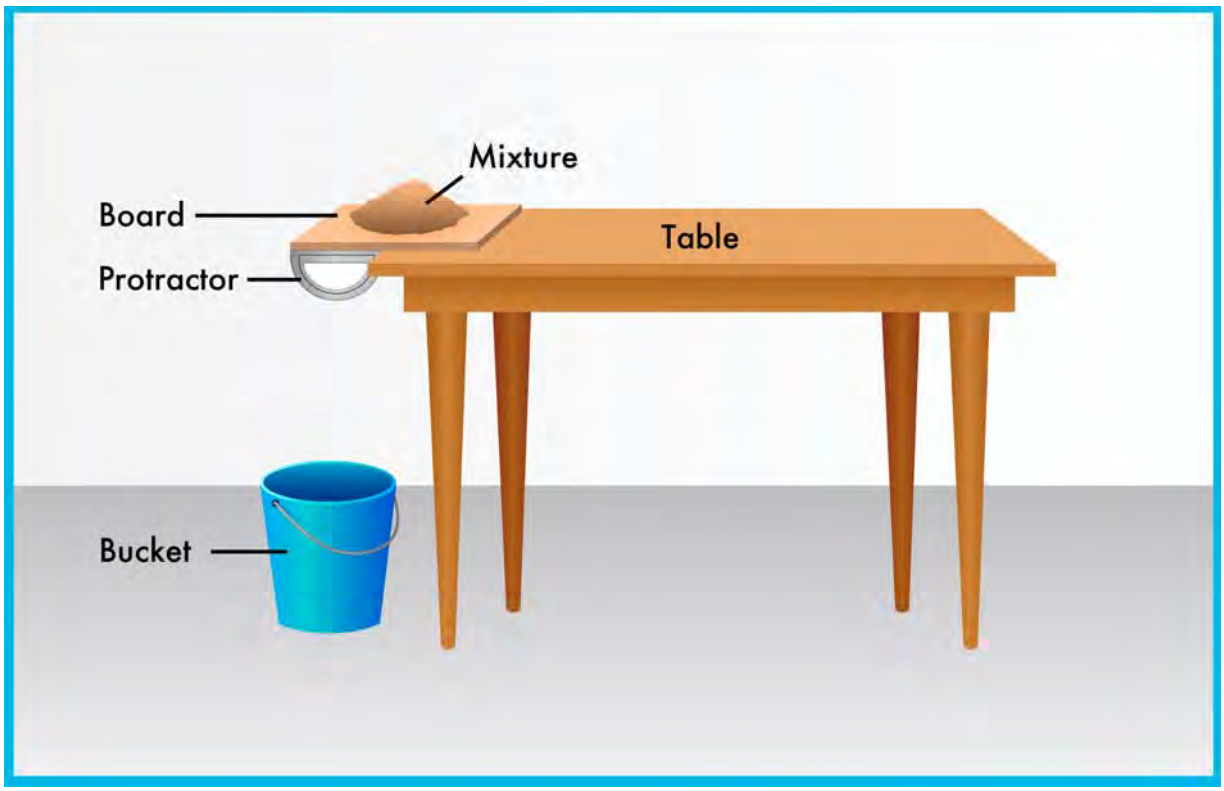
If necessary, explain to students that angle of repose refers to the steepest angle, relative to the horizontal, that a material can maintain before sliding. This angle can vary between 0° and 90°. (That is, if a material has an angle of repose of 45°, it can rest without sliding on an incline with a slope of 45°; if the slope increases above 45°, the material will begin to slide down the incline.)

Explain that for Directed Inquiry, groups should explore a variety of combinations of sediment sizes and quantities, as well as water contents to obtain data that will help them hypothesize which mixture of sediment and water is most likely to produce a gravity flow; they will then test their hypotheses in Guided Inquiry. Explain that groups should not aim to make a soupy mixture that runs the instant they incline their boards; rather, groups should aim to make a solid mixture that breaks cohesion and begins to flow only gradually. The students should keep each mixture of sediment and water in a separate bowl.

To create and test their mixtures, groups should follow this procedure:

1. Begin by placing two sediment samples of different grain size in a mixing bowl (e.g., 1 cup of sand and ½ cup of clay). Record these amounts in your data table.
2. Add a specific amount of water (e.g., ½ cup) to the mixing bowl. Record this amount in your data table.
3. Stir the mixture of sediments and water with the spoon. If the mixture is too soupy, add more sediment of a specific grain size to the bowl, recording the amount in the data table. If the mixture does not hold together, add more water to the bowl, recording the amount in the data table.

4. Place the board on a table or another flat surface off the ground, and scoop the mixture on top of the board. Move the board to the edge of the table and place the bucket on the floor beneath the board, to catch the mixture as it falls to the ground. One group member should hold the board halfway over the table's edge so that its slope remains flat. Another group member should hold the protractor flush against the side of the table, with the curved side facing the ground, as shown in the following diagram:



5. The group member holding the board should gradually increase the slope of its incline, about 5° at a time, until the mixture begins to slide off the board; the group member holding the protractor should use the protractor to check the board's incline. Another group member should record in the table the angle at which the mixture begins to lose its stability and slide off the board.
6. When the mixture has slid off the board into the bucket, the group should scoop the mixture back into its original mixing bowl; the group should also wipe down the board so it is clear for the next test.
7. The group should then create a new mixture in a new mixing bowl using a different ratio of sediments and water, determine the angle of repose of the new mixture, and record the data in its table. The group should repeat this process for about 6 different mixtures. Encourage students to explore a wide variety of mixtures; the data they collect will help them to hypothesize, in Guided Inquiry, which mixture is most likely to produce a gravity flow.

8. When groups finish, they should dispose of their sediments, in accordance with the

school's policy, and clean out all their mixing bowls to reuse for Guided Inquiry.

Here is a sample data table for Directed Inquiry:

	Sand amount (cups)	Silt amount (cups)	Clay amount (cups)	Water amount (cups)	Describe the look and feel of the mixture.	Angle of repose
Trial 1						
Trial 2						
Trial 3						
Trial 4						
Trial 5						
Trial 6						

Guided Inquiry

Based on the data they obtained in Directed Inquiry, each group should hypothesize an answer to the following guiding question:

- Which combination of sediments will be most likely to produce a gravity flow (as measured by the smallest angle of repose)?

Students should consider the following sediment combinations:

- Mostly sand with small amounts of silt or clay
- Mostly silt with small amounts of sand or clay
- Mostly clay with small amounts of sand or silt
- Equal amounts of silt and clay with little to no sand
- Equal amounts of sand and clay with little to no silt
- Equal amounts of sand and silt with little to no clay
- Equal amounts of sand, silt, and clay.

Emphasize that groups should keep the amount of water in each mixture constant; to do this, they should begin by pouring water in their mixing bowls and then add a little bit of sediment at a time, stirring in between additions, until the mixture holds together without being too soupy.

Groups can develop their own plans for testing their hypotheses and recording and analyzing their data, based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry:

- What is the independent variable in your test? *(mixture of sediments)*
- What is the dependent variable in your test? *(angle of repose)*
- In addition to water content, what variables should you keep constant? *(height of board above ground; increments of incline slope (i.e., 5° at a time); time between each adjustment of incline slope)*
- Why is accuracy of the data you recorded important? *(If data is not recorded with accuracy, conclusions cannot me made regarding the reliability of the measurements that were taken.)*

Give groups time to run their tests and analyze their data. Then discuss each group's results as a class. Ask students whether they think they have run enough tests on enough combinations of sediments to determine which combination of silt, sand, and clay is most likely to produce a gravity flow. Then ask them to consider the limitations on the precision of the data they collected, such as cost of materials and time, and how that may have affected repeat measurements. Students may want to refine their procedure or design accordingly.

Analysis and Conclusions

1. How does grain size affect a gravity flow?
   A mixture with a higher concentration of coarse grains (sand-sized) will lose cohesion more easily than a mixture with finer grains (clay-sized). Finer grains tend to be "sticky" and maintain cohesion.

2. How could a rainstorm make a stable mixture unstable, resulting in a gravity flow?
   Water content increases the mixture's ability to flow. A mixture of sediment that is stable under normal conditions could become unstable during a heavy rainstorm.

3. How does angle of incline affect gravity flow?
   Sediment becomes unstable when placed on an angle. As the angle increases, the sediments are affected more strongly by gravity and become more likely to flow.

4. How do geologic engineers use this knowledge when building houses, roads, and other structures?
   Geologic engineers must examine the mixture of sediment in an area before construction can begin. They also examine the natural slope of the surrounding countryside. To avoid gravity flows that can endanger human lives and destroy private and public buildings, roads, and other structures, engineers often grade the landscape to achieve the most stable angle of inclination possible.

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
  - Design and conduct investigations using:
    - Multiple trials - repeated tests with the same variables to check for variability of results
  - Make or use models that:
    - Allow the testing of a hypothesis with results that can be extrapolated to the real thing
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Describing it so that it can be easily repeated by a fellow scientist
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Volume
  - Choose appropriate tools to conduct an investigation:
    - Other laboratory equipment
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
  - Use the appropriate format to record data:
    - Table
    - Writing (journal, worksheet, electronic text
- Interpret Data
  - Identify and interpret patterns using:
    - Analysis of data collected during an investigation
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Comparing results to hypothesis
    - Answering the testable question
    - Extrapolating results beyond the investigation
    - Formulating scientific explanations/arguments
- Communication in Science
  - Report results using:
    - Written report
    - Table/graph showing data
- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating an investigative design
    - Evaluating a conclusion
- Scientific Investigation
  - Scientific Investigation:

        - Science investigation begins with a testable question.
        - New observations should be made when there is disagreement among initial observations.
        - When a scientific investigation is repeated, a similar result is expected.
        - Hypotheses are valuable, even if they turn out not to be true, because they lead to further investigation.
        - Scientific investigation leads to more questions.
        - Different explanations can be given for the same evidence, and it is not always possible to tell which one is correct without further inquiry.
        - Scientific investigations lead to the development of scientific explanations.
- Scientific Endeavor
    - Characteristics of Science:
        - Science is based on factual knowledge.
        - Scientists are curious about wanting to know how things work.
        - One way to make sense of something is to think of how it relates to something more familiar.
        - Scientific claims can be substantiated using data and observation.
- Engineering and Technology
    - Uses of Technology:
        - Constraints, such as gravity or materials characteristics, must be taken into account as a new design is developed.
        - Even a good design may fail even though steps are taken ahead of time to reduce the likelihood of failure.
    - Societal Issues:
        - Scientific discoveries have benefitted people in many ways.

Exploration Teacher Guide: Mechanical and Chemical Weathering

Overview

The breaking down and alteration of pre-existing rocks on or near Earth's surface is called weathering. In this Exploration, students investigate the types of weathering and identify the associated agent.

Student Learning Objectives

- Examine different types of chemical weathering in different rock types and landforms.
- Examine different types of mechanical weathering in different rock types and landforms.
- Identify the agents associated with different types of weathering.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students select a landform using the radio button options in the *Select Landform* section and then select a weathering using the radio button options in the *Select Weathering Type* section. Based on the selection made in the *Select Weathering* section, the third section will change to either *Select Chemical Weathering* or *Select Mechanical Weathering*. The options in the *Select Chemical Weathering* and *Select Mechanical Weathering* sections change depending on the landform selected. After making selections in all three sections, students use the *Start* button to view an animation of the selected weathering on the selected landform. After viewing the animation, students use the *Proceed* button to identify the agent associated with the selected weathering.

Students may use the *Reset* button at any time in the Exploration to undo what they have done and select another combination of landform and weathering.

In the *Tracker* tab, students track the types of weathering that they have examined. They can also track the agents that they have identified correctly and examine the effects of weathering using the *Before* and *After* images.

Answers to Questions in the Student Worksheet

1. What is weathering?

   Answer: Weathering is the breaking down and alteration of pre-existing rocks and minerals on or near Earth's surface. Weathering can either change the physical properties only or both physical properties and chemical composition of the parent rock or mineral.

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2. Compare and contrast mechanical and chemical weathering.

   Answer: The physical breakdown of pre-existing rocks is called mechanical weathering. Fragments produced as a result of mechanical weathering have the same characteristics as the parent rock. This is because the chemical composition is not altered by mechanical weathering. The breaking down and alteration of pre-existing rocks with both physical and chemical changes is called chemical weathering. Rock and mineral fragments produced as a result of chemical weathering differ significantly from the parent rock because their chemical composition has changed.

3. Describe the role of living things in weathering of rocks.

   Answer: Organic life causes mechanical weathering of rocks. The roots of plants growing in the cracks of rocks exert outward pressure which causes weathering. Burrowing animals also cause weathering of rocks by opening passages for water and air to infiltrate. Living things also cause chemical weathering. Some organisms secrete acids that break down rocks and minerals. Rainwater becomes acidic as it falls through the air and reacts with carbon dioxide that is released by living things. Organisms can also cause oxidation.

4. Classify the following types of weathering as either mechanical or chemical weathering. Justify each classification.

   a. Oxidation

   b. Exfoliation

   c. Hydrolysis

   d. Frost weathering

   Answer:

   a. Oxidation: Chemical weathering. Oxidation is considered chemical weathering because it involves the reaction of minerals with oxygen. The reaction produces new chemical compounds and new minerals and rocks.

   b. Exfoliation: Mechanical weathering. Exfoliation is considered mechanical weathering because it involves only a physical breakdown of the rock. The rocks break as pressure is released. Chemical changes are not necessarily involved in exfoliation.

   c. Hydrolysis: Chemical weathering. Hydrolysis is considered to be chemical weathering because it involves chemical changes. Compounds in the rocks and minerals react with water to form new compounds.

   d. Frost Weathering: Mechanical Weathering. Frost weathering is considered to be mechanical weathering because it involves the physical break down of rocks as a result of water freezing and expanding in cracks.

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5. Identify the agents associated with the following types of weathering.

    a. Unloading

    b. Dissolution

    c. Frost Action

    d. Carbonation

Answer:

a. Unloading: Pressure

b. Dissolution: Water

c. Frost Action: Ice, pressure

d. Carbonation: Carbon dioxide

6. Change in temperature causes weathering. Justify this statement.

Answer: Weathering due to a change in temperature is common in arid environments. Expansion and contraction of rocks due to changes in temperature causes weathering to occur by creating cracks which allow water and air to infiltrate. Changes in temperature are also responsible for frost weathering. Water in cracks freezes and exerts pressure on the rocks.

7. Describe the process of exfoliation.

Answer: Exfoliation is a type of mechanical weathering that is caused by sudden or gradual unloading of overburden rocks. It causes the outer layers of the exposed rock to expand more than the rocks below. Top layers of the rock then fall off, or exfoliate.

8. Explain how limestone weathers as a result of carbonation.

Answer: Water absorbs carbon dioxide from the atmosphere to form carbonic acid.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

This carbonic acid present in percolating water then reacts with calcite in the limestone and dissolves it.

$$CaCO_3 + H_2CO_3 \rightarrow Ca^{+2} + 2HCO_3^{-1}$$

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9. Use a chemical reaction to explain the formation of kaolin from orthoclase.

   Answer: Orthoclase (a feldspar mineral) in acidic water hydrolyses to form kaolin (a clay mineral).

$$2KAlSi_3O_8 + 3H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 4SiO_2 + 2K(OH)$$

10. Write a chemical reaction to describe the formation of hematite from pyrite. What type of reaction is this?

    Answer: Pyrite undergoes oxidation to form hematite.

$$4FeS_2 + 15O_2 + 8H_2O \rightarrow 2Fe_2O_3 + 8H_2SO_4$$

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The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students select a landform using the radio button options in the *Select Landform* section and then select a weathering using the radio button options in the *Select Weathering Type* section. Based on the selection made in the *Select Weathering* section, the third section will change to either *Select Chemical Weathering* or *Select Mechanical Weathering*. The options in the *Select Chemical Weathering* and *Select Mechanical Weathering* sections change depending on the landform selected. After making selections in all three sections, students use the *Start* button to view an animation of the selected weathering on the selected landform. After viewing the animation, students use the *Proceed* button to identify the agent associated with the selected weathering.

Students may use the *Reset* button at any time in the Exploration to undo what they have done and select another combination of landform and weathering.

In the *Tracker* tab, students track the types of weathering that they have examined. They can also track the agents that they have identified correctly and examine the effects of weathering using the *Before* and *After* images.

Answers to Questions in the Student Worksheet

1. What is weathering?

   Answer: Weathering is the breaking down and alteration of pre-existing rocks and minerals on or near Earth's surface. Weathering can either change the physical properties only or both physical properties and chemical composition of the parent rock or mineral.

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2. Compare and contrast mechanical and chemical weathering.

   Answer: The physical breakdown of pre-existing rocks is called mechanical weathering. Fragments produced as a result of mechanical weathering have the same characteristics as the parent rock. This is because the chemical composition is not altered by mechanical weathering. The breaking down and alteration of pre-existing rocks with both physical and chemical changes is called chemical weathering. Rock and mineral fragments produced as a result of chemical weathering differ significantly from the parent rock because their chemical composition has changed.

3. Describe the role of living things in weathering of rocks.

   Answer: Organic life causes mechanical weathering of rocks. The roots of plants growing in the cracks of rocks exert outward pressure which causes weathering. Burrowing animals also cause weathering of rocks by opening passages for water and air to infiltrate. Living things also cause chemical weathering. Some organisms secrete acids that break down rocks and minerals. Rainwater becomes acidic as it falls through the air and reacts with carbon dioxide that is released by living things. Organisms can also cause oxidation.

4. Classify the following types of weathering as either mechanical or chemical weathering. Justify each classification.

   a. Oxidation

   b. Exfoliation

   c. Hydrolysis

   d. Frost weathering

   Answer:

   a. Oxidation: Chemical weathering. Oxidation is considered chemical weathering because it involves the reaction of minerals with oxygen. The reaction produces new chemical compounds and new minerals and rocks.

   b. Exfoliation: Mechanical weathering. Exfoliation is considered mechanical weathering because it involves only a physical breakdown of the rock. The rocks break as pressure is released. Chemical changes are not necessarily involved in exfoliation.

   c. Hydrolysis: Chemical weathering. Hydrolysis is considered to be chemical weathering because it involves chemical changes. Compounds in the rocks and minerals react with water to form new compounds.

   d. Frost Weathering: Mechanical Weathering. Frost weathering is considered to be mechanical weathering because it involves the physical break down of rocks as a result of water freezing and expanding in cracks.

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5. Identify the agents associated with the following types of weathering.

    a. Unloading

    b. Dissolution

    c. Frost Action

    d. Carbonation

Answer:

a. Unloading: Pressure

b. Dissolution: Water

c. Frost Action: Ice, pressure

d. Carbonation: Carbon dioxide

6. Change in temperature causes weathering. Justify this statement.

Answer: Weathering due to a change in temperature is common in arid environments. Expansion and contraction of rocks due to changes in temperature causes weathering to occur by creating cracks which allow water and air to infiltrate. Changes in temperature are also responsible for frost weathering. Water in cracks freezes and exerts pressure on the rocks.

7. Describe the process of exfoliation.

Answer: Exfoliation is a type of mechanical weathering that is caused by sudden or gradual unloading of overburden rocks. It causes the outer layers of the exposed rock to expand more than the rocks below. Top layers of the rock then fall off, or exfoliate.

8. Explain how limestone weathers as a result of carbonation.

Answer: Water absorbs carbon dioxide from the atmosphere to form carbonic acid.

$$CO_2 + H_2O \rightarrow H_2CO_3$$

This carbonic acid present in percolating water then reacts with calcite in the limestone and dissolves it.

$$CaCO_3 + H_2CO_3 \rightarrow Ca^{+2} + 2HCO_3^{-1}$$

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9. Use a chemical reaction to explain the formation of kaolin from orthoclase.

   Answer: Orthoclase (a feldspar mineral) in acidic water hydrolyses to form kaolin (a clay mineral).

$$2KAlSi_3O_8 + 3H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 4SiO_2 + 2K(OH)$$

10. Write a chemical reaction to describe the formation of hematite from pyrite. What type of reaction is this?

    Answer: Pyrite undergoes oxidation to form hematite.

$$4FeS_2 + 15O_2 + 8H_2O \rightarrow 2Fe_2O_3 + 8H_2SO_4$$

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Exploration Teacher Guide: Mechanical and Chemical Weathering

Overview

The breaking down and alteration of pre-existing rocks on or near Earth's surface is called weathering. In this Exploration, students investigate the types of weathering and identify the associated agent.

Student Learning Objectives

- Examine different types of chemical weathering in different rock types and landforms.
- Examine different types of mechanical weathering in different rock types and landforms.
- Identify the agents associated with different types of weathering.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students select a landform using the radio button options in the *Select Landform* section and then select a weathering using the radio button options in the *Select Weathering Type* section. Based on the selection made in the *Select Weathering* section, the third section will change to either *Select Chemical Weathering* or *Select Mechanical Weathering*. The options in the *Select Chemical Weathering* and *Select Mechanical Weathering* sections change depending on the landform selected. After making selections in all three sections, students use the *Start* button to view an animation of the selected weathering on the selected landform. After viewing the animation, students use the *Proceed* button to identify the agent associated with the selected weathering.

Students may use the *Reset* button at any time in the Exploration to undo what they have done and select another combination of landform and weathering.

In the *Tracker* tab, students track the types of weathering that they have examined. They can also track the agents that they have identified correctly and examine the effects of weathering using the *Before* and *After* images.

Answers to Questions in the Student Worksheet

1. What is weathering?

   Answer: Weathering is the breaking down and alteration of pre-existing rocks and minerals on or near Earth's surface. Weathering can either change the physical properties only or both physical properties and chemical composition of the parent rock or mineral.

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   Answer: The physical breakdown of pre-existing rocks is called mechanical weathering. Fragments produced as a result of mechanical weathering have the same characteristics as the parent rock. This is because the chemical composition is not altered by mechanical weathering. The breaking down and alteration of pre-existing rocks with both physical and chemical changes is called chemical weathering. Rock and mineral fragments produced as a result of chemical weathering differ significantly from the parent rock because their chemical composition has changed.

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   Answer: Organic life causes mechanical weathering of rocks. The roots of plants growing in the cracks of rocks exert outward pressure which causes weathering. Burrowing animals also cause weathering of rocks by opening passages for water and air to infiltrate. Living things also cause chemical weathering. Some organisms secrete acids that break down rocks and minerals. Rainwater becomes acidic as it falls through the air and reacts with carbon dioxide that is released by living things. Organisms can also cause oxidation.

4. Classify the following types of weathering as either mechanical or chemical weathering. Justify each classification.

   a. Oxidation

   b. Exfoliation

   c. Hydrolysis

   d. Frost weathering

   Answer:

   a. Oxidation: Chemical weathering. Oxidation is considered chemical weathering because it involves the reaction of minerals with oxygen. The reaction produces new chemical compounds and new minerals and rocks.

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   c. Hydrolysis: Chemical weathering. Hydrolysis is considered to be chemical weathering because it involves chemical changes. Compounds in the rocks and minerals react with water to form new compounds.

   d. Frost Weathering: Mechanical Weathering. Frost weathering is considered to be mechanical weathering because it involves the physical break down of rocks as a result of water freezing and expanding in cracks.

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5. Identify the agents associated with the following types of weathering.

    a. Unloading

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    c. Frost Action

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Answer:

a. Unloading: Pressure

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c. Frost Action: Ice, pressure

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Answer: Weathering due to a change in temperature is common in arid environments. Expansion and contraction of rocks due to changes in temperature causes weathering to occur by creating cracks which allow water and air to infiltrate. Changes in temperature are also responsible for frost weathering. Water in cracks freezes and exerts pressure on the rocks.

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    Answer: Pyrite undergoes oxidation to form hematite.

$$4FeS_2 + 15O_2 + 8H_2O \rightarrow 2Fe_2O_3 + 8H_2SO_4$$

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Hands-On Activity

Observe Erosion and Deposition

Objective:
Students will observe erosion and deposition around their school.

Estimated time to complete: 50 minutes

Safety Precautions:
Set clear boundaries for outdoor activities so that students know exactly where they can and cannot go. Make students aware of any safety hazards in the area, such as vehicle traffic or poison oak.

Materials:
For each student:

- Clipboard
- Drawing paper
- Hand lens

For each small group:

- Digital camera (if available)

Procedure:
Prior to teaching this activity, plan a route for the class to walk. Search for a location or walking path that will provide access to a variety of examples of erosion and deposition. Where applicable, look for evidence of the following:

- Soil that is open to blowing wind
- Loose sediments on a hillside
- Recently deforested or cleared land
- Streams (particularly with bends where the current slows and sediments are deposited)
- Valleys or depressions where sediments may gather

On the day of the activity, explain to the class that you will be taking a walk to look for examples of erosion and deposition. Describe the walking route and alert students to any safety hazards. Instruct students to stick together as a class, even if they are working in small groups to make observations.

On the walk, give students a chance to notice examples of erosion and deposition. If necessary, point out a feature and ask guiding questions, such as:

- *What do you notice about this feature?*
- *How do you think it has changed over time?*
- *Can you find any evidence of sediments that have been transported from another location?*

- *How do you think these sediments were transported here? By wind? Water? Gravity? How can you tell?*

Encourage students to use evidence to support their explanations. As students observe examples of erosion or deposition, they should sketch their observations. Remind students to record the locations of their observations and to label the parts of their drawings and the evidence of each agent of erosion or deposition. (You may need to pre-teach the term *agent*, which refers to the natural force or event that caused the erosion or deposition, such as blowing wind, flowing water, or glacial movement.) If cameras are available, groups may also photograph each example of erosion or deposition. If necessary, have groups share cameras; keep tabs on camera use to ensure that cameras are being used appropriately and that each student has an opportunity to take photographs. If you do not have enough cameras, you may wish to allow students who have cell phone cameras to use them to take photographs.

The walk should take about half the session. For the remainder of the session, students can use their notes and photographs to create posters or—depending on their skills and the availability of Web 2.0 tools—Web pages detailing erosion and deposition around your school to link to the class Web site or blog. If necessary, instruct students to complete their presentations for homework.

Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Design and conduct field studies using:
    - Survey - collects multiple data points at one point in time
  - Practice lab safety by:
    - Following lab safety procedures
- Gather Data
  - Use senses to observe:
    - Seeing (color, shape, size, texture)
  - Use the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
    - Sketch
    - Diagram
    - Photograph/image
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Formulating scientific explanations/arguments
    - Showing the application of the scientific concept or process being investigated
- Communication in Science
  - Report results using:
    - Scientific illustration with proper labeling
    - Images or video
- Patterns and Systems
  - Patterns and Change:
    - Some changes are very slow and some are very fast and that some of these changes may be hard to see and/or record.
    - Things that change may do so in steady, repetitive or irregular ways.
- Scientific Investigation
  - Scientific Investigation:
    - Different explanations can be given for the same evidence, and it is not always possible to tell which one is correct without further inquiry.
  - Scientific Data and Outcomes:
    - People are more likely to believe ideas if good reasons are given for them.

Hands-On Lab

Can you Save Sandy Village from Erosion?

Timing: One 90-minute class session

Objective(s):
Students will design a solution to a complex erosion problem affecting a small village. Groups will then compare, analyze, and evaluate their different designs, considering costs, safety, and aesthetics, as well as environmental and social impacts.

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should be warned against keeping the sand in their box. If sand spills on the floor, it should be cleaned up immediately to prevent someone from slipping. After students clean up the materials from their lab, they should wash their hands.

Materials:
Per group:

- print-out of the problem
- shoe box, 1
- plastic shopping bag, 1
- sand, 1 L
- tap water to moisten sand, 250 mL
- index cards, 3
- scissors
- plastic wrap
- stones, 40–50 walnut-sized
- wooden skewers
- cardboard
- craft sticks
- modeling clay, fist-sized
- green paper to represent vegetation, 20x20 cm squares
- tap water in a small graduated cylinder
- chart containing the price list and durability of materials

Teacher Preparation:

- Gather materials in advance of students performing the lab.
- Print out the cost chart and the problem sheet for each group.
- If possible, have stones that are of similar size, about the size of a walnut.
- If possible, mix the sand and water before the lab to ensure each group has the same soil conditions during the lab.

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Procedure

1. As a group, gather the necessary materials.
2. Lay out the plastic bag on the table to protect the surface from moisture, and place the shoe box on top of the bag.
3. If the sand is dry, mix tap water with the sand until it is moist enough to hold a shape, like a sandcastle.
4. Fill half of the shoe box with the wet sand. Push the sand up against the side of the box until the sand is level with the top. Pack the sand into a wall-shape.
5. Cut the index cards in half. Fold each piece in half to form a tent-shaped form. Put the resulting 6 tents into the box at the base of the sand wall you have created. These will represent the village homes.
6. Read the problem together as a group.
7. Using the different materials and the costs chart, work together to design a way to prevent the sand from sliding down onto the houses below.
8. Once you have decided on a design and have carried it out in the shoe box, add up the costs of the materials you used.
9. Write a proposal to the villagers that includes reasons why you chose the materials. Remember to consider costs, durability, aesthetics, and environmental impact.
10. Present the proposal and design to the class.
11. Evaluate each different design and proposal based on the same criteria. Record your thoughts in your science journal as each group presents.
12. As a class, discuss the advantages and disadvantages of each design.
13. Clean up carefully by keeping the plastic bag under the shoe box while you dispose of the sand in case moisture has leaked through the box.

Problem

Can you save Sandy Village from destruction? Sandy Village sits at a base of a cliff. During the past 3 years, the area has experienced higher levels of rainfall, and the soil in the cliff has become saturated. Your group must design a way to prevent erosion and to keep the soil from burying the village. You may use any of the materials listed, but each item has a monetary value and a length of time that it will last. Your group will submit a proposal to the villagers that considers costs, the durability of the fix, aesthetics, and the impact on the environment.

Material	Cost	Durability
1 stone	$ 100.00	30 years
1 lump of clay	$ 100.00	30 years
1 wooden skewer	$ 50.00	15 years
plastic sheet, 8 ½ x 11	$ 1000.00	5 years
1 wooden craft stick	$ 50.00	15 years
cardboard sheet, 8 ½ x 11	$ 500.00	2 years
vegetation square 20x20 cm	$ 2000.00	adds 10 years to the materials

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Analysis and Conclusions

1. Which design in the class was most cost effective? Was it the one that would last the longest? Explain.
   The cheapest fix would have used materials that did not last as long. Those materials would need to be replaced more frequently to maintain their strength. However, the designers may have felt there were necessary trade-offs depending on their priorities.

2. What was more important to your group, cost or durability? Why?
   Groups may have decided using future money for upkeep was more of a priority than an expensive long-term solution. They may have gambled on future rain levels being less and on the possibility of inventions of new technologies. Or they may have decided that their technological solution was more effective at preventing the erosion than more expensive ones.

3. Which was a higher priority for your design, the villagers' safety or the impact on the environment? Why?
   Students will have different answers that reflect how important they decided aesthetics or the environment was over cost. They may believe that human lives hold a priority over the environment.

4. What problems did your group have designing the fix for the wall of eroding sand?
   There may not have been enough stones or craft sticks. Students may have thought of different materials they would have liked to use and found it frustrating to use only the available materials. Groups may have had difficulty agreeing on what criteria were the priority.

5. What improvements could you make to your design after seeing the other solutions?
   Different solutions may have inspired students to use materials in a different way, think about combining technologies, or recognize that different criteria should have more of a place in their design.

6. Based on what you observed during this lab, what recommendations would you make to actual municipalities in Florida that are struggling with beach erosion? If you had to recommend one solution, what would you recommend and why? *Answers will vary. Students may recommend spending more money for a better long-term fix, or they may say that it depends on available funding and community goals.*

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that
    - simulate the real thing that cannot easily be studied or manipulated
    - have as many details as possible replicated from the real thing
    - function exactly like or similarly to the real thing
  - Practice lab safety by
    - following lab safety procedures
- Gather Data
  - Use senses to observe
    - seeing (color, shape, size, texture, motion)
  - Uses the appropriate format to record data
    - writing (journal, worksheet, electronic text)
- Evaluate Evidence
  - Assessing the conclusion by
    - identifying alternative explanations
  - Communication in Science
    - peer presentation
- Analyze Scientific Results
  - Participate in critiquing/peer review by
    - evaluating an investigative design
    - identifying alternative explanations
- Engineering and Technology
  - Uses of Technology
    - Technology extends the ability of people to make positive and/or negative changes in the world.
  - Engineering Design
    - Constraints, such as gravity or materials characteristics, must be taken into account as a new design is developed.
    - Even a good design may fail even though steps are taken ahead of time to reduce the likelihood of failure.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

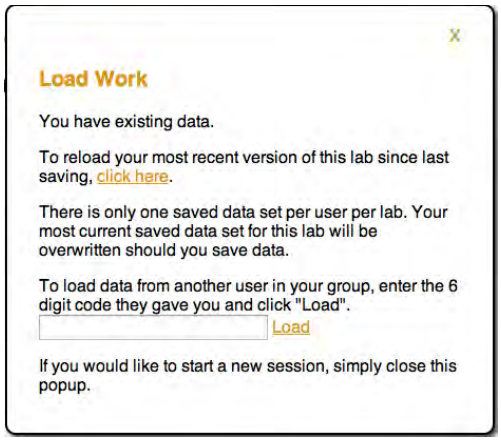
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

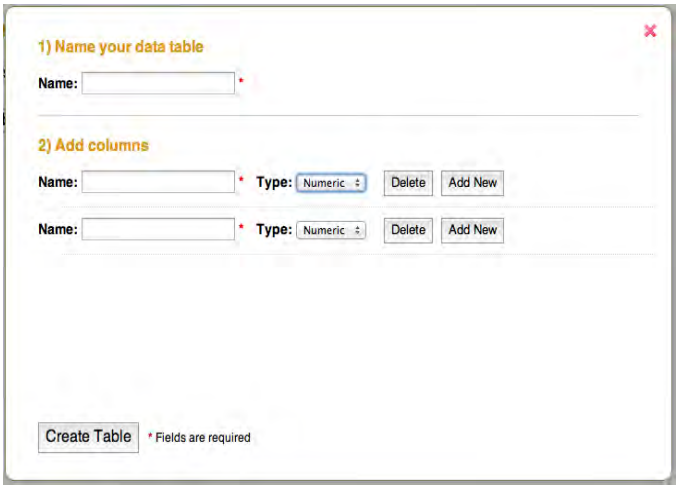
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



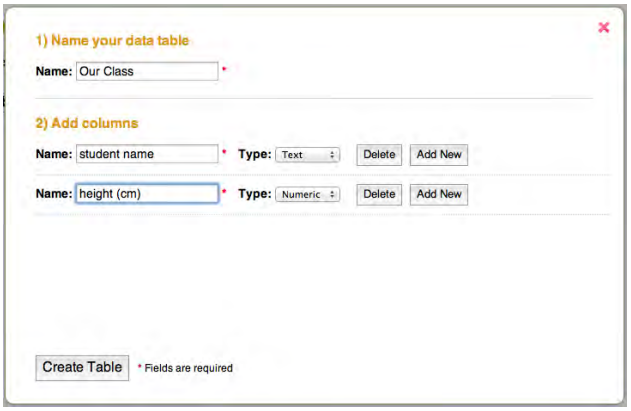
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

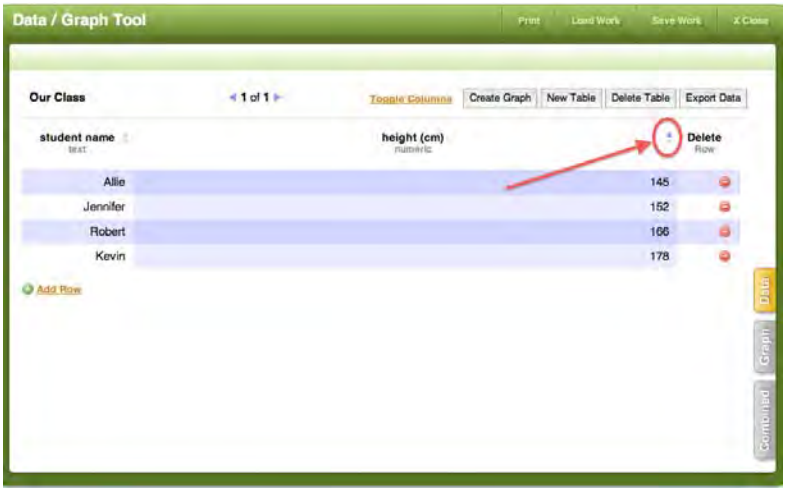
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

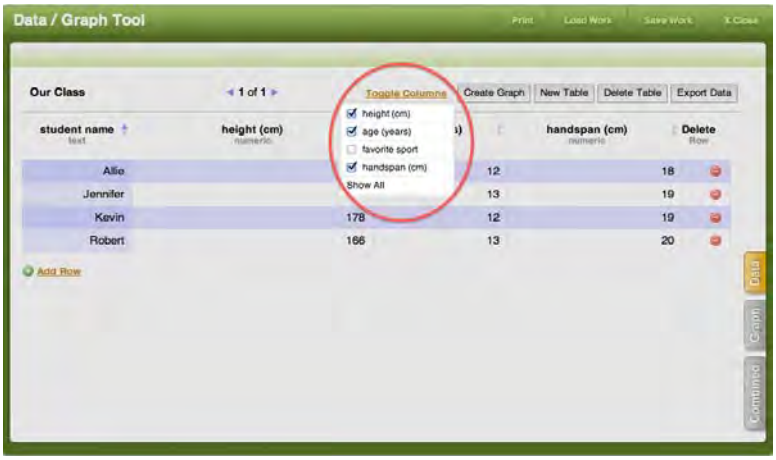


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

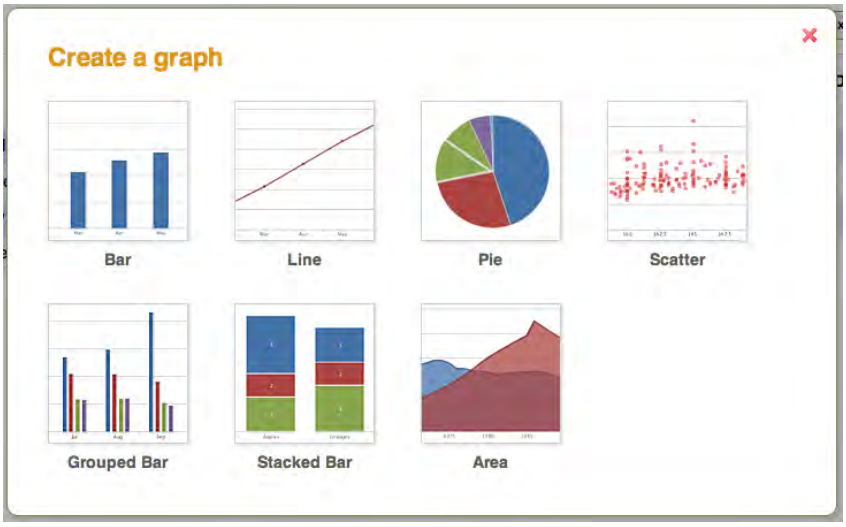
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

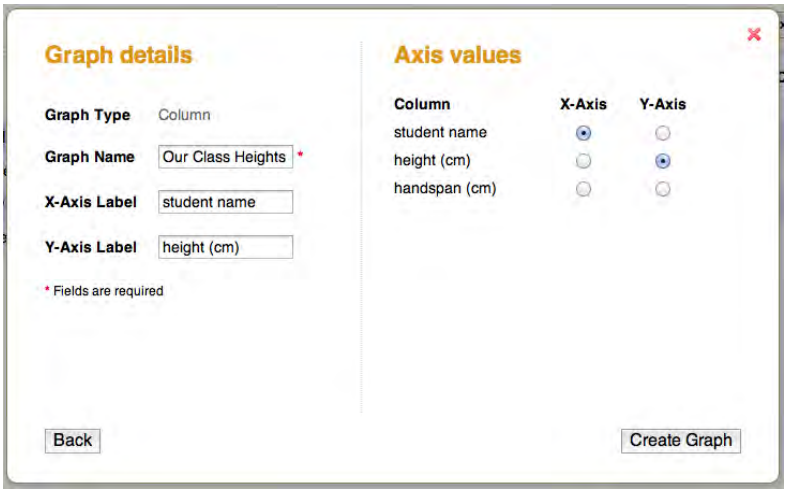
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

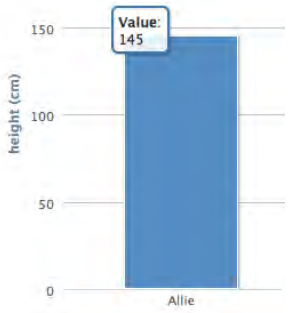


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

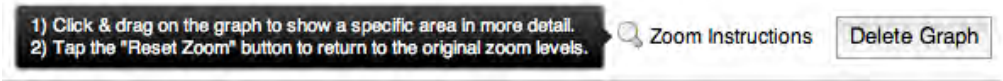
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Exploration Teacher Guide: Erosion and Deposition

Overview

The processes of erosion and deposition have been changing Earth's physical appearance since its formation. In this Exploration, students analyze core samples and landforms to study these processes in detail.

Student Learning Objectives

- Examine the apparatus used for obtaining core samples.
- Analyze core samples and identify the agent responsible for deposition.
- Identify whether a particular landform is formed by erosion or deposition.
- Investigate the role of the agent responsible for the formation of the landform.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

Using the *Apparatus* tab, students can learn about the operation of the coring device. The *Setup* option presents the context for the device's operation in the field. The *Coring Device* option provides details about the equipment's components and operation.

In the *Core* tab, students are provided with three core samples to choose from. They click on any one of the samples to continue examining it. They use the *Proceed* button to study the different layers of the selected core sample in detail. They then click on the different layers of the diagrammatic representation of the core sample to learn more about them. The *Proceed* button is active after the students analyze all the layers. On clicking the *Proceed* button, students are asked a question about the agent that led to the formation of the core. The *Glacier*, *River*, and *Wind* radio buttons are used to answer this question. The students use the *Submit* button to validate their answer. They may use the *Select Another Core Sample* button to examine another sample.

In the *Landform* tab, students identify the process and agent that led to the formation of selected landforms. They use the forward and back arrows of the *Select Landform* navigator to browse through the different landforms. They use the radio button options to identify the process and agent responsible for the formation of the selected landform. Students then use the *Submit* button to validate their answers.

They can use the *Reset* button to undo what they have done and clear the radio button selections for the existing landforms. They may use the *Start Over* button to start analyzing landforms afresh.

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The *Tracker* tab provides a review of each of the agents responsible for creating landforms. Students can review the diagrammatic representation of the core, and image of the core obtained by the coring device, and the process by which the agents created the landforms.

Answers to Questions in the Student Worksheet

1. Explain the structure and operation of a coring device.

   Answer: The coring device consists of three main parts. These include the linear actuator, the subcoring frame, and the piston. The subcoring frame is a removable box, which is designed to push polybutyrate tubes into the sediment using the linear actuator. These tubes, along with the piston, recover an undisturbed subcore of the main sample. After the surface samples are taken, the subcores are removed from the frame.

2. List three agents that cause erosion.

   Answer: Wind, rivers, and glaciers cause erosion.

3. Differentiate between erosion and deposition.

   Answer: Erosion occurs when a rock is lost from preexisting locations. Deposition occurs when sediments collect in an area.

4. Describe the process of core analysis.

   Answer: The core sample obtained using a coring device consists of layers that formed due to the action of wind, rivers, glaciers and other natural agents. Analysis of the layers of the core sample provides geologists with important clues about the how the present day landform came into being.

5. List the names of three landforms formed by deposition.

   Answer: Alluvial fans, moraines, and sand dunes are examples of landforms that are formed by deposition.

6. Explain which agent and process leads to the formation of a mushroom rock.

   Answer: Mushroom rocks are formed due to erosion by wind.

7. Which landform results from erosion by a glacier?

   Answer: Aretes results from erosion by a glacier.

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8. List any two landforms, other than those covered in the Exploration, that result from the processes of erosion or deposition. Include the agents responsible for the formation.

   Answer: A cirque is a landform that is created due to the process of erosion by a glacier. A delta is a landform that is created due to deposition by a river.

9. Explain the purpose of studying the diagrammatic representation of core samples obtained through coring.

   Answer: The diagrammatic representation of core samples obtained through coring helps identify the deposition patterns of rocks that form the layers in the core. The deposition patterns in turn help identification of the agents and processes that created a landform.

10. Identify the agent responsible for the following landforms:

    a. Yardang

    b. Kame

    Answer:

    a. Yardang – This landform is formed due to erosion by wind.

    b. Kame – This landform is formed due to deposition by glaciers.

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Hands-On Lab

Streaming Water

Timing: one 45-minute class session

Objective(s):
Students will design stream tables to model and observe erosion and deposition by water.

Safety Precautions:
Have towels on hand to mop up any spilled water on the floor. Remind students to use caution and that the floor could be slippery if wet. Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should never leave the lab area unattended. Remind students to wear safety equipment including goggles, gloves, and lab aprons. Students should place waste water in the “Waste Water” bucket provided. Wet soil should be placed in the “Soil Bucket” provided

Materials:

For the class

- 1 large bucket to labeled “Waste Water.”
- 1 large bucket or bin labeled “Wet Soil.”

Per group:

- safety goggles, one pair per student
- lab apron, one per student
- sheets of newspaper
- old towels
- stream table or large a plastic tray/box with hole at one end (see Figure 1)
- container with a small hole in it
- large bucket
- water
- blocks to elevate (tilt) the stream table or tray box
- topsoil
- Other soil samples that could include:
    - sand
    - gravel (fine and course)
    - peat
    - mulch

Teacher Preparation:

- Gather materials in advance of students' performing the lab.
- If possible, set up one completed stream table with soil arranged as a model.
- Take photographs of the model stream table in various stages to show groups having trouble visualizing the task.

Part 1: Setting up and Using the Stream Table

Procedure

Demonstrate how to set up a stream table/plastic box, including setting the elevation, arranging the soil, , pouring water using a container with a hole in it, measuring a gully and how the bucket at the bottom collects water. An example set-up is provided below (see figure 1).

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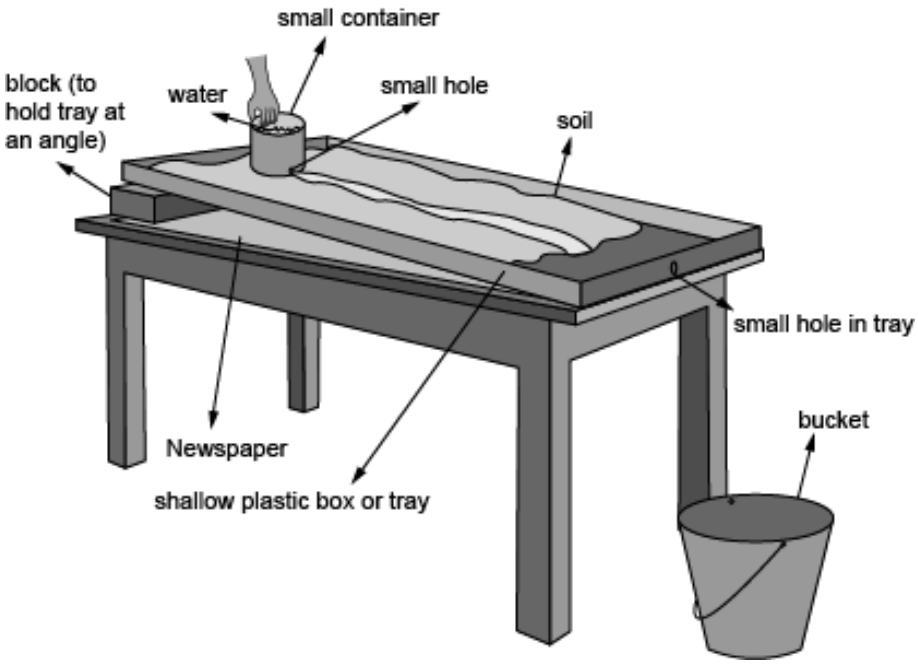
How to Set up



Model what to do with the old towels in case of a spill.

1. Ask students to describe erosion they have seen in nearby areas. Have students describe how familiar areas look before and after heavy rainstorms (for example a nearby construction area). Ask students to describe deposition they have seen in nearby areas. Ask students to provide examples of the relationship between how soil is is eroded, transported and deposited.
2. Students should work in their lab groups to set up their stream table or plastic tray/box. They should set up wooden blocks under one end of the table and slowly increase the elevation at that end until the water flows freely down the table and into the bucket below.
3. Once the elevation is set students should fill the stream table with topsoil. If they are using a tray or box they should push back the soil from the lower end of the box/tray using a ruler, as shown in figure 2. Next, they should half fill the container with the hole with water and holding the container allow the water to slowly pour out onto the topsoil from the top of the stream table. Students should observe qualitatively what happens to the soil as the water moves through it (Particles of soil move along with the water). Students should count the numbers of streambeds/gullies formed and draw a sketch of the pattern they produce. They should use a ruler to measure how wide and deep each gully is in millimeters. Students should observe the water at the base of the stream table or tray/box and in the bucket below (It contains soil that was carried along with the water). Remind students to pour water in their group's bucket into the waste bucket so that soil does not go down the drain.

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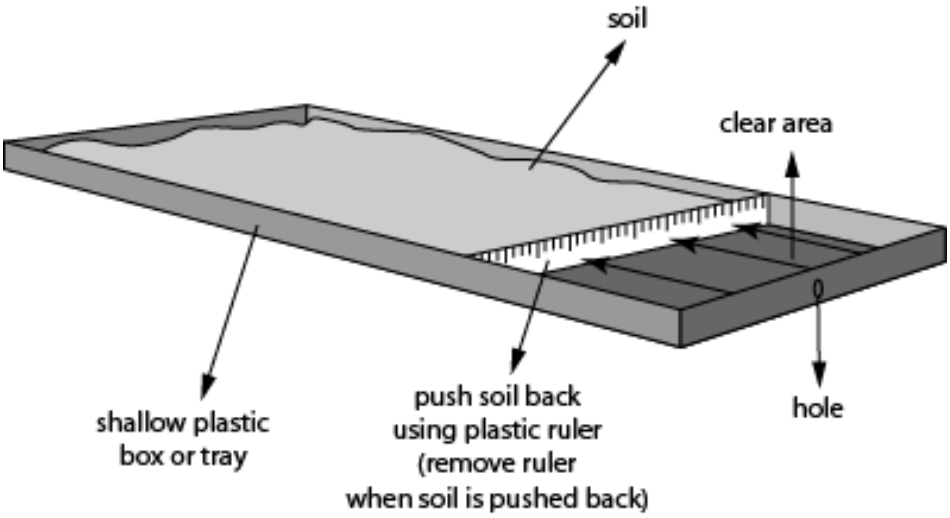
How to Arrange the Soil



4. Have students investigate how the water has spread through the soil by using a pencil to dig small trenches (1-2 cm long) at different 5 cm intervals from the main stream (see figure 3). (Students will observe that, although most of the water travels down is a stream or series of streams some travels underground through the soil making it very wet.)

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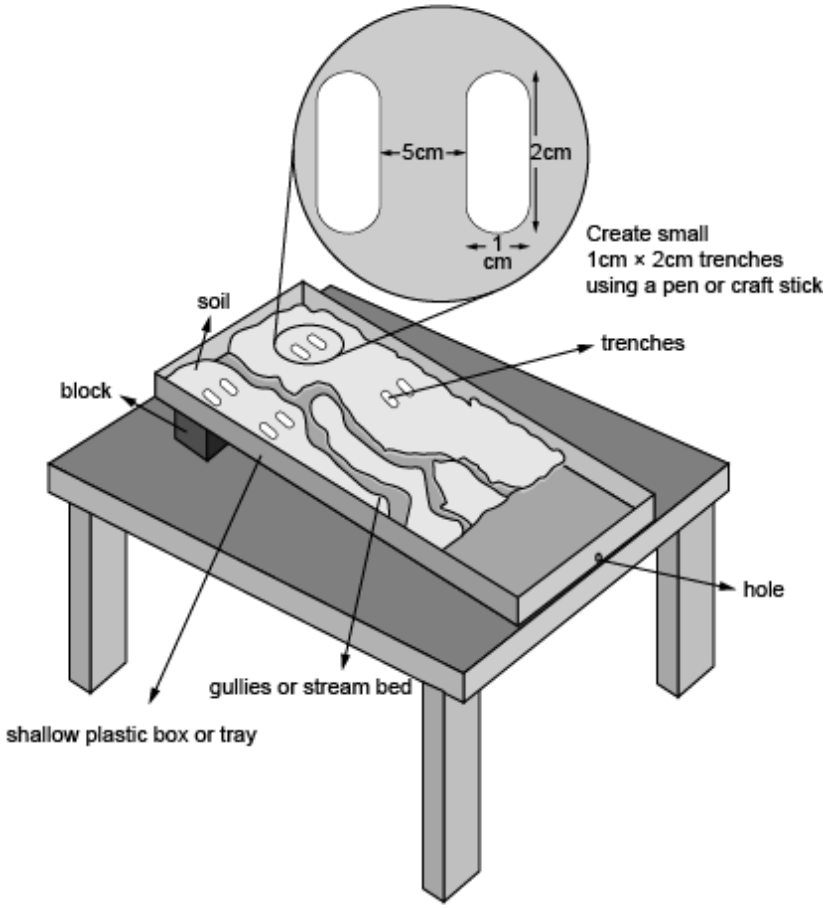
Digging the small trenches



5. Students then should rearrange the soil to its original configuration, adding more if required. Next have them increase the elevation at the elevated end by about 5 cm. They should refill the container with the hole and allow water to travel down the stream table again. Students should observe what happens to the speed of water as the water travels down the table (It moves more quickly through the gully). They should count the number of stream beds/gullies and measure and draw their pattern as before (They will most likely observe fewer deeper streambeds/gullies) Students should record what happens to the soil as the water moves through it (moving more particles of soil from the sides of the gully along with it). Students should observe the water in the bucket below (It contains more soil). The bucket should be emptied. Remind students to pour their water into the waste water bucket provided. the drain.

6. Again have students investigate **how** the water has spread through the soil by using a pencil to dig small trenches at different 5 cm intervals from the main stream. (Students will observe that, with the increased gradient more water has drained away.)

7. Next have students tip out their soil into the “Soil Bucket” and plan how they can use different layers of materials such as gravel, sand, mulch, and other soils provided, to simulate different rock types and strata.. Students should plan what they intend to do and then consult with the teacher before proceeding,

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8. They should conduct the procedure as before, measuring the width and depth of the streambeds and gullies and investigating any lateral movement of the soil.

9. At the end, students should make sure that all wet soil and muddy water goes in the appropriate bucket.. Any spilled water on the floor should be mopped up with a wet towel. Remind students to be careful as they walk around the room, as the floors may be wet.

10. Students should take time to fill out their information sheet, and each groups should share and discuss their findings on the next class day.

11. After the discussion have students list the factors that determine the nature of erosion features and the rate of erosion. (Ideas will include the slope, the amount of water, the nature of the substrate—particularly the size of particles). Ask them what impact slope is likely to have on ground water. (The steeper the streambed the less water moves laterally into groundwater.) Did they observe any other factors that impacted how far water moved from the main streambeds? (Particle size may have an impact, as some of the "soil" types, such as gravel are more permeable than others.)

12. From what they have observed ask students to brainstorm ways that soil erosion could be reduced. Record their ideas as a diagram and have students enter this into their notebook. If desired extend this lab to include methods of reducing erosion such as terracing, dams and groundcover.

13. Brainstorm how erosion by wind or ice might be different than erosion by water.

Analysis and Conclusions

1. Define erosion and describe examples of erosion you have seen in nearby areas.

The movement of soil and rock by agents such as running water, wind or ice. A local example would be the erosion of soil from denuded slopes near on the school grounds.

2. Define deposition and describe examples of deposition you have seen in nearby areas.

The process by which sediments, soil, and rocks are added to a land mass or landform. After a storm we can see soil washed onto the roadway.

3. What role does water play in the relationship between how sediment moves by erosion to how it accumulates in deposition? Use qualitative and quantitative data from the lab activity to support your answer.

The more soil eroded from the soil in the stream table the more that is deposited in the bucket. The more water that passed over the soil the more soil was eroded. We poured the same quantity of water down our model with both the shallow and steep incline. When we increased the incline the water ran faster and more soil was eroded. We estimate that about twice the amount of soil accumulated in the bucket using the steep incline than with the shallow incline. The mean depth of the gullies in our model increased from 6mm for the shallow incline to 14mmwith the steep incline.

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Both of these observations suggest that the greater the rate of water flow the greater the rate of erosion and the more sediment will accumulate downstream where flow slows or stops (as in the bucket).

4. How did the increase in the incline impact the rate of erosion, the erosional features produced in your model?

Increasing the incline increased the speed of the water and this increased the rate of erosion. The steeper the incline the deeper the gullies. We observed that with the first incline there were a lot of shallow streams. With the steeper incline the flow concentrated in one gully that rapidly deepened.

5. In addition to water travelling down gullies and streambeds was there any evidence in your model of water traveling through the soil? If so:

a) What does this water represent?

Groundwater

b) Did the amount or distance this water traveled vary with the incline of the stream table?

The water traveled sideways from the direction incline about 10 cm when the incline was low but was only detectable at about 5 cm when the incline was decreased.

c) Where was this water most plentiful?

Water was most plentiful nearest the stream beds and gullies, and near the base of the slope.

d) How could this information help predict the best places to drill wells

Successful wells are most likely to be dug near water courses or in low lying areas.

6. Predict: How does erosion and deposition occur with each of the following materials or forces?

- ice
- wind
- gravity
- lava

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Observe Change and Consistency
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Events that change, such as erosion and soil deposition, can be described in patterns.

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Hands-On Lab

Analyzing Biological Diversity, Extinction, and Evolution

Timing: one 90-minute class session

Objective(s):
Students will analyze and represent data and to make models related to the concepts of biological diversity, extinction, and evolutionary tree diagrams.

Safety Precautions:
Students should demonstrate safe and appropriate behavior when browsing the Internet for resources.

Materials:
Per student group:

- poster board or large sheets of butcher paper
- centimeter ruler

Teacher Preparation:
Set up three stations before students arrive. Station one should have a computer with graphing software. Station two should have a computer with Internet access, large sheets of paper, and centimeter rulers. Station three should have a computer with Internet access, large sheets of paper, and centimeter rulers. Prepare a copy of the Student Investigation Sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Review the procedure for each station with the class.

Station 1: Biological Diversity Data
Students should examine the three tables of biological diversity data provided. As a group, they should decide the best way to represent the data in each table. For example, the data in Table 1 are best presented in a line graph, which will show the yearly variation and the overall downward trend. The data in Table 2 are best shown in a pie graph because they are displayed as percentages. The data in Table 3 are best shown in a histogram, or bar graph. A bar graph will show that Mt. Nlonako has very high amphibian concentration compared to the other three sites in Cameroon.

Year	Number of Loggerhead Turtle Nests on South Carolina Coastline
1980	4334
1981	7276
1982	4627
1985	3728
1986	5266
1987	2955
1990	4491
1991	3657
1992	3941
1995	2959
1996	3892
1997	2169

Table 1. Number of loggerhead turtle nests on the South Carolina coastline from 1980–1997

Status	Percentage of Primate Species in Each Category
Extinct	0.5
Extinct in the Wild	0.0
Critically Endangered	8.9
Endangered	20.8
Vulnerable	18.8
Near Threatened	5.6
Least Concern	31.9
Data Deficient	13.5

Table 2. Conservation status of worldwide primate population as of 2010.

	Mt. Nlonako	Korup National Park	Dja Faunal Reserve	Nkongsamba area
area in km^2	150	1240	8400	10000
amphibian species found	93	88	70	100
amphibian species/ km^2	0.62	0.07	0.01	0.01

Table 3. Amphibian species found in various sites in Cameroon.

Students should construct their graphs using computer software. If software is not available, they can use paper and pencil.

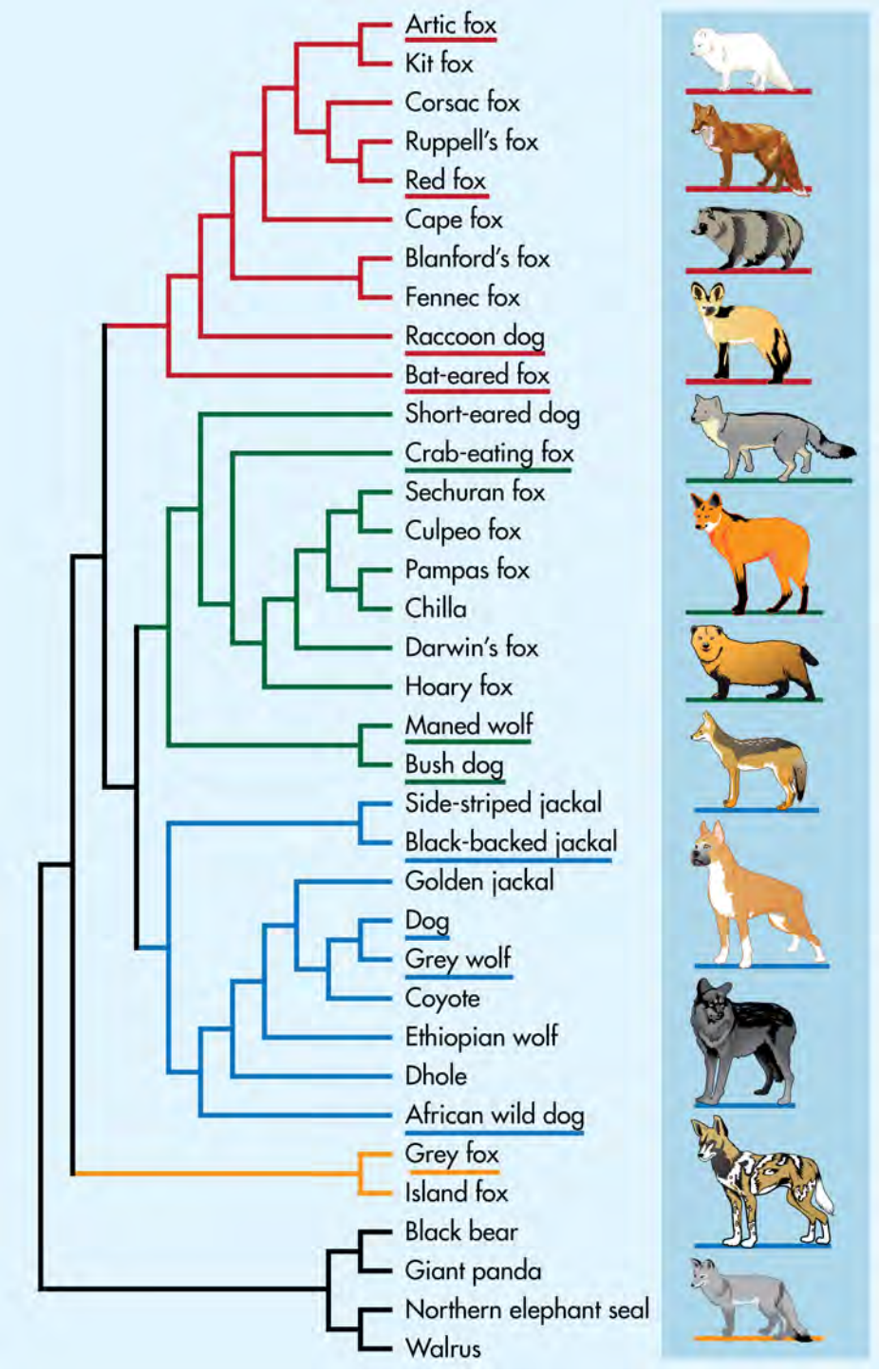
Underneath each graph, they should include a short summary of what the data represent. For instance, for the data in Table 1, they could write, “The data suggest that the number of sea turtle nests in South Carolina is declining.” Students should also list one or two questions that they have about the data or what the data suggest. For example: “Why do some areas have more biological diversity than others?” or “What can we do to prevent primates from being on the endangered species list?”

Station 2: Extinction

At this station, students will research several extinct organisms and compare them to their modern, living relatives. For example, students could research some of the organisms found in the La Brea tar pits, such as the mastodon, mammoth, saber-toothed cat, dire wolf, ground sloth, and ancient camel. It may be helpful for students to watch **The La Brea Tar Pits** video as an introduction. Students should pick two or three organisms and research their physical dimensions. Then, students should compare the physical dimensions of the extinct organisms to their modern, living relatives. Students should use rulers to draw scale models of an extinct organism and its modern, living relative. For example, *Megatherium*, or the giant ground sloth, stood 6 meters tall on its hind legs. A modern three-toed sloth is about half a meter tall. Students could construct a scale using their rulers, such as 10 centimeters represents 1 meter. So the giant ground sloth would take up 60 centimeters on the page and the modern sloth would take only 30 centimeters. Underneath their scale models, students should list two similarities and two differences between the extinct organism and its modern relative.

Station 3: Evolutionary Tree Diagrams

Students should find and examine an existing evolutionary tree diagram from the Internet and draw conclusions about its contents. For example, a molecular analysis of the domestic dog and its close and distant relatives resulted in this diagram:



Have students answer the analysis questions in their investigation sheets. Then have students choose three closely related organisms and develop their own evolutionary tree for the organisms. Students should attempt to find the point at which the two animals' evolutionary histories interact. For instance, students could try to find the point at which domestic cats and

roaring cats split. What common characteristics do these two organisms share? What characteristics set them apart? The students could draw a selected portion of the evolutionary tree diagram that shows their two organisms and illustrate it with photos.

Guided Inquiry

Students should circulate through the three stations described in the Directed Inquiry section. Ask the students some guiding questions to help them focus their inquiry:

- What are the best ways to represent data?
- How have organisms changed over time?
- How can scientists trace common ancestors of modern and extinct organisms?

Then, students should brainstorm with their group members to create a fourth station. This fourth station could be a summary station, with the students developing a way to present their findings from all three stations. Or the fourth station could explore the concept of episodic speciation. Students could find video and image resources to teach this concept to their classmates. Have the group write a summary of their ideas and approve each group's ideas before allowing them to create the station.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. How did you choose to represent the data in Tables 1, 2, and 3? Why did you choose those formats? *We used a line graph to represent the data in Table 1 because it was the best way to show the overall trend of the data. We used a pie chart to represent the data in Table 2 because pie charts are the best way to show percentage data. We used a bar graph to represent the data in Table 3 because it showed how the concentrations of amphibians in each location compared to the others.*

2. If you were a wildlife conservation manager in Cameroon, which area would you focus on conserving, and why? *I would make an effort to conserve the land around Mt. Nlonako. This small area, only 150 km^2, has 93 species of amphibians. The high biological diversity of this area makes it important for conservation. If Mt. Nlonako has such a high amphibian biological diversity, it may also have high biological diversity for other types of animals as well.*

3. The data in Table 1 describe the egg-laying activities of loggerhead turtles. Loggerhead turtles are an important predator in the marine ecosystem, feeding on jellies, crabs, mollusks, and occasionally vegetation. What would you do to reverse the population decline of loggerhead

turtles? *I would make sure that the beaches the loggerheads use for nesting are protected during nesting season.*

4. What differences did you observe between modern, living animals and their extinct relatives? *I noticed that some of the extinct animals were much, much larger than their modern counterparts. They also had body parts that we no longer see in the modern equivalents, such as the long teeth that extend outside of the mouth in saber-toothed cats.*

5. Imagine that a particular plant was an important ingredient in human medicine, but it was starting to die out. How might using an evolutionary tree diagram to help scientists find similar plants? *The evolutionary tree diagram would show other plants that shared a common ancestor. It's possible that these other plants would also have the material we needed for making medicine.*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - asks a question about a specific science concept or process
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Are based on logic and evidence
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Length/distance/depth
  - Choose appropriate tools to conduct an investigation:
    - Ruler/tape Measure
  - Use the appropriate format to record data:
    - Table
    - Graph
    - Chart
    - Writing (journal, worksheet, electronic text)
    - Sketch
  - Identify and interpret patterns using:
    - Trends in data
    - Graphed data points
    - Tables and graphs
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Reporting trends and patterns in the data
    - Showing the application of the scientific concept or process being investigated
- Communication in Science
  - Report results using:
    - Scientific illustration with proper labeling
    - Images or video
    - Table/graph showing data
- Patterns and Systems
  - Patterns and Change:
    - Certain things change in some ways and stay the same in others, such as in their color, size, and weight.
- Engineering and Technology
  - Uses of Technology:

- Computers have sped up and extended people's ability to collect, store, compile, and analyze data; prepare research reports; and share data and ideas with other investigators.

Hands-On Lab

Analyzing Biological Diversity, Extinction, and Evolution

Timing: one 90-minute class session

Objective(s):
Students will analyze and represent data and to make models related to the concepts of biological diversity, extinction, and evolutionary tree diagrams.

Safety Precautions:
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Materials:
Per student group:

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- centimeter ruler

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Directed Inquiry

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Critically Endangered	8.9
Endangered	20.8
Vulnerable	18.8
Near Threatened	5.6
Least Concern	31.9
Data Deficient	13.5

Table 2. Conservation status of worldwide primate population as of 2010.

	Mt. Nlonako	Korup National Park	Dja Faunal Reserve	Nkongsamba area
area in km^2	150	1240	8400	10000
amphibian species found	93	88	70	100
amphibian species/ km^2	0.62	0.07	0.01	0.01

Table 3. Amphibian species found in various sites in Cameroon.

Students should construct their graphs using computer software. If software is not available, they can use paper and pencil.

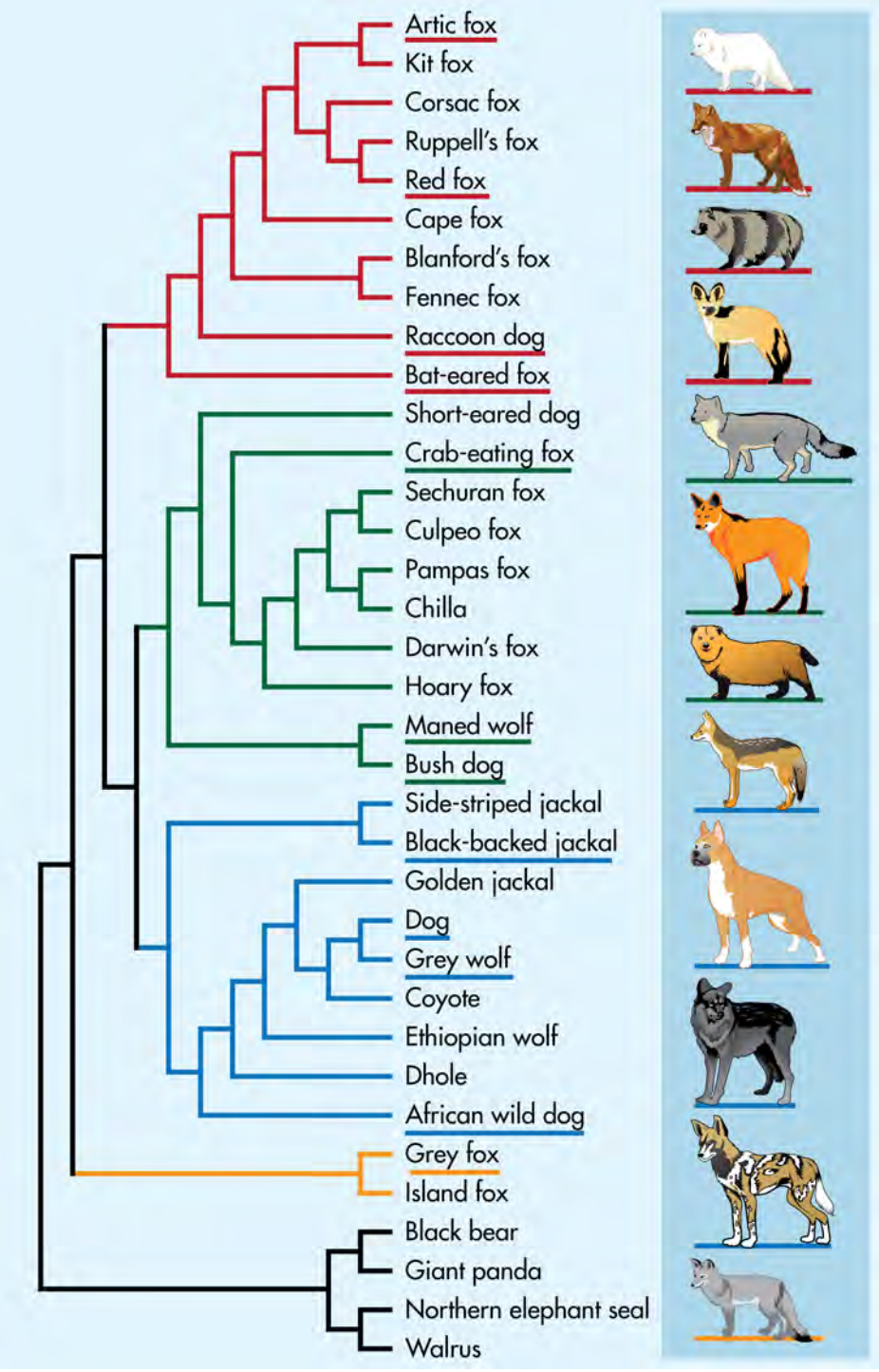
Underneath each graph, they should include a short summary of what the data represent. For instance, for the data in Table 1, they could write, “The data suggest that the number of sea turtle nests in South Carolina is declining.” Students should also list one or two questions that they have about the data or what the data suggest. For example: “Why do some areas have more biological diversity than others?” or “What can we do to prevent primates from being on the endangered species list?”

Station 2: Extinction

At this station, students will research several extinct organisms and compare them to their modern, living relatives. For example, students could research some of the organisms found in the La Brea tar pits, such as the mastodon, mammoth, saber-toothed cat, dire wolf, ground sloth, and ancient camel. It may be helpful for students to watch **The La Brea Tar Pits** video as an introduction. Students should pick two or three organisms and research their physical dimensions. Then, students should compare the physical dimensions of the extinct organisms to their modern, living relatives. Students should use rulers to draw scale models of an extinct organism and its modern, living relative. For example, *Megatherium*, or the giant ground sloth, stood 6 meters tall on its hind legs. A modern three-toed sloth is about half a meter tall. Students could construct a scale using their rulers, such as 10 centimeters represents 1 meter. So the giant ground sloth would take up 60 centimeters on the page and the modern sloth would take only 30 centimeters. Underneath their scale models, students should list two similarities and two differences between the extinct organism and its modern relative.

Station 3: Evolutionary Tree Diagrams

Students should find and examine an existing evolutionary tree diagram from the Internet and draw conclusions about its contents. For example, a molecular analysis of the domestic dog and its close and distant relatives resulted in this diagram:



Have students answer the analysis questions in their investigation sheets. Then have students choose three closely related organisms and develop their own evolutionary tree for the organisms. Students should attempt to find the point at which the two animals' evolutionary histories interact. For instance, students could try to find the point at which domestic cats and

roaring cats split. What common characteristics do these two organisms share? What characteristics set them apart? The students could draw a selected portion of the evolutionary tree diagram that shows their two organisms and illustrate it with photos.

Guided Inquiry

Students should circulate through the three stations described in the Directed Inquiry section. Ask the students some guiding questions to help them focus their inquiry:

- What are the best ways to represent data?
- How have organisms changed over time?
- How can scientists trace common ancestors of modern and extinct organisms?

Then, students should brainstorm with their group members to create a fourth station. This fourth station could be a summary station, with the students developing a way to present their findings from all three stations. Or the fourth station could explore the concept of episodic speciation. Students could find video and image resources to teach this concept to their classmates. Have the group write a summary of their ideas and approve each group's ideas before allowing them to create the station.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. How did you choose to represent the data in Tables 1, 2, and 3? Why did you choose those formats? *We used a line graph to represent the data in Table 1 because it was the best way to show the overall trend of the data. We used a pie chart to represent the data in Table 2 because pie charts are the best way to show percentage data. We used a bar graph to represent the data in Table 3 because it showed how the concentrations of amphibians in each location compared to the others.*

2. If you were a wildlife conservation manager in Cameroon, which area would you focus on conserving, and why? *I would make an effort to conserve the land around Mt. Nlonako. This small area, only 150 km^2, has 93 species of amphibians. The high biological diversity of this area makes it important for conservation. If Mt. Nlonako has such a high amphibian biological diversity, it may also have high biological diversity for other types of animals as well.*

3. The data in Table 1 describe the egg-laying activities of loggerhead turtles. Loggerhead turtles are an important predator in the marine ecosystem, feeding on jellies, crabs, mollusks, and occasionally vegetation. What would you do to reverse the population decline of loggerhead

turtles? *I would make sure that the beaches the loggerheads use for nesting are protected during nesting season.*

4. What differences did you observe between modern, living animals and their extinct relatives? *I noticed that some of the extinct animals were much, much larger than their modern counterparts. They also had body parts that we no longer see in the modern equivalents, such as the long teeth that extend outside of the mouth in saber-toothed cats.*

5. Imagine that a particular plant was an important ingredient in human medicine, but it was starting to die out. How might using an evolutionary tree diagram to help scientists find similar plants? *The evolutionary tree diagram would show other plants that shared a common ancestor. It's possible that these other plants would also have the material we needed for making medicine.*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - asks a question about a specific science concept or process
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Are based on logic and evidence
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Length/distance/depth
  - Choose appropriate tools to conduct an investigation:
    - Ruler/tape Measure
  - Use the appropriate format to record data:
    - Table
    - Graph
    - Chart
    - Writing (journal, worksheet, electronic text)
    - Sketch
  - Identify and interpret patterns using:
    - Trends in data
    - Graphed data points
    - Tables and graphs
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Reporting trends and patterns in the data
    - Showing the application of the scientific concept or process being investigated
- Communication in Science
  - Report results using:
    - Scientific illustration with proper labeling
    - Images or video
    - Table/graph showing data
- Patterns and Systems
  - Patterns and Change:
    - Certain things change in some ways and stay the same in others, such as in their color, size, and weight.
- Engineering and Technology
  - Uses of Technology:

- Computers have sped up and extended people's ability to collect, store, compile, and analyze data; prepare research reports; and share data and ideas with other investigators.

Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

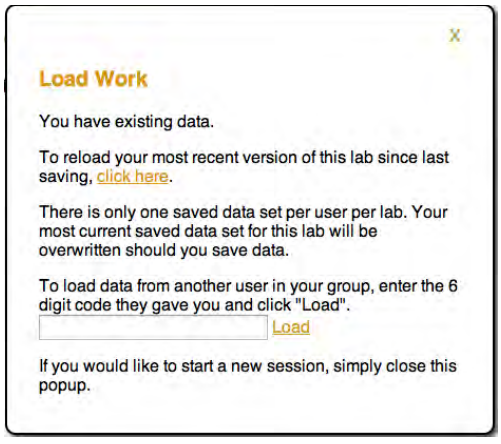
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

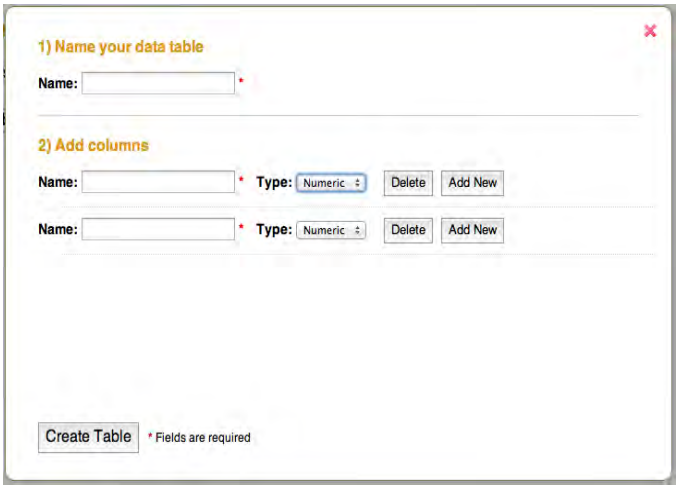
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



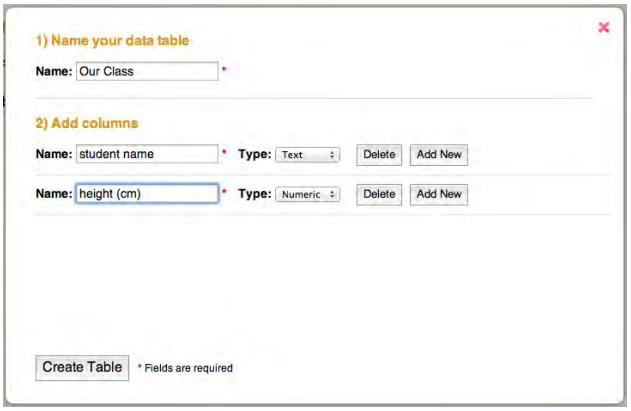
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

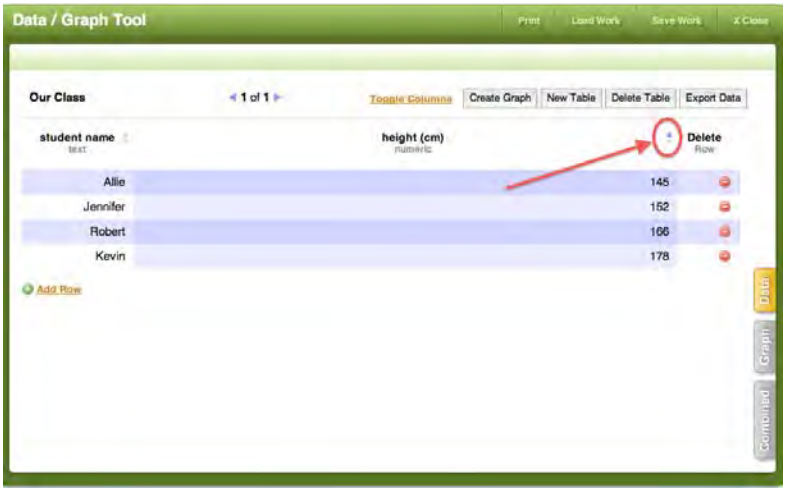
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

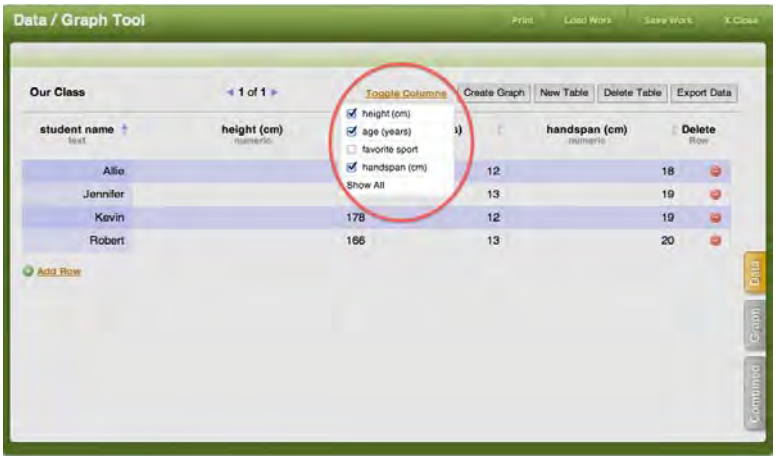


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

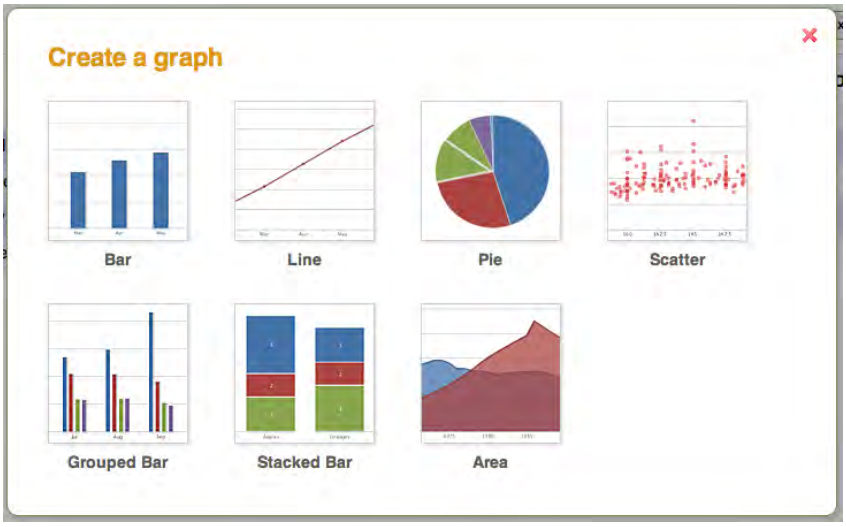
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

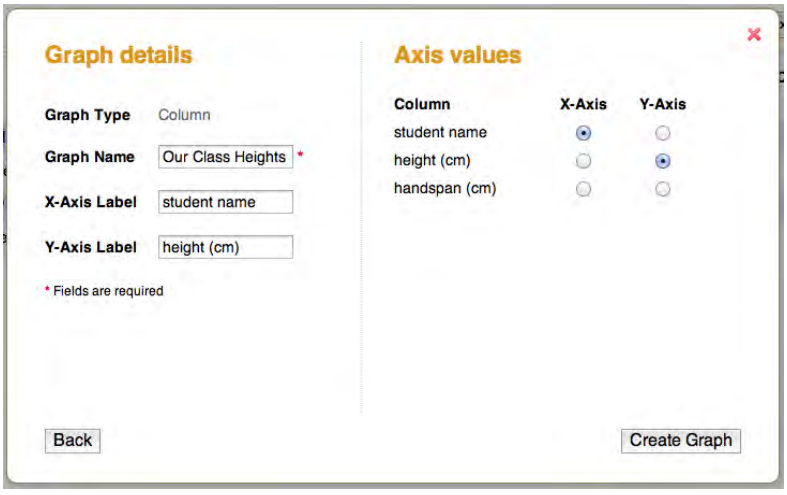
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

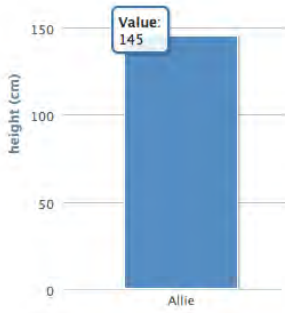


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

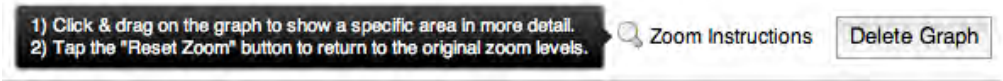
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Exploration Teacher Guide: The History of Life on Earth

Overview

In this Exploration, students will observe the evolutionary tree and explore the evolutionary path of various organisms. They will also compare evolutionary paths of different organisms.

Students will be able to analyze the similarities between the organisms.

Student Learning Objectives

- Explore the evolutionary path of various organisms.
- Compare the evolutionary paths of organisms.
- Examine similar characteristics between organisms.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students select any organism present on the evolutionary tree by clicking on it. The evolutionary path of the selected organism gets highlighted and students read about the characteristics of that organism.

In the *Compare* tab, students select any two organisms they want to compare by clicking on them. The evolutionary paths of the selected organisms get highlighted. The common link between the selected organisms is also displayed. Students read about the similarities between the selected organisms and the characteristics of the common link.

Answers to Questions in Student Worksheet

1. Explain what an evolutionary tree is. Also explain why it is important.

   Answer: The evolutionary tree is a diagram that shows the evolutionary relationship among different organisms. It is based on similarities and difference in physical, behavioral, and/or genetic characteristics of organisms. It is important as it is used to study the history of life on Earth.

2. Define the term extinct. Also explain the phenomenon of mass extinction.

   Answer: Extinction denotes the end of an organism or a species. An extinct organism is one that no longer exists. Mass extinction refers to the extinction of a large number of species at the same time. This may be because of catastrophic natural calamities or events.

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3. Explain what eukaryotes are.

   Answer: Eukaryotes are organism with cells that contain complex membrane bound structures. They evolved from prokaryotes.

4. Track the evolutionary path of a butterfly and comment on it.

   Answer: The evolutionary path of a butterfly is origin of species to eukaryotes to bilateria. Butterflies evolved around 570 million years ago. They use their wings as a camouflage to protect themselves from predators.

5. Name one extinct and one living tetrapod.

   Answer: Dinosaurs are extinct tetrapods. Elephants are living tetrapods.

6. Explain what vertebrates are.

   Answer: Vertebrates are organisms that have a back bone. Reptiles, mammals, birds, and fish are all vertebrates.

7. Explain the term hominids. Give one example of a hominid.

   Answer: Organisms belonging to the family Hominidae are called hominids. Hominids are erect, bipedal, primate mammals. Modern man is an example of a hominid.

8. Compare the evolutionary path of an apple and a lungfish. Comment on the similarities observed.

   Answer: Both apples and lungfish are multicellular and are euakryotes. Eukaryotes are organism with cells that contain complex membrane bound structures. They evolved from prokaryotes.

9. Identify and comment on the common link between an elephant and modern man.

   Answer: The common link between an elephant and modern man is mammals. Mammals are organisms that contain mammary glands, possess hair and are warm blooded.

10. Compare and contrast chimpanzees and modern humans.

    Answer: Chimpanzees and modern humans belong to the family Hominidae. They display remarkable behavioral and genetic similarities. Modern humans are the most evolved species, socially and culturally.

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11. The evolutionary tree described in the Exploration is a small sample of the evolution of organisms. Name any two organisms that you think are missing. Identify where you would place them on the tree using the characteristics you have learned about.

    Answer: Two organisms that may be missing from this diagram of the evolutionary tree are crocodile and blue whale. Crocodile would be placed under reptiles with rattle snake and blue whale would be placed under mammals with elephants.

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Hands-On Activity

Life on Earth: A Timeline

Objective:
Students will use a geographical map to represent the major events in the rise of animals on Earth.

Estimated time to complete: 30 minutes

Materials:

For each small group of 3 or 4 students:

- copy of a local map
- centimeter ruler
- protractor

Procedure:
In this activity, students will map the major events of animals on Earth onto a geographical map. Each major stage in the rise of animals will be represented (see tables below).

Before class begins, print out copies of a local map. If possible, choose a map that has a scale reading 5 miles. Try to make an interesting feature as the center of your map (for instance, the location of your school or town). You will need to calculate the relationship between miles on the map and millions of years. Assume that 10 million years equals 1 mile. To convert millions of years into miles on the map, divide each time period by 10 million years. Look at Figure 1 to see the equation in action.

Find the scale on the map. Measure the miles unit in centimeters. If your map shows 5 miles = 1.9cm, multiply the number of miles in your time period by 1.9 cm, then divide by 5 miles. This will tell you how many centimeters are needed to represent that time period. If your scale is different, substitute your numbers, but use the same equation. See Figure 1.

When doing this activity with your students, distribute copies of the table shown in Figure 3. The “Time Period” column should already be filled in, and the students should use the **Core Multimedia Reading Path Explore** section on **The Rise of the Animals** to fill in the information in the “Event” column. Depending on the math skills of your class, you can leave both the “Miles” and “Centimeters” columns blank (Figure 4). You will need to supply the class with the following piece of information:
10 million years = 1 mile on the map [Scale information from your particular map: X miles = Y centimeters]

Figure 1

Time period	Event	Miles	Centimeters
600mya	Simple animals appear	$= \frac{600\text{mya} * 1 \text{ mile}}{10\text{mya (60 miles)}}$	$= \frac{60 \text{ miles} \times 1.9 \text{ cm}}{5 \text{ miles (22.80 cm)}}$
570mya	Early arthropods appear	$= \frac{570\text{mya} * 1 \text{ mile}}{10\text{mya (57 miles)}}$	$= \frac{57 \text{ miles} \times 1.9 \text{ cm}}{5 \text{ miles (21.66 cm)}}$

This completed sample table assumes that 10 million years = 1 mile and that 5 miles on the map = 1.9cm; mya = million years ago.

Figure 2

Time period	Event	Miles	Centimeters
600mya	Simple animals appear	60	22.80
570mya	Early arthropods appear	57	21.66
550mya	Vertebrates appear	55	20.90
500mya	Early fish appear	50	19.00
360mya	Amphibians become dominant	36	13.68
300mya	Reptiles appear	30	11.40
200mya	Mammals appear	20	7.60
150mya	Birds appear	15	5.70
2.5mya	Genus *Homo* appears	0.25	0.10

Figure 3

Time period	Event	Miles	Centimeters
600 mya		60	
570 mya		57	
550 mya		55	
500 mya		50	
360 mya		36	
300 mya		30	
200 mya		20	
150 mya		15	
2.5 mya		0.25	

Figure 4

Time period	Event	Miles	Centimeters
600mya			
570mya			
550mya			
500mya			
360mya			
300mya			
200mya			
150mya			
2.5mya			

Once students have completed their calculations, have them choose a point at the center of the map. This will be the point from which they make their measurements. Students should use their rulers to measure the correct number of centimeters away from the center point for each major event. For instance, they should measure 22.8 cm from the center point to represent the first appearance of simple animals. At 22.8 cm, they should make a dot with their pencil.

Students should place the anchor of the protractor at the center point and extend the arm of the protractor until the pencil is positioned at the dot marking 22.8 cm. Then students should draw a circle around the center point. The radius of the circle should be 22.8 cm. This step should be repeated for each event. Students should label each circle with a description of the particular event.

After the students have drawn a circle for every life event, they will have a model representing the timeline of the rise of animals on Earth. For an extra challenge, provide them with a larger map; see if they can model the distance needed to show the origin of Earth 4.55 billion years ago.

Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Apply mathematical operations and principles to replicate the real thing.
    - Are based on logic and evidence
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Length/distance/depth
    - Time
  - Choose appropriate tools to conduct an investigation:
    - Ruler/tape Measure

- Patterns and Systems
  - Patterns and Change:
    - Patterns in nature may be simple repeating patterns or complex growing or changing patterns.
    - Some changes are very slow and some are very fast and that some of these changes may be hard to see and/or record.
    - Things that change may do so in steady, repetitive or irregular ways.
    - Mathematical patterns help to predict future events and describe change in systems.

Exploration Teacher Guide: Absolute Dating

Overview

In this Exploration, students will measure and calculate the parent-daughter ratio of isotopes used to find the absolute age of geologic samples. They will then convert parent-daughter ratio to percentage of original parent atoms remaining, and use this to determine the absolute age of the samples.

Student Learning Objectives

- Identify the isotopes used for the absolute dating of geologic samples.
- Examine the experimental setup used for absolute dating.
- Investigate the relationship between parent-daughter ratios of isotopes, half-life of a parent, and age of a rock or mineral sample.
- Calculate the absolute age of the sample from the percentage of original parent atoms remaining in the sample.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

Students can use the *Apparatus* Tab to examine the apparatus used for absolute dating. The radio buttons for *Experimental Setup* and *Mass Spectrometer* can be used to toggle between the two.

The procedure for absolute dating varies from isotope to isotope and this exploration is idealized to convey the basic concepts. In the *Find Age* Tab, students must select one of the eight samples that they wish to place in the mass spectrometer. Samples available in the Exploration include *Basalt, Granite, Gneiss, Human Skeleton, Skeleton of Animal, Living Tree, Buried Log,* and *Meteorite*. Students must use the radio buttons for ^{14}C, ^{238}U, and ^{87}Rb to select which parent isotope they want to use for the absolute dating of the selected sample. Checkboxes for *Show Information* and *Show Half-Life* can be used for more information about each isotope. The student must then use the *Measure* button to measure the parent-daughter ratio of the chosen isotope in the sample. If the isotope chosen is inappropriate because of the sample's age or composition, students will be prompted to choose a different one. Clicking on *Proceed* will take students to the next step, where they will use the parent-daughter ration to calculate the percentage of original parent atoms remaining in the sample. Students must then drag the yellow pointer on the graph so that it has a *y*-value that matches the percentage of the original parent isotope atoms that still remain in the sample. The *Check* button can be used to validate the answers and receive feedback about the sample. Students can use the *Select Another Sample* button to restart the Exploration with another sample.

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Students can use the *Tracker* tab to track the samples that they have dated successfully. They can compare the selected elements, their half-lives, remaining element percentage in the sample, and the age of the sample for each run.

Answers to the Questions in the Student Worksheet

Note that some answers provide more information than would be expected from the student. These questions are better used for review and discussion than for assessment

1. Explain what the half life of a radioactive isotope is and why it is important in absolute dating.

   Answer: The half life of an isotope is the time it takes for half of the atoms in an isotope to decay. It is a common way of expressing the rate of radioactive decay. If the half life of a radioactive isotope is known and the parent/daughter ratio can be measured or calculated, the age of the sample can be calculated.

2. Describe how a mass spectrometer is used for absolute dating.

   Answer: A mass spectrometer ionizes the atoms in a sample and then separates the ions according to their mass. It detects and counts individual ions or calculates the number of ions of a particular mass based on the electrical current carried by the beam of ions. The MS can be set to measure parent isotopes, daughter isotopes, or related isotopes. Computer software then analyzes the measurements, comparing the amounts of different isotopes in the sample and calculating isotope ratios. These ratios, along with the half-lives of the isotopes, are then used to calculate the age of the sample.

3. Why is it important to consider the half-life of an isotope, the relative age of the sample, and the composition of the sample when deciding which isotope to use to date a sample?

   Answer: The isotope to be used for dating a sample depends on the relative age and composition of the sample. This is because the carbon, uranium, and rubidium, all have different half-lives. The isotope to be used for absolute dating is selected by approximating the relative age of the sample and choosing an isotope with a corresponding half-life.

4. This exploration is about absolute dating. Yet the feedback on all of the dates says that the ages are "about" a certain number of years. Why doesn't the feedback state that the age is exactly a certain number of years?

   Answer: There is uncertainty in any measurement. With respect to absolute dating of rocks, no technique can provide a date as precise as a single year. The uncertainty in measurement can be less than 1%, but if a rock is 100 millions of years old, for example, 1% is 1 million years. The uncertainty can be caused or affected by a number of factors, including experimental error, possible loss of daughter atoms or addition of parent atoms, the half-life of the isotope being used, the amount of sample used, and the age of the sample.

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5. Use this Exploration to identify the best method for dating bones of animals that are only a few thousand years old. Explain why this is the best choice.

   Answer: The carbon dating method is the best method for dating bones because bones are very rich in carbon and are too young to be dated effectively using rubidium or uranium. Carbon-14 has a half-life of 5,730 years, which is ideal for samples that are a few thousand years old.

6. Imagine you measure the abundance of parent atoms and daughter atoms in a sample and find that there is almost the same number of parent as daughter atoms. What does this tell you about the age of the sample? Explain your answer.

   Answer: The age of the sample must be about the same as the half-life of the isotope. After every half-life, about 50% of the parent atoms have decayed to form daughter atoms, leaving 50% as parent atoms. Assuming there are no daughter atoms to start with, the ratio will therefore be 1:1.

7. Why is it important to have some idea about the relative age of a sample before radiometric dating?

   Answer: The isotope that you choose to use to analyze the rock should have a half-life that is appropriate for the general age of the sample. If the sample is very young and the half-life is very long, not enough atoms will have decayed to provide a statistically valid sample. If the sample is very old and the half-life of the isotope is very short, there will be too few parent atoms left to measure. In general, a half-life close to the actual age of the sample is ideal.

8. Why is it important to be careful interpreting absolute ages of clastic sedimentary rocks such as sandstones?

   Answer: Clastic sedimentary rocks are made of pieces of other rocks and minerals. If you date a sedimentary rock, you may actually be dating a piece of an older rock.

9. Identify three assumptions that radiometric dating relies on.

   Answer: Decay rate of an isotope is constant; there is no addition or removal of parent or daughter atoms except through radioactive decay once the rock forms; the instrument (the mass spectrometer) is measuring accurately.

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10. Carbon-14 decays to form nitrogen-14. Nitrogen-14, however, is a gas and can therefore escape from the sample over time? Because of this, we cannot calculate the age of a sample by measuring the carbon-14 to nitrogen-14 ratio in it. (We use a slightly different method instead.) If we did use this ratio to calculate the age, how would this calculated age differ from the actual age? Explain your answer.

    Answer: The calculated age would be less than the actual age. This would happen because atoms of the daughter isotope, N-14, have escaped. The ratio of parent to daughter atoms would be higher, which would make it look like the percentage of parent atoms remaining was higher than it is, and that therefore less time has passed.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

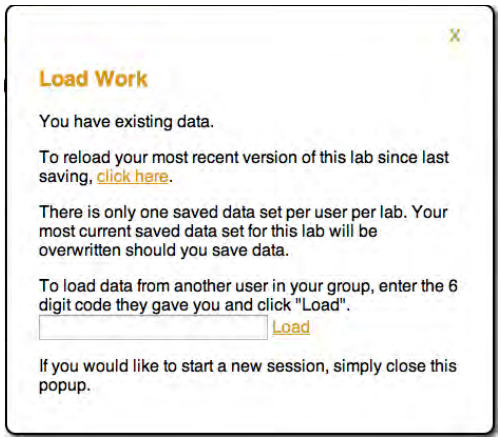
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

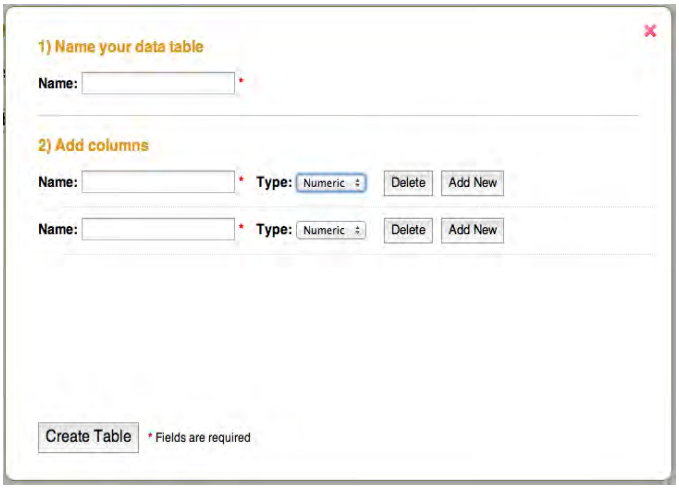
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



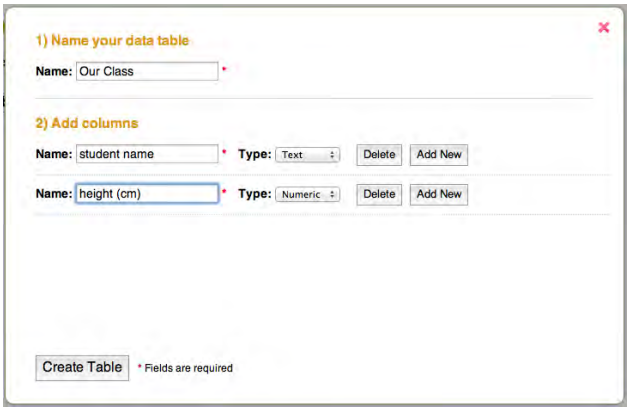
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

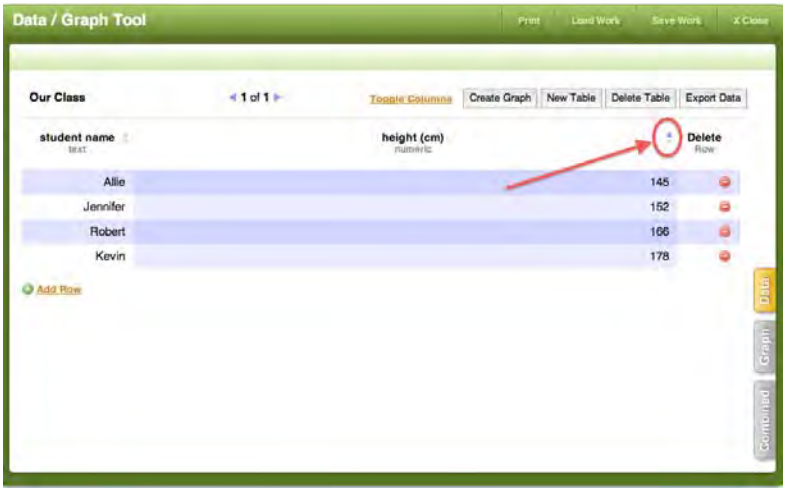
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

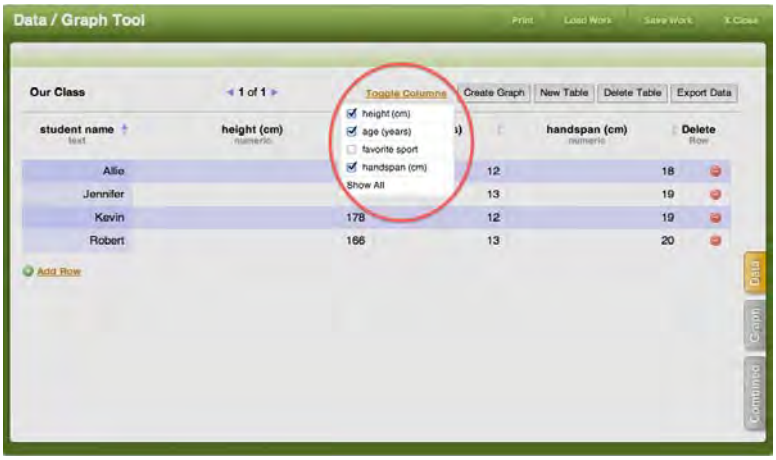


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

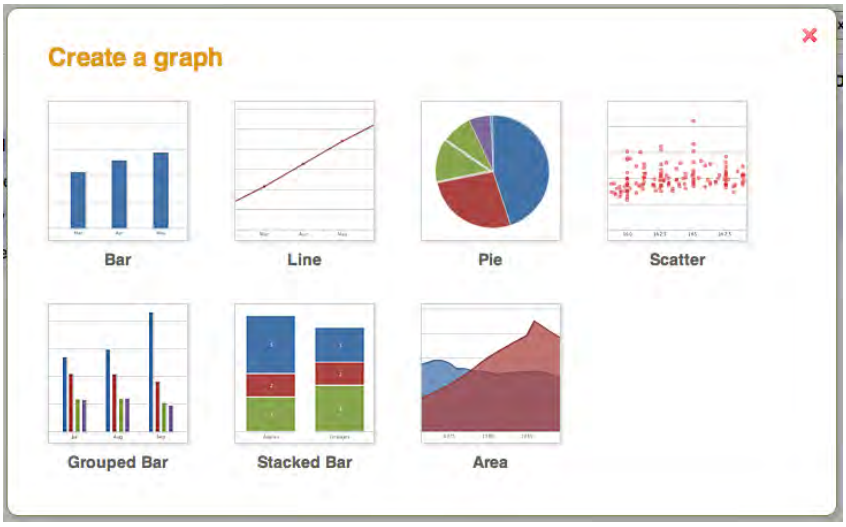
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

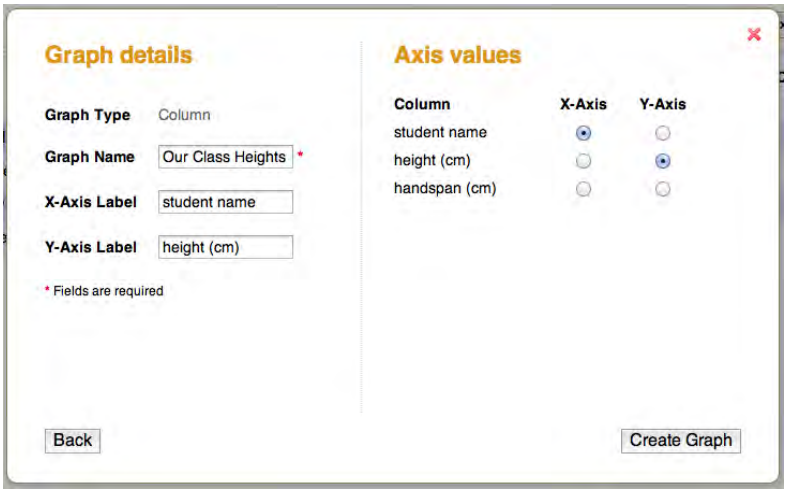
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

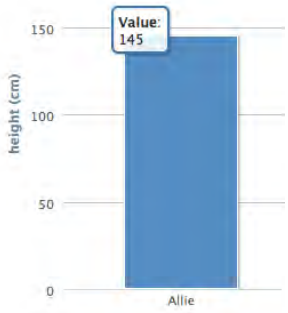


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

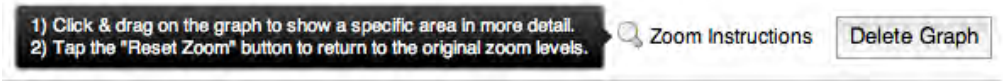
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Exploration Teacher Guide: Earth's Interior

Overview

In this Exploration, students examine structural layers of Earth's interior and their properties. Students also identify the mineral composition of layers.

Student Learning Objectives

- Examine the five structural layers of Earth's interior.
- Identify the mineral composition for each of the five layers.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In this Exploration, students use models to investigate the five structural layers of Earth's interior.

In the *Explore* tab, students use the slider to select one of the five layers from the model of Earth's interior. Upon selection, information about the selected layer is displayed. Students use the *Proceed* button to view an animation of the selected layer. More information about the selected layer is displayed. Students click the *Proceed* button for the next section, in which they identify the mineral composition of the selected layer. Students use the radio button options to select the correct mineral composition. They use the *Submit* button to validate their selections.

Students can use the *Select Another Layer* button at any time during the Exploration to restart and select another layer.

The *Tracker* tab records the options that the student selects in the *Explore* tab after the student correctly identifies the mineral composition of each selected layer.

Answers to Questions in Student Worksheet

1. Identify the composition of oceanic and continental crustal rocks. In a model of Earth's interior, where would these rocks appear?

   Answer: Oceanic crust is composed primarily of dark-colored mafic rocks, rich in iron and magnesium. Continental crust is composed primarily of light-colored felsic rocks rich in silica and feldspars. Crustal rocks would appear in the part of a model that represents Earth's lithosphere: Earth's crust is the upper part of the lithosphere.

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2. Describe how Earth's crust responds to the addition and removal of mass.

   Answer: The height of the surface of Earth's crust varies in response to addition and removal of materials from Earth's interior due to processes such as earthquakes, volcanoes, and tsunamis.

3. Name the transition zone from the mantle to the core-mantle boundary and explain its significance.

   Answer: The transition zone from the mantle to the core-mantle boundary is called the "D layer." It is the zone where the lower mantle (which consists of silicate rock) meets Earth's liquid-iron outer core.

4. How does a geologist know the thickness of different layers inside Earth? How might a model of Earth's interior show the relative thickness of each layer?

   Answer: Geologists know the thickness of different layers inside Earth by studying the behavior of seismic waves (earthquake waves) as they move through Earth. P waves can travel through both solid and liquid layers, while S waves can travel through solid layers only. The time it takes for the P and S waves to pass through layers indicates the thickness of the layers. A model of Earth's interior should show each layer in order from lithosphere to inner core. Layers that are thicker in actuality should be thicker in the model. For example, the average thickness of the lithosphere is approximately 100 km, and the asthenosphere is between 500 and 600 km thick; therefore, in a model of Earth's interior, the part that represents the asthenosphere should be five to six times as thick as the part that represents the lithosphere.

5. Explain the term *rheology* and name the rheological layers of Earth. How might a model of Earth's interior distinguish among Earth's rheological layers and compositional layers?

   Answer: *Rheology* is the study of how matter deforms and flows, either in a solid or a liquid state. The names of the rheological layers of Earth are the lithosphere, asthenosphere, mesosphere, liquid outer core, and solid inner core. In contrast, Earth has three compositional layers: the crust, mantle, and core. The rheological and compositional layers overlap. A model might use solid lines to distinguish among Earth's compositional layers and use colors to distinguish among Earth's rheological layers. For example, by shading the crust and the upper mantle red, a model could show where the lithosphere begins and ends.

6. Explain the similarities between Earth's mineral composition and that of meteorites.

   Answer: Extraterrestrial rocks that have landed on the surface of Earth are called meteorites. Meteorites are composed mainly of pyroxenes, olivines, chondrites, iron-nickel metals, coesite, and stishovite, which are very similar to the overall composition of Earth.

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7. In this Exploration, select *asthenosphere* and examine how the tectonic plates below the continents are subducted. List two names given to the boundaries where subduction occurs and explain what these boundaries characterize.

   Answer: Subduction occurs at convergent boundaries of oceanic and continental crust. They also are called destructive boundaries because oceanic crust is destroyed during subduction, and continental crust is shortened as it is folded and faulted.

8. Explain how geologists know that the mesosphere is more rigid than the overlying asthenosphere.

   Answer: Geologists know the mesosphere is more rigid than the overlying asthenosphere by the way seismic waves behave when they move through it. When seismic waves move from the asthenosphere to the mesosphere, they speed up. This is evidence that the mesosphere is denser and less fluid.

9. List one characteristic feature of the asthenosphere and one of the mesosphere. How might a model of Earth's interior represent these features?

   Answer: The hot rocks of the asthenosphere rise, while cooler rocks sink to produce convection currents. A model might use arrows to show the directions in which differently colored rocks move. (For example, hotter rocks could be shaded red and labeled with an upward-pointing arrow; cooler rocks could be shaded blue and labeled with a downward-pointing arrow.) The mesosphere causes hot spot volcanism when narrow plumes of hot mantle move from deep within the mesosphere to the surface. To represent such a plume, a model might include a narrow column, shaded dark red, extending from the part that represents the mesosphere to the surface.

10. Describe the main features of Earth's core. How might a model of Earth's interior represent these features?

    Answer: Earth's core is divided into an outer core and an inner core. The outer core is liquid, and the inner core is solid. The temperature of the outer core ranges from about 3500°C at the outer portion to about 6000°C at the inner portion. The inner core temperature is about 6000°C, which is hotter than the surface of the sun. A model might include labels that identify the temperature and state of matter (that is, solid or liquid) of each layer.

11. Explain what creates the magnetic field surrounding Earth's outer core.

    Answer: Earth's outer core is composed of liquid metal. Convection currents of liquid metal in the outer core are thought to create Earth's magnetic field.

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Hands-On Lab

Earth's Interior

Timing: one 90-minute class session

Objective(s):
The students will create water layers of different densities to represent the layering of Earth's interior.

Safety Precautions:

- Care should be taken when working with glassware. Broken glass should be cleaned up immediately and disposed of properly.
- Students should use the beaker tongs and hot mat when working with heated beakers.
- Students should wear safety goggles when handling solutions.

Materials:
Per group:

- 2.5-gallon fish tank
- 2 gallons of water, room temperature
- Container of salt
- (3) 2.0-L beakers
- Glass pipette
- Stirring rod
- Measuring cups and spoons
- Balance
- Heating unit
- Thermometer
- Beaker tongs
- Hot mat
- Red dye
- Blue dye
- Yellow dye
- Pencil
- Colored pencils
- Safety goggles

Teacher Preparation:

- Create a rubric for yourself for grading purposes.
- Prepare a copy of the laboratory, including the Student Investigation Sheet, for each student.
- Print out appropriate student worksheet from Assignment Builder

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry
Remind students that density equals a substance's mass per unit volume. In this lab, students will need to create three water samples with different densities. Students should label their beakers as follows:

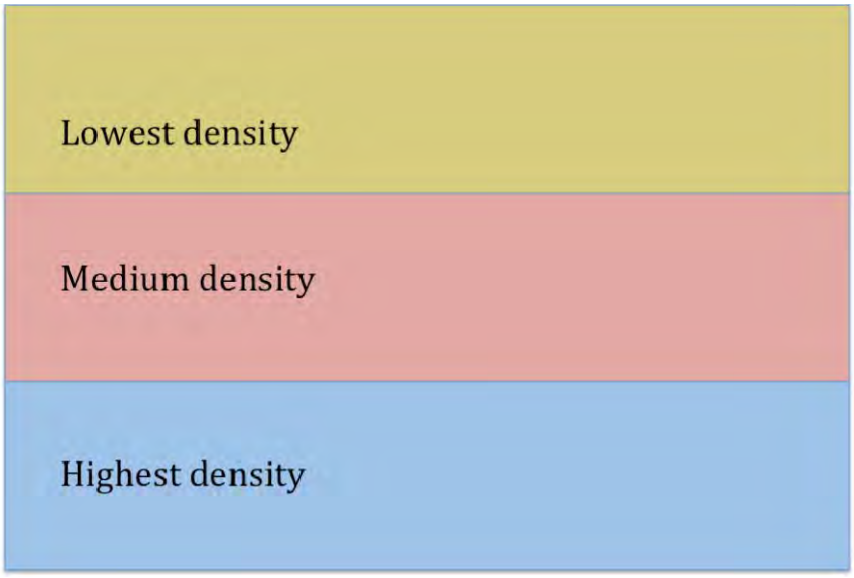
- 1 (lowest density)
- 2 (medium density)
- 3 (highest density)

Students will need to determine how much salt to add to each beaker to produce the three different densities. Before students combine salt with the water, double check their math to ensure that they are producing three water samples with significantly different densities. The student should add salt to the beaker first, and then add about three-fourths the required water. Place the water on the hot plate and increase the temperature to a low-medium setting. Advise the students to stir the solution gently until the salt dissolves. The students should handle the hot glassware with tongs and place the beaker on a hot mat for it to cool. Repeat this procedure for the two remaining samples, adding the appropriate amount of salt and water to each. When all of the water samples have returned to room temperature, add water to top off each sample at 2 L.

The students should then add three to four drops of dye to each beaker. Dye water sample 1 yellow, water sample 2 red, and water sample 3 blue. Instruct students to carefully pour water sample 1 (least dense) into the fish tank first. Students should practice using the pipette to pour the water into the fish tank. The students should next add water sample 2 (medium density). Carefully use the pipette to pour the water into the fish tank; placing the tip of the pipette directly above the bottom of the tank will minimize mixing the water samples. When the water sample 2 has been added, students should note how the two samples interact. When the water is calm, very carefully use the pipette to transfer water sample 3 (most dense) to the fish tank; again, placing the tip of the pipette directly above the bottom of

the tank will minimize mixing the water samples. Have the students observe how the water samples interact.

Have the students draw a rectangle consisting of three layers and note their observations of each layer. The students should produce an image similar to the one below:



Guided Inquiry

Explain that students will use fluids with different densities to model the layering of Earth's interior layers. Distribute the materials and allow students to develop their own procedures and plans for collecting data, based on their knowledge of the content and materials used. Ask the students some guiding questions to help them focus their inquiry:

- What is density?
- What happens when liquids with different densities interact?
- What do you think will happen when three water samples with different densities are placed in a fish tank?

Analysis and Conclusions:

In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. How does density affect the way that water interacts in the fish tank?

The water samples separated into distinct layers based on density. The densest water sample sank to the bottom of the fish tank. Each successive layer is less dense than the layer beneath it. The water interacts slightly along the edges where the different samples meet. For example, the interface between

water samples 3 and 2 is slightly purple (mixing of red and blue). At the same time, the interface between water samples 2 and 1 is slightly orange (mixing of red and yellow).

2. If the three water samples represent Earth's interior, identify each layer. How is this an inaccurate model of Earth's interior?
The three water samples represent the three layers in Earth's interior. The blue layer represents the core (there is no differentiation between the inner core and outer core in this lab). The red layer is the mantle. The yellow layer is the crust. In this lab, each layer is about the same thickness. However, Earth's crust is much thinner than either its mantle or its core. Also, Earth's interior includes solid as well as liquid layers, whereas the fish tank contains only liquid layers.

3. How does the composition of Earth's interior affect density differences?
The core is composed of molten metals, primarily nickel and iron. This material is very dense and sinks to the center of the planet, much like the blue water sample (3) sinks to the bottom of the fish tank. The mantle is composed of molten metals along with aluminum and silica. It is less dense and lies on top of the core, much like the red water sample (2), which floats on top of water sample 3 with little mixing. The lightest layer of Earth is the crust. There are two types of crust (continental and oceanic), but both types are less dense than the mantle. Oceanic crust is primarily iron and magnesium silicates. Continental crust is primarily aluminum silicates. The crust is represented by the yellow water sample (1).

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
    - Require the changing of one variable at a time
    - Can be answered with a science investigation or observational study
  - Develop predictions/hypotheses that:
    - State what may happen in an investigation based on prior knowledge or experience (prediction)
    - State the expected cause and effect (if-then statement) in an investigation based on prior knowledge and experience (hypothesis)
- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Function exactly like or similarly to the real thing
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
    - Incorporating laboratory safety practices into the investigation design
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Volume
    - Mass
    - Temperature
  - Choose appropriate tools to conduct an investigation:
    - Glassware (beakers, flasks, watch glass, etc.)
    - Bunsen burner
    - Thermometer
    - Balance
    - Pipette
    - Erlenmeyer flask
    - Graduated cylinder
    - Other Laboratory equipment
    - Hot plates
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
  - Use the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
    - Sketch
    - Diagram
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation

        - Comparing results to hypothesis
        - Answering the testable question
        - Extrapolating results beyond the investigation
- Communication in Science
    - Report results using:
        - Peer presentation
        - Written report
        - Scientific illustration with proper labeling
- Scientific Endeavor
    - Characteristics of Science:
        - One way to make sense of something is to think of how it relates to something more familiar.

Hands-On Lab

Model Earth's Interior

Timing: one 90-minute class session

Objective(s):
Students will model Earth's interior, including its structural and compositional layers.

Safety Precautions:
Offer safety reminders to students relevant to the modeling materials they are working with. For example, remind students to use caution with sharp edges if working with cutting tools. Students should not eat or drink anything in the lab.

Materials:
Per group:

- Assortment of modeling materials and tools (e.g., clay, modeling dough, foam, sponge, paints, yarn, aluminum foil, craft knives, paintbrushes, glue)
- Metric ruler
- **Thicknesses of Earth's Interior Layers** chart

Teacher Preparation:
Before the lab, collect and sort modeling materials so that each group will have access to a sufficient supply of a variety of materials. Groups will not be creating a 3-dimensional model of the entire globe or even half the globe; instead, they will simply show a thin cross-section of the planet. To conserve materials, models may be nearly 2-dimensional, and they should stop at Earth's center—for the purposes of this lab, students may assume that the "bottom" half of Earth's interior mirrors the "top" half. If materials are extremely limited, groups may simply create 2-dimensional posters. You may wish to create your own model prior to class so that you can better anticipate obstacles.

Guided Inquiry will likely require more time to complete than Directed Inquiry. If class time is limited, you may need to assign students parts of the lab to complete for homework.

Make a copy of the Student Investigation Sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Divide students into small groups. Explain that the goal of the lab is to create scale models of Earth's interior layers. Give students a few minutes to discuss with their groups what it means for a model to be "to scale," then discuss responses as a class. If students have difficulty with the concept, ask them to imagine making a scale model of themselves as a 1-m tall clay statue. Ask students questions to guide their thinking, such as:

- What would it mean for your 1-m statue to be "to scale"? *(My body parts would be in the right proportion; my head wouldn't be too big or small compared to my body.)*
- How would you figure out how big you needed to make each part of the statue in order for it to be to scale? *(I would first measure the size of each of my body parts—its length or thickness. Then I would compare these measurements to the size of my whole body by making each body part a fraction or proportion of my whole body. I would then divide the statue into the same proportions using much smaller measurements based on a total height of 1 meter.)*
- How could you follow this process to create a scale model of Earth's interior? *(I would divide the radius of the model by the radius of Earth to figure out what fraction each layer needs to be reduced by.)*

Next, give students a chart containing the thickness of each structural and compositional layer:

Thicknesses of Earth's Interior Layers

Structural Layer	**Approximate Thickness**
Lithosphere	15–300 km (from Earth's surface to top of asthenosphere; average thickness of 80 km)
Asthenosphere	250 km (from bottom of lithosphere to top of mesosphere)
Mesosphere	2550 km (from bottom of asthenosphere to top of outer core)
Outer Core	2200 km (from bottom of mesosphere to top of inner core)
Inner Core	1250 km (radius—i.e., from bottom of outer core to Earth's center)
Compositional Layer	**Approximate Thickness**
Oceanic Crust	5–10 km (from Earth's surface to top of mantle)
Continental Crust	30–100 km (from Earth's surface to top of mantle)
Mantle	2900 km (from bottom of crust to top of outer core)
Core	3450 km (radius—i.e., from bottom of mantle to Earth's center)

Instruct each group to use these data to determine a scale for their models. For example, if every centimeter represents 10 km, then they would need to create a model of Earth with a radius of approximately 630 cm; this is probably too large—a scale of 0.5 cm = 1 km is more reasonable. Again, emphasize that groups will not be creating a 3-dimensional model of the entire globe or even half the globe—they should show only a cross-section of the planet. Groups may also create several models to allow them to use multiple scales—i.e., because the difference in thickness between Earth's top layers and its middle and bottom layers is so great, one model could focus on the crust, while a second model could focus on the mantle and core.

However groups make their models, they should use different materials, colors, or textures to represent each layer, and include labels or a key that identifies each layer and describes its main features. Challenge groups to represent Earth's structural as well as compositional layers in their models; however, you may wish to modify the lab to allow struggling students to represent only one set of layers.

Groups should begin by sketching their models on paper, testing their scale and labeling the thickness of each layer. Check their work and correct any errors in scaling. Then, point out the available modeling materials and instruct groups to determine which materials should represent which layer of Earth. Each group should provide a rationale for its choices based on the actual composition of each layer. (For example, more brittle materials could be used for the lithosphere and more fluid materials could be used for the asthenosphere.) If students struggle, ask them the following guiding questions:

- How will you build the model so that the layers come out in the proper order and thicknesses?
- How will you build the model so that it provides a clear view of Earth's interior structures?
- How can your model represent processes in Earth's interior, like convection? (Note that simple arrows may be necessary to model dynamic processes such as convection.)
- How will you label your model to give viewers information?

Finally, have groups build their models. When they are finished, groups should display their models for the class, ask for feedback, and make any necessary adjustments to improve the accuracy of the models. Have group members discuss the following "wrap-up" questions:

- What were some of the challenges in creating a scale model? *(sample answers: figuring out the correct thicknesses of each layer; accurately representing the crustal thickness relative to the much thicker mantle and core)*
- What are the models good at representing? *(sample answers: the relative thicknesses of the layers; some of the properties of each layer)*
- What are some of the limitations of the models? *(sample answers: It is difficult to show movement in the model, so it was difficult to represent convection cells and lithospheric plate motion.)*

Guided Inquiry

Students can develop their own plans for using the materials to create a scale model of the interior structures of Earth. Students should also conduct their own research to determine the thickness of each of Earth's structural and composition layers. Ask the students some guiding questions to help them focus their inquiry:

- How will you use the information you learn about the thickness of each of Earth's layers to create an accurate scale model?
- How can you use different materials to represent some of the characteristics of Earth's interior layers?
- How will you construct your model to provide a view of Earth's interior?

Groups should begin by sketching their models on paper, testing their scale and labeling the thickness of each layer. Check their work and correct any errors in scaling. Then, point out the available modeling materials and instruct groups to determine which materials should represent which layer of Earth. Each group should provide a rationale for its choices based on the actual composition of each layer. Once you have approved a group's plan, allow its members to build their model.

When groups have completed their models, they should display them for the class, ask for feedback, and make any necessary adjustments to improve the accuracy of the models. Have group members discuss the following "wrap-up" questions:

- What were some of the challenges in creating a scale model? *(sample answers: figuring out the correct thicknesses of each layer; accurately representing the crustal thickness relative to the much thicker mantle and core)*
- What are the models good at representing? *(sample answers: the relative thicknesses of the layers; some of the properties of each layer)*
- What are some of the limitations of the models? *(sample answers: It is difficult to show movement in the model, so it was difficult to represent convection cells and lithospheric plate motion.)*

Analysis and Conclusions:

In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. How did you figure out the appropriate thickness of each layer in your scale model? *Sample response: I figured out the thickness of each layer as a fraction of Earth's radius and then applied those same fractions to the radius of the model.*

2. Were you able to accurately represent the scales of all the layers? Explain. *Sample response: It was difficult to accurately represent the thickness of the crust because it was only a fraction of a percent. Also, different types of crust have different thickness.*

3. What were the challenges of building the model? *Sample answers: remembering to double the thickness of the inner core; adding each layer without deforming the ones beneath; cutting the model to reveal the inside structure without crushing or distorting layers.*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Apply mathematical operations and principles to replicate the real thing.
    - Have been revised as new knowledge and information has been obtained
    - Are based on logic and evidence
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
  - Practice lab safety by:
    - Following lab safety procedures
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Length/distance/depth
  - Choose appropriate tools to conduct an investigation:
    - Ruler/tape Measure
  - Use senses to observe:
    - Seeing (color, shape, size, texture,)
    - Touching (shape, size)
    - Kinesthetic (balance, position)
  - Identify and interpret patterns using:
    - Tables and graphs
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Examining how investigations can be improved
    - Formulating scientific explanations/arguments
    - Showing the application of the scientific concept or process being investigated
- Communication in Science
  - Report results using:
    - Peer presentation
- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating an investigative design
    - Analyzing scientific explanations
- Patterns and Systems
  - Patterns and Change:
    - Many patterns in nature contain symmetry.
- Scientific Endeavor

- Characteristics of Science:
  - Science is based on factual knowledge.
  - An important part of science is the critical review and analysis of any idea or conclusion.

Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

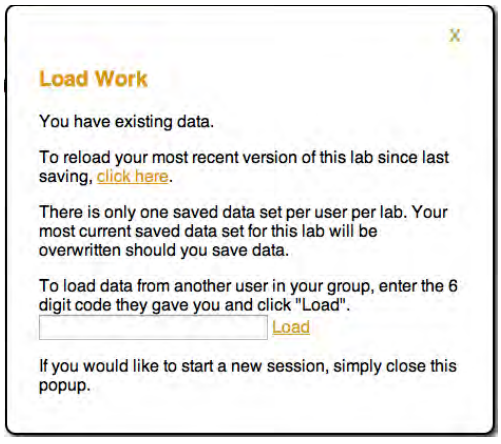
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

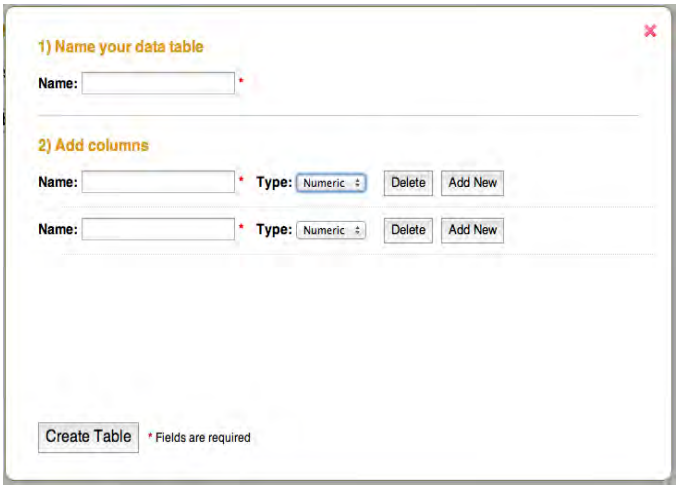
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



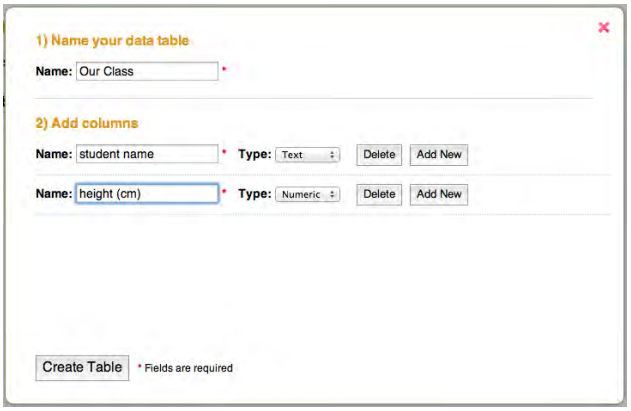
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

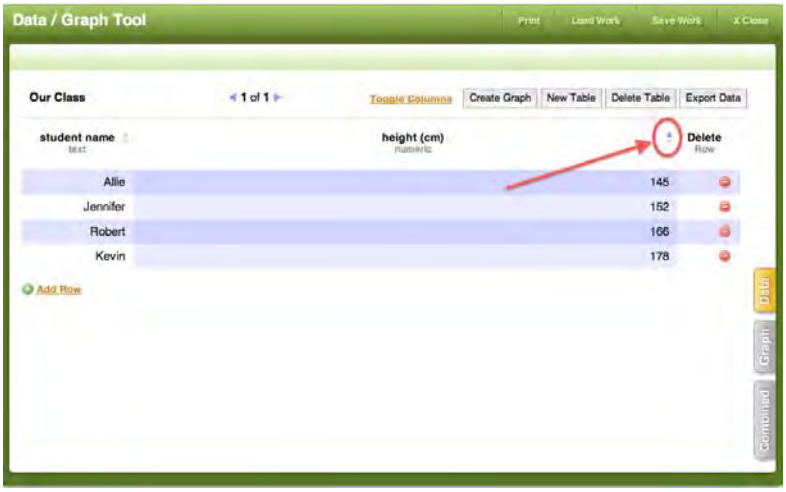
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

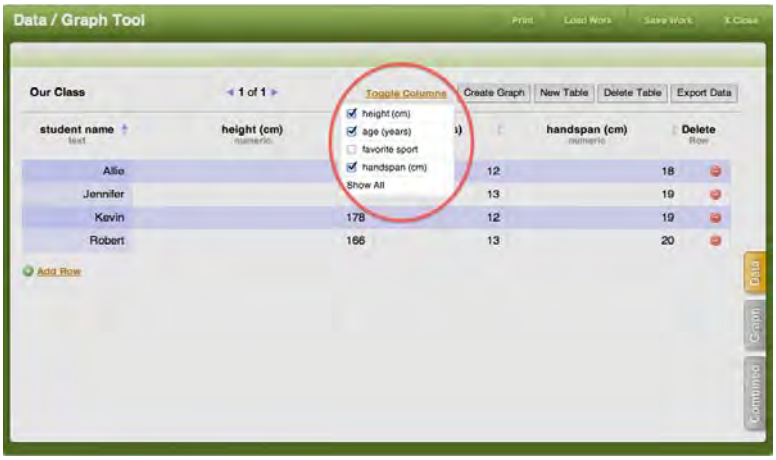


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

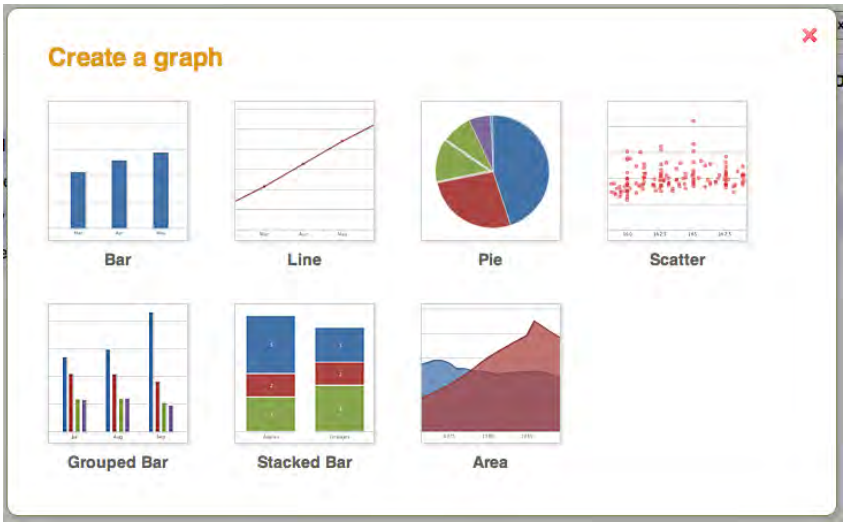
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

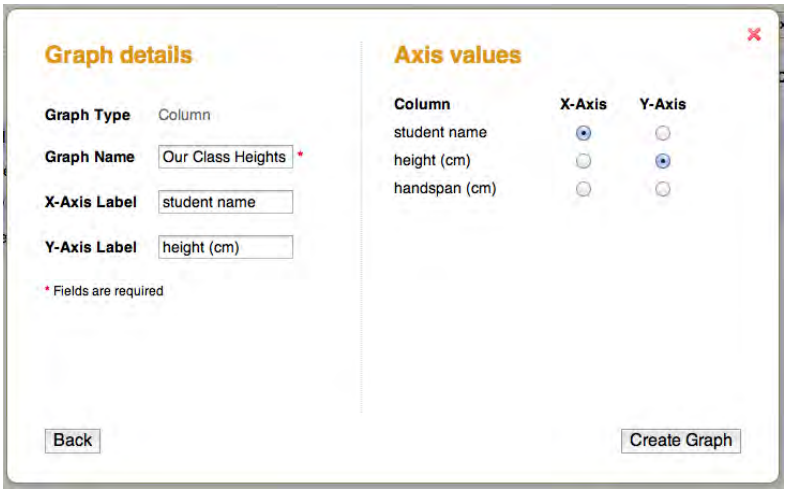
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

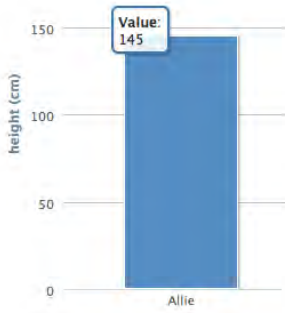


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

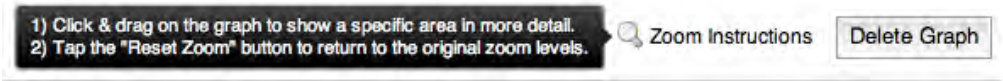
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Demonstrating Plate Tectonics

Timing: one 90-minute class session

Objective(s):
This lab will allow students to visualize various types of plate tectonic processes and evidence for plate tectonics. Students will learn about the apparent fit of continental coastlines, features that match across oceans, mantle convection, the symmetrical patterns that result from seafloor spreading, and subduction.

Safety Precautions:
Students should be advised to wear goggles, aprons, heat-proof gloves or oven mitts, and closed-toed shoes, and take caution around the hot water and hot plates. Teachers may wish to choose the best set of foam "continents" from the class and perform the hot water portion of the lab as a demonstration.

Materials:
Per small group:

- Several sheets of craft foam (for best results, at least 7 sheets per group)
- Large world map or other printout displaying the shapes of each of the 7 continents
- Tracing paper
- Permanent and fine-tipped markers
- Scissors
- Large, clear, glass container (such as a fish tank) filled half to three-quarters with water
- 1 hot plate (large enough to hold glass container)
- Thermometer
- 1 bottle of food coloring
- 1 sheet of long (at least 14 inches), unlined paper
- Ruler
- Two bricks of brown (or similar color), soft, modeling clay or dough
- 1 sheet of long (at least 14 inches), blue paper
- 2 desks pushed together

Teacher Preparation:
Gather the materials needed for each group. Expanded polystyrene (EPS) foam is recommended for best results. Teachers may wish to test the craft foam in advance for heat resistance—the foam must be able to withstand hot water without melting. For each group, place a large, open, glass container atop a hot plate. Fill each container about half-way to three-quarters with water. (Alternatively, teachers may wish to set up one such station at the front of the classroom to perform the mantle convection part of the lab as a demonstration only. This will help avoid any safety issues for the students and will require fewer materials.)

The Hands-On Lab: **Investigating Evidence for Continental Drift** for the high school Earth and Space Science concept **The Continental Drift Hypothesis** contains diagrams from which

students may obtain cut-outs of each continent. (If you use another source, remember that most 2-dimensional maps distort the sizes of the continents, particularly Antarctica; you may need to combine multiple sources to obtain appropriately scaled cut-outs of all seven continents.)

In addition to the other materials needed for each group, prepare for each student a copy of the Student Investigation Sheet found at the end of this lab.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

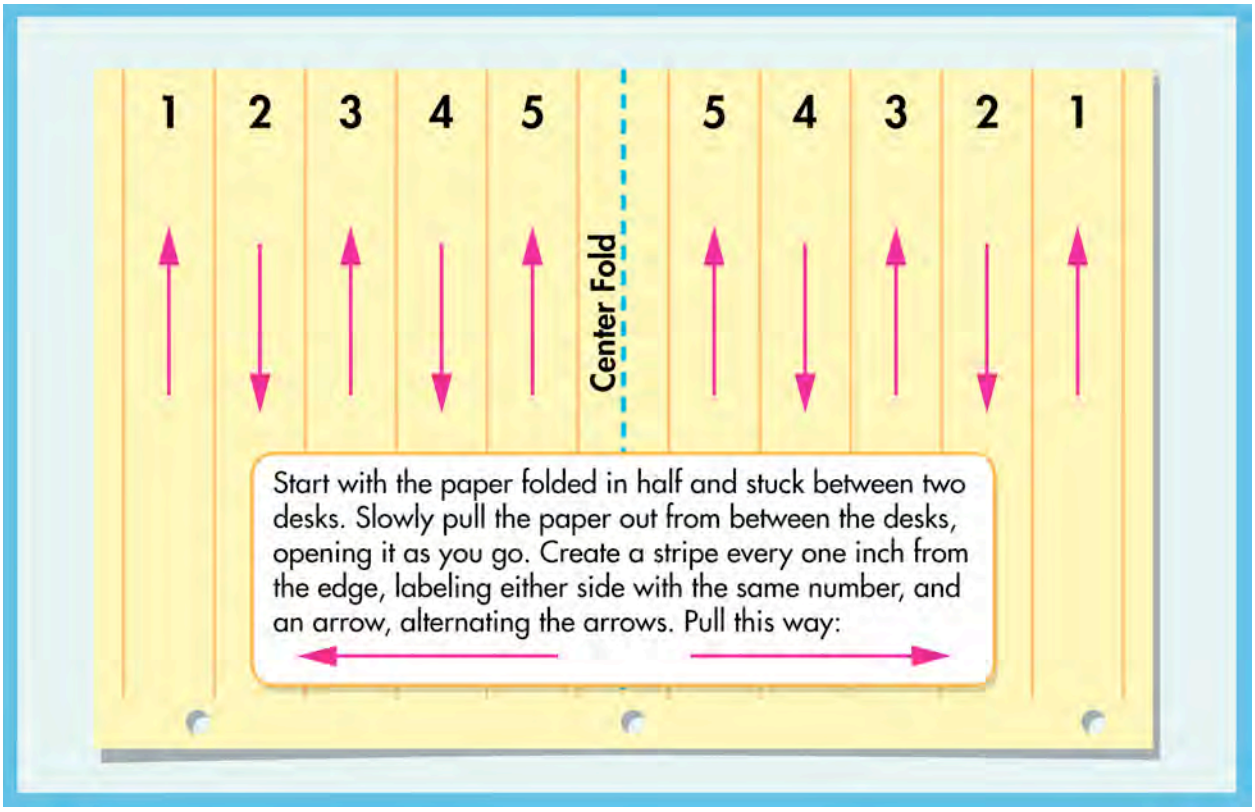
You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>
Divide class into groups of 2–4 students and distribute materials to each group. Instruct students to trace the shapes of the seven continents from the world map onto the tracing paper. Then instruct groups to place their tracing paper on the craft foam and cut the shapes of each continent out of the foam. Have groups "fit" the foam continents together to see how the coastlines match up (e.g., the eastern coastline of South America fits into the western coastline of Africa). Students can also draw matching fossils or other features on opposite coastlines (i.e., two different continents separated by an ocean) using permanent marker. This section of the lab procedure demonstrates the evidence for continental drift, including the apparent fit of continents and the discoveries of matching fossils and geological features on opposite sides of oceans. Instruct each student to write a paragraph explaining how this evidence supports both continental drift and the theory of plate tectonics; when they finish, students should discuss their responses within their groups.

Explain that the following part of the lab demonstrates the process of mantle convection. Instruct each group to place its foam continents in the container of water on its hot plate. Students should place the thermometer in the water. Instruct the groups to turn on their hot plates and

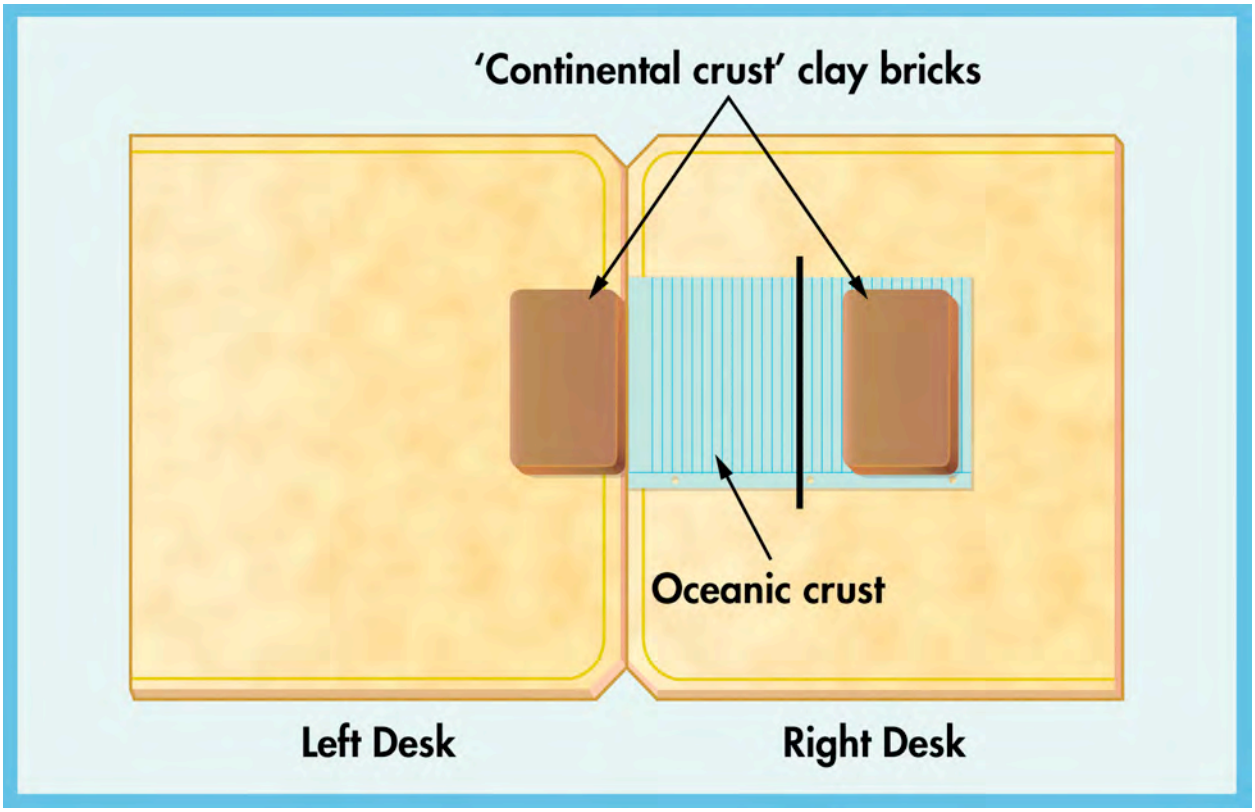
heat the water until it is approximately 60 degrees Celsius. Groups should reduce the heat setting on their hotplates and then place a few drops of food coloring into the water near one side of the container; this will make it easier to see the convection cycles after the water heats. Have students note how the convection cycles move the foam continents and the red food coloring, and have them write a paragraph explaining how this relates to mantle convection and plate tectonics.

Explain that the following part of the lab demonstrates how divergent boundaries form seafloor spreading centers, as well as how symmetrical patterns of age and magnetic polarity form on either side of mid-ocean ridges. Give each group a long sheet of unlined paper. Instruct each group to fold its paper in half and draw a series of vertical lines about an inch apart between either side of the fold and the paper's edges, creating a dozen or so "stripes." Each group should then place its paper (with the fold at the bottom) between two desks that are pushed together. Instruct each group to slowly pull the two ends of its paper between the two desks, stopping each time a new pair of stripes appears, and numbering these stripes. (For example, the outside inch of either side of the paper will each be labeled 1, the next inch toward the middle of the paper will be labeled 2, and so on.) In addition to numbering the stripes, instruct each group to draw vertical arrows, alternating direction with each pair of stripes. The following diagram shows how the paper should look by the time it has been completely pulled between the desks. Students can also watch the video segment **The Ocean Floor: Clues About Continental Drift on Earth** (from approximately 1:35–2:30) to see an example of this process.



When groups finish, instruct each student to write a paragraph explaining how this part of the lab relates to seafloor spreading, symmetrical age patterns on either side of mid-ocean ridges, magnetic pole reversals, and plate tectonics.

Explain that the following part of the lab demonstrates how subduction zones form between oceanic and continental crust and how the folding of continental crust on a large scale can produce folded mountains. Give each group a long sheet of blue paper and two bricks of soft brown clay or dough. The brown clay represents continental crust, and the blue paper represents oceanic crust. Groups should keep their desks pushed together. Instruct each group to place one of its “continental crust” clay bricks on the edge of the left-hand desk where it meets the right-hand desk. Each group should then place its sheet of blue paper on the right-hand desk and place the other “continental crust” clay brick on top of the right-hand side of the paper. Each group should then draw a line down the center of its blue paper and label the left-hand side of the blue paper “oceanic crust.” The resulting arrangement will model two “continents” with an “ocean” between, as shown below:



Next, instruct each group to begin pulling its “oceanic crust” paper down between the two desks, so that the “oceanic crust” is subducting beneath the left-hand “continental crust” and pulling the right-hand “continental crust” along with it. Once the two “continents” meet, have students push the clay bricks together and observe how they “fold” in the middle. Instruct the students to write

a paragraph explaining how this relates to subduction zones, convergent boundaries, slab pull, folding, mountain building, and plate tectonics.

Guided Inquiry

Students can develop their own plans for demonstrating plate tectonics, based on their knowledge of the concepts and materials provided. Ask the students some guiding questions to help them focus their inquiry:

- How can the materials provided be used to demonstrate the following events and phenomena?
    - Continental drift
    - Mantle convection
    - Seafloor spreading
    - Subduction
    - Folding and mountain building
- How does each of these events or phenomena relate to plate tectonics?

Divide class into groups of 2–4 students and distribute materials to each group. Instruct groups to use the craft foam, map or cut-outs of the continents, tracing paper, permanent markers, and scissors to demonstrate the evidence for continental drift, including the apparent fit of continents and the discoveries of matching fossils and geological features on opposite sides of oceans. Groups should come up with their own procedures, and each student should write a paragraph explaining how his or her group's procedure demonstrates these concepts and relates to the theory of plate tectonics.

Instruct groups to use their foam continents, the container of water, the hot plate, and the food coloring to demonstrate how mantle convection drives tectonic plate motion. Groups should come up with their own procedures, and each student should write a paragraph explaining how his or her group's procedure demonstrates these concepts and relates to the theory of plate tectonics. Instruct groups not to allow the water in their containers to reach a full, rolling boil, lest they risk melting their foam. Make sure that students wear goggles, aprons, heat-proof gloves or oven mitts, and closed-toed shoes, and use caution around the hot water.

Next, give groups the long sheets of unlined paper and fine-tipped markers. Instruct each group to fold its paper in half and place the paper (with the fold at the bottom) between two desks that are pushed together. Groups should come up with their own methods for using the materials to demonstrate the concepts of seafloor spreading, symmetrical age patterns on either side of mid-ocean ridges, magnetic pole reversals, and plate tectonics. Each student should write a paragraph explaining how his or her group's demonstration represents divergent boundaries in the form of seafloor spreading centers, as well as symmetrical patterns of age and magnetic polarity on either side of mid-ocean ridges.

Next, give each group a long sheet of blue paper ("oceanic crust") and two bricks of soft brown clay or dough ("continental crust"). Instruct each group to set up its materials as described in the Directed Inquiry section of this lab. Groups should come up with their own methods for using the materials to demonstrate the concepts of subduction zones, convergent boundaries, slab pull, folding, mountain building, and plate tectonics. Each student should write a paragraph explaining how his or her group's demonstration represents convergent boundaries in the form of subduction zones and continent-continent convergence, slab pull, folding, and mountain building.

After about 60 minutes, regroup as a class and discuss the choices each group has made to this point. Compare and contrast the demonstrations developed by different groups. Ask students to explain how their demonstrations represent the key concepts that relate to plate tectonics.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. The apparent fit of continents and the matching of fossils and geologic features on opposite sides of oceans were used as evidence for Wegener's continental drift hypothesis. How has this evidence for continental drift evolved into evidence for the theory of plate tectonics? *The theory of plate tectonics describes how tectonic plates move together and apart over time. Unlike the continental drift hypothesis, the theory of plate tectonics explains the mechanisms that cause the continents to drift.*

2. Observations of convection cycles in hot water can be used to help visualize mantle convection. How do convection cycles in water differ from convection in Earth's mantle? *The mantle is made of soft, solid rock, not water or some other liquid. This means that the mantle is significantly more viscous than water—i.e., it flows more slowly. Therefore, convection happens much more slowly in Earth's mantle than in water.*

3. Explain how one type of plate boundary, such as a subduction zone, can eventually lead to another type of plate boundary, such as convergence between continents. *Eventually, a subduction zone between a continental plate and an oceanic plate can cause an ocean to close, bringing two continents on either side of the ocean together.*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - Asks a question about a specific science concept or process.
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship.
- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated.
    - Have as many details as possible replicated from the real thing.
    - Function exactly like or similarly to the real thing.
  - Practice lab safety by:
    - Following lab safety procedures
    - Incorporating laboratory safety practices into the investigation design
- Communication in Science
  - Report results using:
    - Written report
- Scientific Investigation
  - Scientific Data and Outcomes
    - People are more likely to believe ideas if good reasons are given for them.
- Scientific Endeavor
  - Characteristics of Science
    - Scientists are curious about wanting to know how things work.
    - One way to make sense of something is to think of how it relates to something more familiar.
    - Scientific theories are based on accumulated evidence.
    - Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory* leads to looking at old observations in a new way
    - A theory is a well-supported and widely accepted explanation for what is observed in the natural world.
  - Historical Perspectives
    - Theories are developed over time by the accumulation of evidence.

Exploration Teacher Guide: Evidence for Plate Tectonics

Overview

Mountain building, much of which is a result of plate tectonics, can be studied by making detailed maps of the rock formations that make up the mountain system. These maps include not only the rock type and age, but also the orientation of the rock layers, which can reveal how the layers have been faulted, tilted, and folded. In this Exploration, students examine the structure of the rock formations along a transect. They also examine the rock types and ages, and measure the strike and dip of the layers at each location.

Student Learning Objectives

- Examine the structure of the rock formations along the transect.
- Examine the rock types and ages of rocks at each location along the transect.
- Identify the strike and dip of layers at each location along the transect.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion. Note that some questions may require critical thinking and application of concepts and skills not addressed directly in this Exploration. These questions are better for discussion than assessment.

Using this Exploration

In the *Apparatus* tab, students get familiar with the apparatus used in this Exploration. They learn about the working of the Brunton compass and its parts. They may use the *View Image* button to observe the parts of the compass face. They learn the procedures to set the magnetic declination of the area, measure the strike, and measure the dip of geological features with the help of animations by selecting the respective radio button options and then using the *View* button.

In step 1 of the *Explore* tab, students select a location that they want to examine using any one of the ten options along a transect and then selecting the *Examine* button. Students may also use the *Reset* button to undo what they have done. They use the *Proceed* button to identify the strike of the outcrop at the selected location.

In step 2 of the *Explore* tab, students select the *Read* button and then the radio button options to record the strike of the outcrop. They use the *Proceed* button to identify the dip of the outcrop at the selected location.

In step 3 of the *Explore* tab, students select the *Read* button and then the radio button options to record the dip of the outcrop. They may also use the *Zoom In* button to view the clinometer scale up close.

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On correctly recording the strike and dip at five or more locations, students can either examine more locations by using the *Examine Another Location* button or analyze the data that they have collected by using the *Map* button. Students then use the *Proceed* button to identify the structure in step 4 of the *Explore* tab.

Students identify the structure by choosing one of four clickable options. On correctly identifying the structure, they then identify the tectonic environment that the structure most likely formed in. They use the radio button options to make their selections and the *Submit* button to validate their selections.

In the *Tracker* tab, students track the locations along the transect that they have explored. They also examine the type of rock, age of rock, fossil, strike and dip of each of these locations.

Answers to Questions in the Student Worksheet

1. What is magnetic declination? Why is it important to set or check the magnetic declination on a compass whenever you go out into the field to map rock formations? What can happen if you do not make sure the declination on the compass is set correctly?

   Answer: The difference between the direction of true north and the direction of magnetic north, wherever you are is called magnetic declination. It is important to check or set the declination on the compass because magnetic north moves continuously. This means that the difference in direction between true north and magnetic north changes over time and is different from place to place. If the declination is not correct, all of your strike measurements will be incorrect.

2. Explain how the strike of a plane is measured.

   Answer: To measure strike, place the compass against the plane that you want to measure. (That is, against the surface of the layer of rock or against the fault plane.) Orient the front end (the end with the sighting arm) so that the rock layer is dipping off to the right of the compass. Orient the compass so that it is against the plane, and is also horizontal from front to back, as well as from side to side. When the compass is perfectly horizontal, the bubble in the bull's eye tube will be in the center of its circle. Read and record the number that the north end of the needle is pointing to. This is the strike of the plane.

3. The directions E (East) and W (West) appear reversed in the Brunton Compass. Explain.

   Answer: The directions E (East) and W (West) appear reversed in the Brunton Compass for taking direct readings. The needle of the compass always points to the magnetic North pole. If the user turns clockwise by 90° to face West, the needle of the compass points towards the W (West) marker on the compass. If the directions E (East) and W (West) were not reversed, the needle would be pointing towards E (East) marker the compass.

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4. What is the difference between azimuthal notation and quadrant notation while using a Brunton compass? Provide four conversions of azimuthal and quadrant notation.

   Answer: Azimuthal notation is whole circle bearing with respect to the North. The readings range from 0° to 360°, where both 0 and 360 are due North Quadrant notation divides the whole circle bearing into four equal quadrants and the readings are taken with respect to North or South, and East or West. The readings range from S0° - 90° E/W or N0° - 90° E/W, where S15° W, for example, means 15° west of south.

Table 1: Examples of azimuthal notation and their quadrant notation

Azimuthal	Quadrant
20°	N20° E
170°	S10° E
200°	S20° W
290°	N70° W

5. In this Exploration, the Brunton compass is used to measure the strike and dip of an outcrop at a given location. Describe some other uses of the Brunton compass.

   Answer: Apart from measuring the strike and dip, the Brunton compass can be used to measure the plunge of linear features, to measure the vertical angles and height of features, to measure the bearing of line between two points, and as a hand level on a Jacob's staff.

6. Describe the typical deformation associated with the following tectonic boundaries:

   a. Convergent

   b. Divergent

   Answer:

   a. Folding and thrust (or reverse) faulting is associated with convergent boundaries.

   b. Thinning and extension of the lithosphere, and normal faulting area associated with divergent boundaries.

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7. Determine whether the following statements are correct. If incorrect, modify the statement such that it is correct.

    a. In a convergent tectonic environment, plates move towards each other and collide to cause deformation.

    b. In a transform tectonic environment, plates move away from each other and cause deformation.

    c. In a monocline, the layers dip in the same direction.

    d. The dip of a vertical feature is 0°.

Answer:

a. Correct.

b. Incorrect. In a transform tectonic environment, plates slide past each other and cause deformation.

c. Correct.

d. Incorrect. The dip of a vertical feature is 90°.

8. In this exploration, you collected data on not only the strike and dip of the rock layers, but also the rock type, fossils present, and age of the layers. Explain how each of these pieces of data helps a geologist interpret what the formation looks like underground and what the formation can tell us about the tectonic history of the area.

Answer:

a. Strike and dip provide information about the orientation of the layers. This helps us figure out the overall shape of the formation. This gives us clues about how the formation was deformed and from which direction the forces that deformed the rock may have come.

b. The rock type helps us to correlate different outcrops and tell the difference between different layers. The rock type also gives us clues about the environment that the rock formed in.

c. The fossils present give us clues about the environment the rock formed in and the age of the rock.

d. Knowing the age of the rock layers is important because the order that the layers are founds indicates whether the rocks have been turned upside down or not. The order can also indicate whether the formation is folded into a syncline (younger rocks in the center) or an anticline (older rocks in the center).

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9. Assume that the structure you explored in this Exploration is real. Explain how it formed in terms of the theory of plate tectonics.

   Answer: This structure is a syncline, which is a type of fold. It formed when a force compressed the rock layers. According to the theory of plate tectonics, this force was likely the force of two tectonic plates (or lithospheric plates) converging, or crashing, causing the rock layers to bend slowly into a U-shape.

10. Describe how the measurements you made would differ if the formation was:

    a. An anticline

    b. A monocline

    c. Undeformed

    Answer:

    a. If the structure was an anticline, the layers would have dipped away from the middle instead of toward the middle. The oldest layer, not the youngest layer, would be in the middle of the structure.

    b. If the structure was a monocline, the layers would have dipped the same way from the beginning to the end of the transect.

    c. Since the rocks are sedimentary, if the layers were undeformed, they would all have been nearly horizontal.

11. Using an isogonic map, identify the magnetic declination at your location.

    Answer:

    Note: The answer to this question varies from location to location.

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Hands-On Lab

Feedback Effects on Earth's Surface Features

In this investigation, students will explore three important geologic concepts: plate tectonics, weathering and erosion, and sedimentation. All three concepts rarely occur together in nature, but when they do the results can be very dramatic. In this experiment, students will model the geologic conditions that have shaped many coastal regions when a continent sits on the edge of a tectonic plate, and that plate overrides another tectonic plate in a process known as subduction. After the continent is forced upward by the subduction, students will then look at how weather and erosion tear down the sharply sculpted features of the uplifted mountain chain to a much more rounded landmass. Finally, we will see how the rock and mineral particles that have been eroded from the landmass are sorted by the amount of energy that is available for transporting the grains of various size, shape, and mass.

Timing: one 90-minute class session

Objective(s):
Students will investigate the uplift of a model mountain chain by tectonic force that mimics two plates colliding in a subduction scenario. This will result in a "coastal" landmass with steep cliffs and a sharp ridgeline. This mountain will then be subjected to erosional forces so that over time the landmass becomes both lowered and rounded, with pockmarks mimicking caves in limestone strata. The eroded particles of sand and gravel will be sorted by particle size, shape, and mass to show that depositional features such as alluvial fans are often well-sorted by the amount of water or wind energy available to transport the particles.

Safety Precautions:
Students should be required to wear all applicable personal protection equipment including goggles, lab gloves, and apron. Any eye or skin irritations or material spills should be immediately reported to the teacher.

Materials:
Per pair:

- Large tray, such as a cat litter box, baking pan, or plastic storage box
- Sand, 2 cups
- Baking soda, 2 cups
- Gravel, fish tank, 2 cups
- Vinegar, 1 cup
- Spray bottle filled with water
- Trowel or board (that will be used to push and sculpt the material)
- Paper towels

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Teacher Preparation:

- Gather materials in advance of students performing the lab.
- Open lab windows if possible to provide adequate ventilation
- Provide a large solid waste container for proper disposal of solid materials
- Provide or require that students provide the required laboratory materials

Procedure

1. Have students empty into a large tray equal amounts of sand, baking soda, and fish tank gravel. Then have them blend the dry materials with their gloved hands or a stirring device. The dry material should cover the bottom of the tray to a depth of about two inches (use more materials if the tray is very large).
2. As one student uses a trowel or piece of wood that fits inside the tray, another student should lightly spray the area in front of the trowel with water. This will both mimic how ocean water is used as a lubricant for subduction events as well as provide a mechanism to allow the particles to stand at a steep angle of repose during the experiment. Students should strive to develop what looks like a steep-walled cliff on the "ocean" side nearest the trowel, as well as a sharp ridgeline on the material that is pushed into the shape of the mountain chain. The end result should be that about a half of the tray has been scraped clean of particles. The experiment works best when the trowel is moving along the longest axis of the tray. Students may need to also wet the side of the mountain chain to provide slope stability. It is acceptable if students use their gloved hands to further shape the mount to the desired sharp ridgeline.
3. Students should note that immediately after the tectonic force is applied, the landmass exhibits sharply angled features such as steep cliffs and a sharp ridgeline. It should be pointed out to them that such angularity is the signature of a landform that was formed very recently in geologic history. Students should be asked to name a mountain chain that today exhibits such features. Appropriate answers would include the Alps, Himalayas, and Rockies.
4. In successive two-ounce increments, students should pour vinegar along the length of the mountain ridgeline. This will mimic chemical and physical erosion of the landmass. After several iterations of vinegar applications, the mountain chain will begin to become lower and rounder as the baking soda reacts. The end product should be a slightly raised mountain chain that is very rounded in form. The slopes of the landmass will be pocked with numerous "caves" where "limestone" strata has been chemically eroded. Students should be able to see that the mountain was weathered by the acidic nature of the vinegar and eroded by the gravitational force of the pourings.
5. In the portion of the tray left bare by the trowel, an alluvial fan should have developed as the vinegar washed into the depression. This same effect may also be noted on the "continental" side of the mountain. Students should note that the sand particles have washed farther from the main landmass than the heavier and coarser fish tank pebbles. In nature, larger and more angular particles are most often found closest to the source of the material, while smaller and rounder particles are found at greater distance from the parent rock.

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Analysis and Conclusions

1. Describe the properties of the landform that resulted from the collision of two tectonic plates. What mountains today exhibit these features?

A mountain chain developed and increased in height as more force was applied. The sea-side of the mountain chain exhibited steep cliffs, and the ridgeline at the top of the mountain chain was sharp and jagged. These features are found in "young" mountains such as the Alps, Himalayas, Andes, and Rockies.

2. What changes took place in the mountain features as more and more "rain" (in the form of vinegar in this experiment) was poured over time? Name mountain chains that show these features today.

The materials that made up the mountain chain reacted, partially dissolved, or washed out, causing the mountain to become more and more rounded in shape as well as lower in elevation. Also, solution caverns formed where the carbonate materials were weathered. These features are found in "mature" mountain chains such as the Appalachians and Ozarks.

3. Why was vinegar used as an erosional driver? What kind of weathering does this mimic?

The slightly acidic vinegar reacts with the baking soda, causing the sand and gravel to collapse and wash away. This was done to mimic the process of chemical weathering, as the vinegar reacted with the baking soda.

4. Describe where the particles of sand were deposited in relation to the particles of gravel. Which type of particle would require more water or wind energy for transportation?

The sand washed farther from the source material than the gravel. The gravel, being heavier and less rounded, would require much more energy to transport than the sand.

5. What type of rock strata would be more likely to form caves: sandstone or limestone? Why?

The baking soda quickly reacted with the vinegar. In nature, limestone, which is calcium carbonate, would be weathered by acid rain to form solution caverns. The silica of sandstone is much more impervious to the effects of acidic rain.

6. Explain whether the changes you observed were reversible or irreversible, and give reasons for your classification.

The changes were irreversible. The "boulders" (gravel) will not roll back uphill to re-form the mountains. Once the rocks have undergone chemical weathering, they do not re-form the same materials.

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

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Exploration Teacher Guide: Absolute Dating

Overview

In this Exploration, students will measure and calculate the parent-daughter ratio of isotopes used to find the absolute age of geologic samples. They will then convert parent-daughter ratio to percentage of original parent atoms remaining, and use this to determine the absolute age of the samples.

Student Learning Objectives

- Identify the isotopes used for the absolute dating of geologic samples.
- Examine the experimental setup used for absolute dating.
- Investigate the relationship between parent-daughter ratios of isotopes, half-life of a parent, and age of a rock or mineral sample.
- Calculate the absolute age of the sample from the percentage of original parent atoms remaining in the sample.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

Students can use the *Apparatus* Tab to examine the apparatus used for absolute dating. The radio buttons for *Experimental Setup* and *Mass Spectrometer* can be used to toggle between the two.

The procedure for absolute dating varies from isotope to isotope and this exploration is idealized to convey the basic concepts. In the *Find Age* Tab, students must select one of the eight samples that they wish to place in the mass spectrometer. Samples available in the Exploration include *Basalt, Granite, Gneiss, Human Skeleton, Skeleton of Animal, Living Tree, Buried Log,* and *Meteorite*. Students must use the radio buttons for ^{14}C, ^{238}U, and ^{87}Rb to select which parent isotope they want to use for the absolute dating of the selected sample. Checkboxes for *Show Information* and *Show Half-Life* can be used for more information about each isotope. The student must then use the *Measure* button to measure the parent-daughter ratio of the chosen isotope in the sample. If the isotope chosen is inappropriate because of the sample's age or composition, students will be prompted to choose a different one. Clicking on *Proceed* will take students to the next step, where they will use the parent-daughter ration to calculate the percentage of original parent atoms remaining in the sample. Students must then drag the yellow pointer on the graph so that it has a *y*-value that matches the percentage of the original parent isotope atoms that still remain in the sample. The *Check* button can be used to validate the answers and receive feedback about the sample. Students can use the *Select Another Sample* button to restart the Exploration with another sample.

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Students can use the *Tracker* tab to track the samples that they have dated successfully. They can compare the selected elements, their half-lives, remaining element percentage in the sample, and the age of the sample for each run.

Answers to the Questions in the Student Worksheet

Note that some answers provide more information than would be expected from the student. These questions are better used for review and discussion than for assessment

1. Explain what the half life of a radioactive isotope is and why it is important in absolute dating.

   Answer: The half life of an isotope is the time it takes for half of the atoms in an isotope to decay. It is a common way of expressing the rate of radioactive decay. If the half life of a radioactive isotope is known and the parent/daughter ratio can be measured or calculated, the age of the sample can be calculated.

2. Describe how a mass spectrometer is used for absolute dating.

   Answer: A mass spectrometer ionizes the atoms in a sample and then separates the ions according to their mass. It detects and counts individual ions or calculates the number of ions of a particular mass based on the electrical current carried by the beam of ions. The MS can be set to measure parent isotopes, daughter isotopes, or related isotopes. Computer software then analyzes the measurements, comparing the amounts of different isotopes in the sample and calculating isotope ratios. These ratios, along with the half-lives of the isotopes, are then used to calculate the age of the sample.

3. Why is it important to consider the half-life of an isotope, the relative age of the sample, and the composition of the sample when deciding which isotope to use to date a sample?

   Answer: The isotope to be used for dating a sample depends on the relative age and composition of the sample. This is because the carbon, uranium, and rubidium, all have different half-lives. The isotope to be used for absolute dating is selected by approximating the relative age of the sample and choosing an isotope with a corresponding half-life.

4. This exploration is about absolute dating. Yet the feedback on all of the dates says that the ages are "about" a certain number of years. Why doesn't the feedback state that the age is exactly a certain number of years?

   Answer: There is uncertainty in any measurement. With respect to absolute dating of rocks, no technique can provide a date as precise as a single year. The uncertainty in measurement can be less than 1%, but if a rock is 100 millions of years old, for example, 1% is 1 million years. The uncertainty can be caused or affected by a number of factors, including experimental error, possible loss of daughter atoms or addition of parent atoms, the half-life of the isotope being used, the amount of sample used, and the age of the sample.

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5. Use this Exploration to identify the best method for dating bones of animals that are only a few thousand years old. Explain why this is the best choice.

   Answer: The carbon dating method is the best method for dating bones because bones are very rich in carbon and are too young to be dated effectively using rubidium or uranium. Carbon-14 has a half-life of 5,730 years, which is ideal for samples that are a few thousand years old.

6. Imagine you measure the abundance of parent atoms and daughter atoms in a sample and find that there is almost the same number of parent as daughter atoms. What does this tell you about the age of the sample? Explain your answer.

   Answer: The age of the sample must be about the same as the half-life of the isotope. After every half-life, about 50% of the parent atoms have decayed to form daughter atoms, leaving 50% as parent atoms. Assuming there are no daughter atoms to start with, the ratio will therefore be 1:1.

7. Why is it important to have some idea about the relative age of a sample before radiometric dating?

   Answer: The isotope that you choose to use to analyze the rock should have a half-life that is appropriate for the general age of the sample. If the sample is very young and the half-life is very long, not enough atoms will have decayed to provide a statistically valid sample. If the sample is very old and the half-life of the isotope is very short, there will be too few parent atoms left to measure. In general, a half-life close to the actual age of the sample is ideal.

8. Why is it important to be careful interpreting absolute ages of clastic sedimentary rocks such as sandstones?

   Answer: Clastic sedimentary rocks are made of pieces of other rocks and minerals. If you date a sedimentary rock, you may actually be dating a piece of an older rock.

9. Identify three assumptions that radiometric dating relies on.

   Answer: Decay rate of an isotope is constant; there is no addition or removal of parent or daughter atoms except through radioactive decay once the rock forms; the instrument (the mass spectrometer) is measuring accurately.

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10. Carbon-14 decays to form nitrogen-14. Nitrogen-14, however, is a gas and can therefore escape from the sample over time? Because of this, we cannot calculate the age of a sample by measuring the carbon-14 to nitrogen-14 ratio in it. (We use a slightly different method instead.) If we did use this ratio to calculate the age, how would this calculated age differ from the actual age? Explain your answer.

    Answer: The calculated age would be less than the actual age. This would happen because atoms of the daughter isotope, N-14, have escaped. The ratio of parent to daughter atoms would be higher, which would make it look like the percentage of parent atoms remaining was higher than it is, and that therefore less time has passed.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

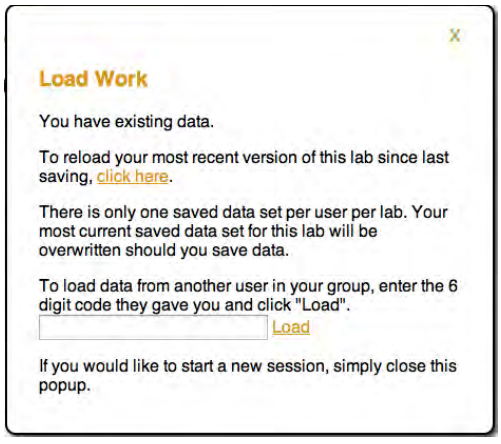
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

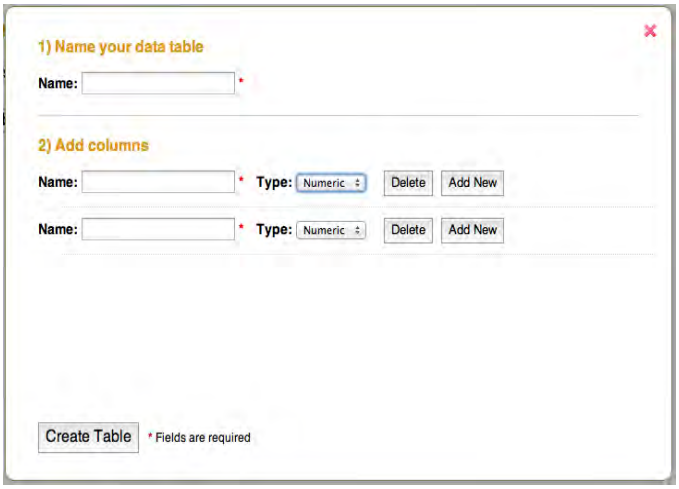
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



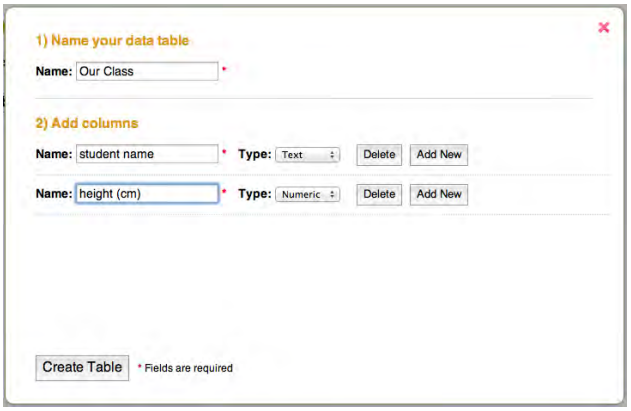
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

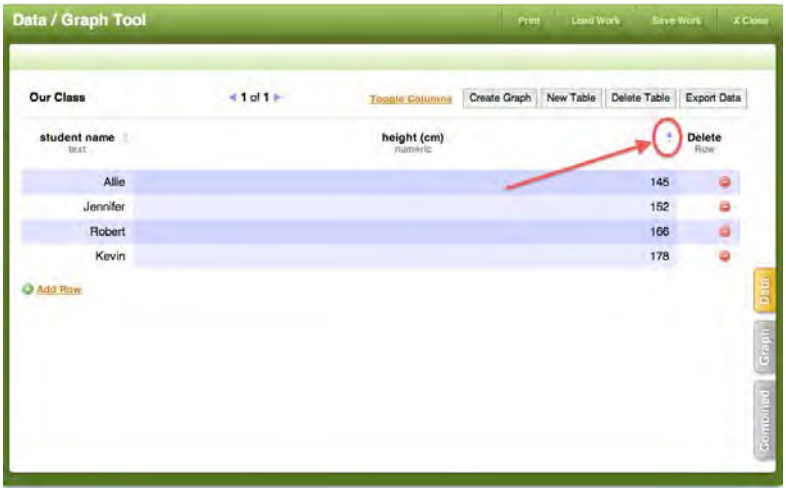
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

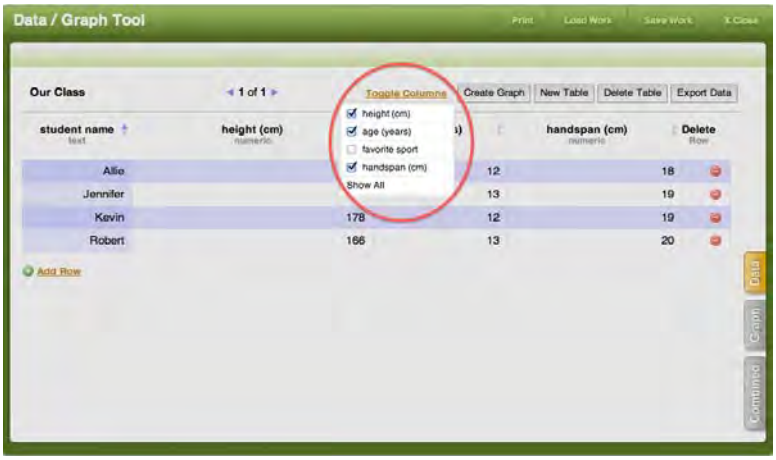


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

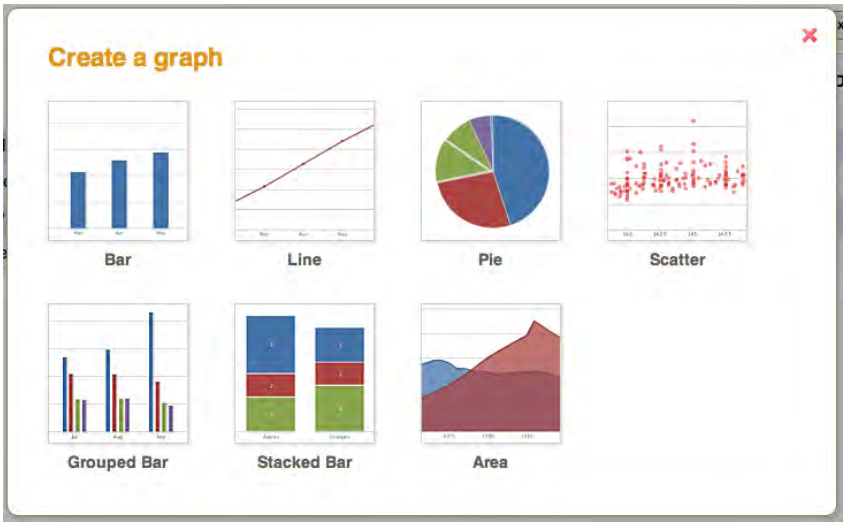
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

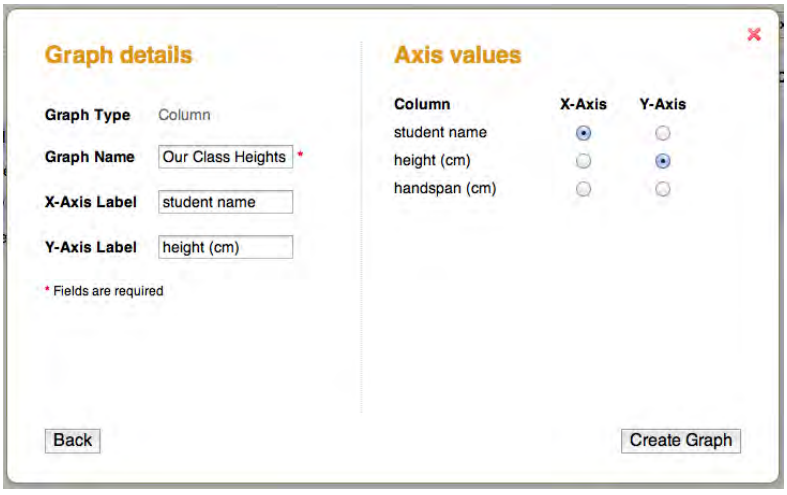
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

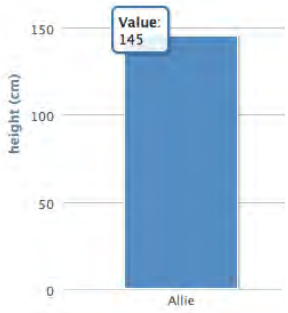


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

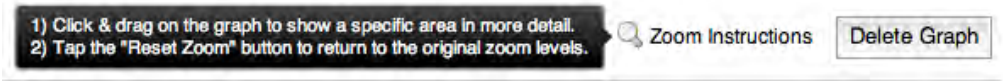
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Determining the Relative Age of Events

Timing: one 90-minute class session

Objective(s):
In this activity, students will construct scientific explanations to describe the geologic history of “rock layers” made of clay. Students will apply the principles of superposition, original horizontality, and cross-cutting relationships to determine the relative age of each layer in the model.

Safety Precautions:
Caution students that they should immediately clean up any clay that falls on the floor to avoid slipping. Encourage students to avoid mixing the colors as they build their models so that the clay can be separated and reused.

Materials:
Per pair or group:

- (5) sticks of modeling clay, different colors
- (1) plastic knife
- (1) sheet of wax paper
- (1) sheet of white paper

Teacher Preparation:
Gather the materials for each group. You will need a set of materials to use for the demonstration in Directed Inquiry.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students’

activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Demonstrate for students how to build a three-dimensional cross-section model of rock layers that have been cut by a fault line using the clay. One possible procedure follows:

1. Work a stick of clay between your hands to soften it.
2. Place the clay on the wax paper and flatten it to form a rectangle. Have students recall the principle of original horizontality.
3. Soften a second stick of clay. Place it above the first piece of clay on the wax paper and flatten it to form a rectangle. Have students recall the principle of superposition by identifying the relative age of each layer.
4. Repeat Step 3 with a third stick of clay.
5. Use the plastic knife to create a diagonal fault line through the rock layers. Move the layers along the fault. Have students recall the principle of cross-cutting relationships to identify the fault as being younger than the layers through which it cuts.
6. Ask students how they could demonstrate folding using the model you have constructed. Solicit answers and then demonstrate folding by grasping the model on each side and gently pressing your hands together to bend and buckle the clay. (Don't press too hard or you'll squish the layers together.)
7. Divide students into pairs or small groups and proceed to the Guided Inquiry.

Guided Inquiry

Each group should plan and construct a model of rock layers that includes the following:

- at least five rock layers (a single color of clay can be used to represent more than one layer, so long as the two layers are separated by at least one other color of clay)
- at least one fault
- at least one example of folding
- at least one unconformity

Instruct students to write the sequence of events that they want their models to illustrate and to sketch on a piece of white paper how the layers appear at each stage. (Remind students to include the process of erosion in an appropriate step in their sequence.) After you have approved a group's sketch, instruct the group to use its sketch as a plan or "blueprint" to build its model.

When groups have built their models, they will exchange their models but not their sketches. Direct students in each group to draw an accurate sketch of the model they have received and to label the key features. Then, instruct students to determine the relative age of each layer or feature and to write the

sequence of events that are represented by the model. Have students compare the answers they wrote with the sequence of events that the model-makers intended and discuss any discrepancies.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. How did you apply the principle of cross-cutting relationships to determine the relative ages of layers or events in the models you built and received? [*I used the principle of cross-cutting relationships to determine when a fault line occurred. A fault line must be younger than the layers through which it cuts.*]

2. How did you model erosion of the layers to make an unconformity? [*I cut away some of the clay across the top of the model.*]

3. Which principle helped you most in determining the first event to happen? [*The principle of superposition helped me realize that the first event to happen was the deposition of the lowest layer of rock.*]

4. When did your analysis mention the principle of original horizontality? Explain how you applied this principle. [*The principle of original horizontality came into play whenever layers were folded. The folding had to be younger than the layers that were folded but older than any horizontal layers above the folded layers.*]

5. How does your model accurately reflect real-world processes? Which real-world processes related to rock formations can you not model? [*We added clay to our models and "dated" the layers by applying the same fundamental principles—superposition, original horizontality, cross-cutting relationships—that geologists apply to date rock layers. However, we created our layers in a very short amount of time. The real-world processes that create and shape rock formations happen over a much longer time span.*]

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated.
    - Are based on logic and evidence.
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation.
- Gather Data
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
    - Touching (temperature, texture, shape, size, vibration, motion)
  - Uses the appropriate format to record data:
    - Sketch
- Interpret Data
  - Identifies and interprets patterns:
    - Based on an analysis of data collected during an investigation
- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Formulating scientific explanations/arguments.
- Communication in Science
  - Report results using:
    - Written report
    - Scientific illustration with proper labeling
    - Images or video
    - Formulating scientific explanations/arguments
- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating a conclusion
    - Analyze scientific explanations
- Patterns and Systems
  - Patterns and Change
    - Some changes are very slow and some are very fast and that some of these changes may be hard to see and/or record.

Hands-On Activity

Distinguishing between Catastrophe and Uniformity

Objective:
Students will develop distinguishing characteristics between the concepts of catastrophe and uniformity.

Estimated time to complete: 30 minutes

Materials:

For each pair of students:

- (1) computer
- (1) dictionary
- each student's science notebook

Procedure:

Instruct students to find a partner and, without using a dictionary, define the word "catastrophe." Students should then look up the word "catastrophe" in a dictionary and write the definition in their science notebooks. Then, with their partners, students should discuss what they think is the most important single word in the definition and write that word in their science notebooks. Next, instruct students to discuss with their partners some famous catastrophes from history. For example, students might discuss Hurricane Katrina, the Dust Bowl of the 1930s, the destruction of Pompeii by the catastrophic eruption of Mount Vesuvius in the year AD 79, etc. Students should list several famous catastrophes in their science notebooks.

Next, instruct partners to examine the following items from the Discovery Education website:

- Item #1: **Hurricane Andrew; property damage** (damage caused by hurricane)
- Item #2: **Hurricane Andrew; damage** (damage caused by tornado)
- Item #3: **Flooded town** (damage caused by flood)
- Item #4: **Forest fire; Yellowstone** (damage caused by forest fire)
- Item #5: **Earthquake; damage** (damage caused by earthquake)
- Item #6: **Tsunami breaking over house** (damage caused by tsunami)
- Item #7: **When Earth Erupts: The Science of a Volcano** (video segment about volcanoes)

After they have examined the images and video segment, partners should write answers to the following questions in their science notebooks:

- *How rapidly or slowly do you think these events occurred?*
- *How much of Earth's surface do you think was changed or affected by these events?*
- *How many species do you think were driven to extinction by these events?*

- *What common characteristic(s) would you use to describe a catastrophic event?*
- *Can you describe other catastrophes that might change Earth's surface in a major way?*

Next, with their partners and without using a dictionary, students should work to define the word "uniform." After their discussion, students should look up the word in a dictionary and write the definition in their science notebooks. Then, instruct students to discuss what they think is the most important single word or pair of words in the definition and to write that single word or pair of words in their science notebooks. Students should also discuss the word "uniformity" and write its definition in their science notebooks.

Next, students should examine the following items from the Discovery Education website. As they examine these images, students should keep the word "uniform" in mind, looking for characteristics in each of these images that can represent this concept:

- Item #8: **Horses and riders (1)** (an equestrian is one who rides on horseback)
- Item #9: **Horses on parade** (equestrians with their horses in a parade)
- Item #10: **Children on bench in Peruvian school** (Peruvian schoolgirls)
- Item #11: **Frictional surface; astroturf** (soccer balls)
- Item #12: **Prairie (5)** (bales of hay made of prairie grasses)
- Item #13: **Waves, radial; water** (waves caused by a stone thrown into water)
- Item #14: **Eddies; Kelvin-Helmholtz clouds** (an eddy is an opposing or circular current)
- Item #15: **Cirrus** (Cirrus clouds)
- Item #16: **Beach, child walking along** (large waves washing ashore)
- Item #17: **The Water Cycle** (animation of the water cycle)
- Item #18: **Weathering and Erosion** (video segment about Weathering and Erosion)
- Item #19: **Rivers Shape the Landscape** (video segment about River Erosion)

After they have examined the items above, instruct students to write answers to the following questions in their science notebooks:

- *Which of these images best represent your concept of the word "uniform"?*
- *Which of these images represent consistent patterns or repeated cycles?*
- *Can you find examples of uniformity in each of the above images? List your examples.*
- *What common characteristic(s) would you use to describe uniformity?*
- *Do you think the waves shown in Item #16 acted approximately the same way a year ago?*
- *Do you think ocean waves act approximately the same way on the opposite of Earth as the waves shown in Item #16?*
- *For how many years do you think the waves shown in Item #16 acted in this manner?*
- *Is the water cycle shown in Item #17 a single event or a continuously repeating cycle?*
- *For how many years in Earth's history do you think the water cycle has acted in the general manner shown in Item #17?*
- *How could the water cycle affect the shape of Earth's surface?*
- *How much of Earth's surface do you think could be affected by weathering, erosion, and deposition?*

Inquiry and Nature of Science Skills in this Activity:

- Patterns and Systems
    - Patterns and Change:
        - Certain things change in some ways and stay the same in others, such as in their color, size, and weight.
        - Some changes are very slow and some are very fast and that some of these changes may be hard to see and/or record.
        - Many patterns in nature occur in cycles.
        - Cycles may be short, such as the second hand of a clock, or long such as the cycle of a year.

Exploration Teacher Guide: Relative Dating

Overview

Scientists analyze geologic cross sections and use principles of relative dating to place rocks and events in their chronological sequence. In this Exploration, students learn to deduce the relative age of rocks by examining the positioning of rock layers in a geologic cross section and the effect of external forces on them.

Student Learning Objectives

- Observe the processes involved in formation of a variety of geologic cross sections.
- Investigate the effects of stress applied to layers of rock.
- Understand the concept of relative age by observing how rock layers and features are arranged.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students build a geologic cross section by using the buttons *Deposit Sediments*, *Add Magma Intrusion,* and *Add Magma Extrusion* in the *Build Cross* section. Students may select one or more of these buttons in any order. On clicking each of these buttons, an animation representing of each of these processes is displayed.

Students can then choose to apply one of the three types of stresses available- *Compression*, *Tension,* and *Shear* by using the buttons provided in the *Apply Stress* section. An animation depicting the action of the stress applied is shown. Simultaneously, the order in which the rock layers are subjected to external forces is displayed in the activity area, from the least recent to most recent. Students may use the *Reset* button to study the effects of another combination of factors.

In the *Tracker* tab, students observe and study the sequence in which the geologic events occurred. They also analyze the type of cross section that formed after the building and stress processes.

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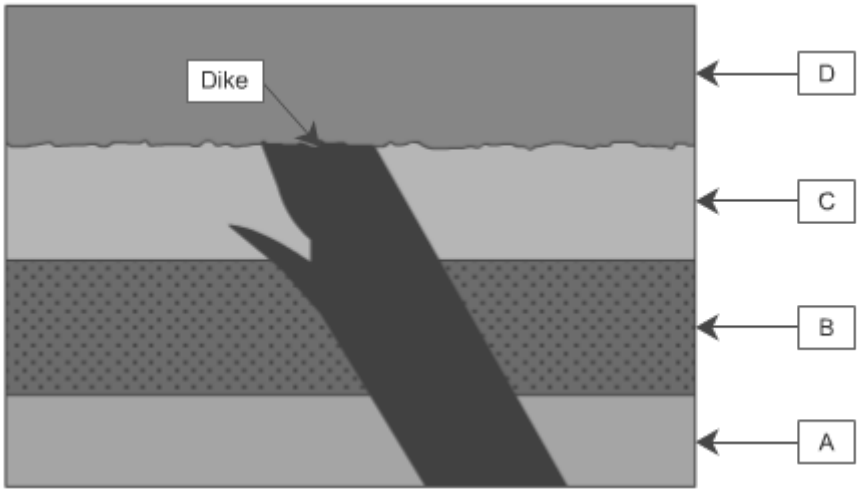
Answers to Questions in the Student Worksheet

1. In a geologic cross section, a magma intrusion cuts across layers A, B, and C. It does not cut across layer D. What can you infer from this about the relative age of the intrusion in comparison to the age of layer D?



Answer: Layer D is younger than the intrusion.

2. Examine the three un-deformed sedimentary rock layers in the geologic cross section. Place the layers from oldest to youngest and explain which principle of relative dating you used.

Answer: The sedimentary rock layers are, from oldest to youngest, sandstone, conglomerate, and shale. The principle of superposition can be used to infer the relative age of the layers.

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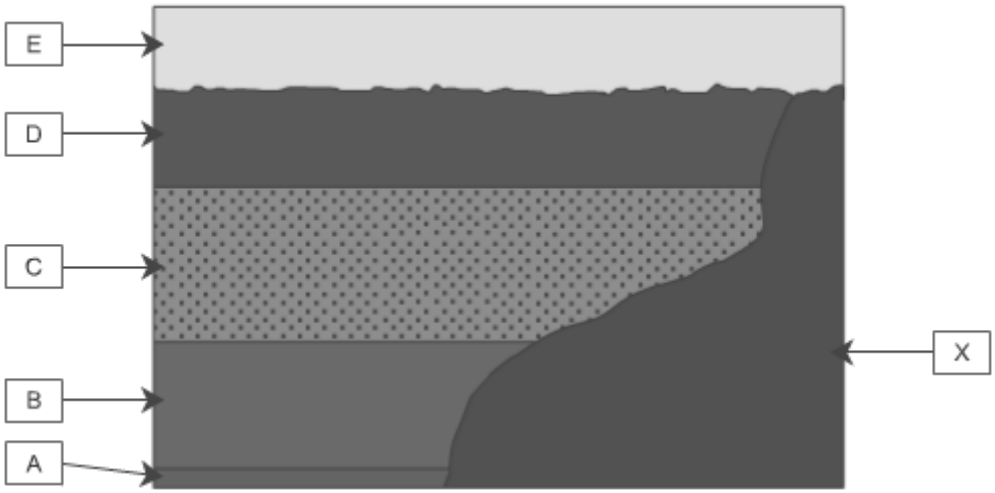
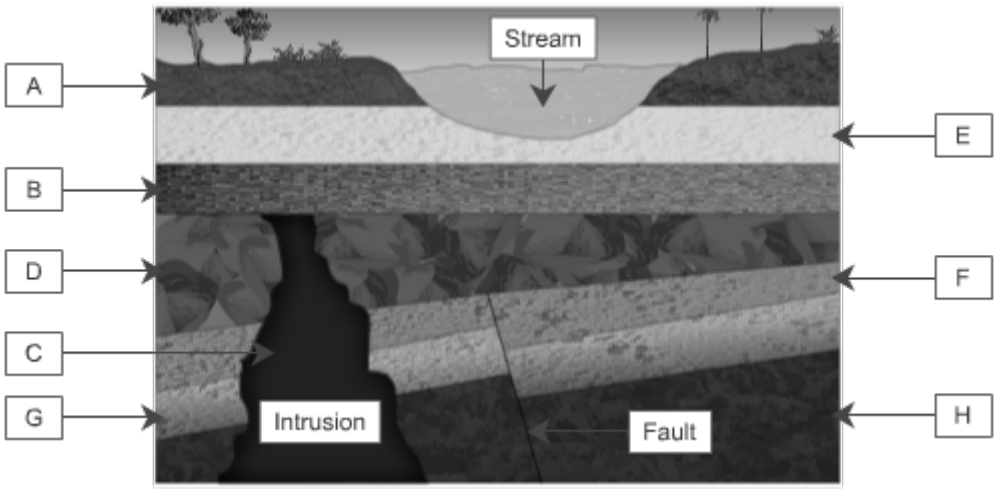
3. Units A, B, C, D, and E are sedimentary rocks. Unit X is granite. Identify the youngest cross section.



Answer: Layer E is the youngest rock in the cross section.

Refer to the cross section given below for questions 4, 5, and 6.



4. Which is younger: the fault or the intrusion?

   Answer: Intrusion is younger than the fault.

5. What kind of rock is the intrusion C made of?

   Answer: The intrusion is made of igneous rock.

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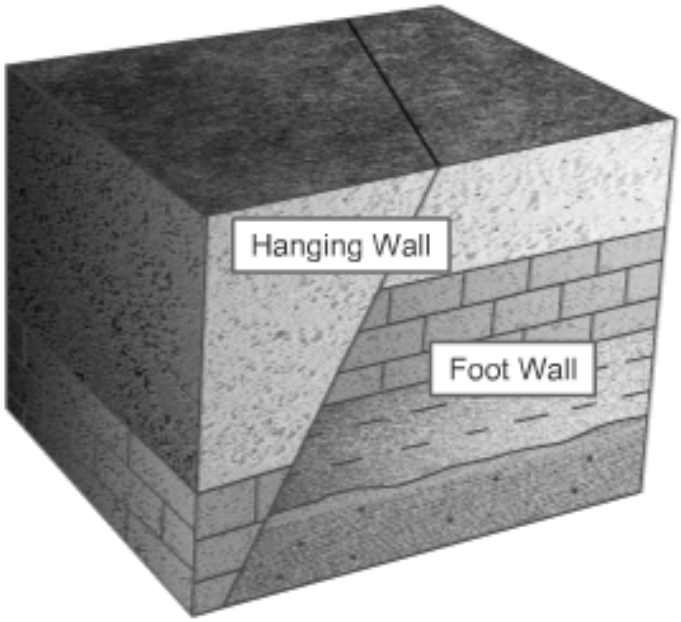
6. Using the principles of relative dating, is it possible to tell how many years have passed between the deposition of layers B and E?

   Answer: No. Using the principles of relative dating, it is not possible to tell how many years have passed between the deposition of layers B and E. We can tell which layer is older, but not how much older.

7. Is this a normal fault or a reverse fault? What kind of stress is likely to have caused this fault movement?



   Answer: Since the hanging wall has moved down relative to the footwall, this is a normal fault. Tension stress is likely to have caused this fault movement.

8. Why are fossils unlikely to be found in an igneous intrusion?

   Answer: Igneous rocks are formed by the solidification of hot magma. Even if the magma formed from a fossil-bearing sedimentary rock, the heat involved in forming the magma would have destroyed the fossils.

9. Using the exploration, create the following types of cross sections. Sketch and label the cross-section:

   a. A cross section in which a magma extrusion is older than sediments deposited.

   b. A cross section in which an intrusion is older than a fault.

   Note: Students answer this question by using the exploration.

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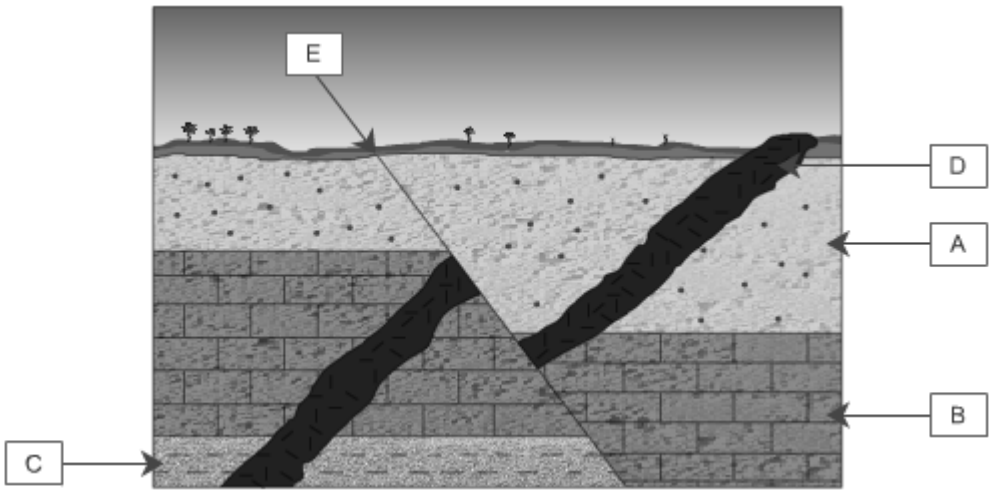
10. Refer to the cross section given below. Use the relative dating principles of superposition and cross-cutting relationships to arrange the geologic events from oldest to youngest.



Answer: The geologic events from oldest to youngest are deposition of C, B, A followed by intrusion of D and then fault E.

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Hands-On Activity

Modeling Geologic Time

In this activity, students will analyze a geologic rock sequence by applying relative and absolute dating techniques. They will develop an understanding of the geologic history represented by the rock sequence, and use this understanding to create a model.

Suggested Materials
Per Pair:

- 1 copy of the **Geologic Rock Sequence** handout
- 1 copy of the **Age Ranges of Index Fossils** handout
- 1 copy of the **Sm-147 Graph** handout
- 1 copy of the **K-40 Graph** handout
- 1 copy of the **U-235 Graph** handout
- 1 Geologic Time Scale diagram
- Science Notebook or loose leaf paper
- pencils
- access to Board Builder

To introduce the activity, provide time for students to review the principles of relative and absolute dating. Students may wish to review the reading passages Radiometric Dating, Biostratigraphy, and Mass Extinctions.

Part 1: Analyzing a Rock Sequence

Procedure

1. Have students examine the **Geologic Rock Sequence** handout.
    a. Explain that this handout represents a rock sequence of 10 layers, along with two unconformities, a fold, and a fault.
    b. Instruct students to begin by using relative dating techniques—including the principles of superposition, cross-cutting relationships, original horizontality, etc.—to determine the order in which the layers, unconformities, fold, and fault formed. Students should ignore the index fossils and isotopes for the moment, focusing solely on the relative ages of the rock layers/features.
    c. Students should record the order of the layers/features in their notes, or in an observation table (see sample observation table below).
2. Next, students should focus on the index fossils they see in the rock layers.
    a. First, instruct students to record the index fossils found in the layers in their notes, or in an observation table (see sample observation table below).
    b. Then, students should record the age range of the layers based on the index fossils.
    c. Students can then use the principle of superposition to further constrain the age range of the layers containing the index fossils. Students should record the adjusted age ranges in their notes, or in an observation table (see sample observation table below).

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3. Next, students should focus on the geologic features containing radioactive isotopes.
    a. Instruct students to record the geologic features found in the rock layers in their notes, or in an observation table (see sample observation table below).
    b. Then, have students record the percentage of the parent isotope remaining in each geologic feature in their notes, or in an observation table (see sample observation table below).
    c. Students should then use the graphs below (i.e., for Sm-147, K-40, and U-235) to determine the absolute age of each geologic feature based on the percentage of each parent isotope remaining. Instruct students to record this in their notes, or in an observation table (see sample observation table below).
    d. Students can then use the principle of superposition to further constrain the age range of the layers containing these geologic features. Students should record the adjusted age ranges in their notes, or in an observation table (see sample observation table below).
4. When students have completed the relative and absolute dating of the rock sequence, they should focus on other conclusions that can be drawn from the rock sequence. Instruct students to record their conclusions in their notes, or in an observation table (see sample observation table below).
    a. Students may infer whether each rock layer formed in a marine or terrestrial environment, based on the types of fossil organisms found in the layers (e.g. trilobites and brachiopods = marine; land plants = terrestrial).
    b. Students may use stratigraphic principles to infer the types of tectonic forces that were applied to the area in which the rock sequence formed.
    c. Students may infer other events that occurred during the formation of the rock sequence (e.g. iridium is rare on Earth, but common in meteorites; K-40 is used to date glass from meteorite impacts; Sm-147 is used to date meteorites).

Students may wish to use DE resources to support and/or expand their conclusions. Helpful resources may include the Decay Rates diagram and the videos Zircons: Time Capsules From Early Earth (8:51) and Iridium and Asteroids (5:54).

Part 2: Making a Timeline

Divide students into small groups so that they may design a timeline using Board Builder. Students should use the information they have gathered and the conclusions they have drawn, as well as further research through DE and other resources, to create a timeline of events that happened in the area in which the rock sequence formed. Events can include extinction events, meteorite impacts, tectonic activity, deposition of sediment, changes in environment, biological activity, etc. Students should answer the **Analysis and Conclusions** questions at the end of the student sheet to help guide them in drawing conclusions that could help with their timelines.

Potentially helpful DE resources include these video segments:

- Iridium: Meteoritic Mass Extinction (5:38)
- Iridium's Link to the Dinosaurs (3:02)
- Cretaceous-Tertiary Extinction (0:49)
- The First Extinctions on Earth (3:38)
- Paleoenvironments (4:45)
- Science in Progress: The Fossil Record (3:18)
- Seedless Plants: Review (2:24)

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Sample observations chart: **Ages of Rock Layers** (student version)**:**

	Layer/ Feature	Index Fossils	Age Range Based on Index Fossils	Adjusted Age Range Based on Superposition	%Parent Isotopes	Absolute Age Based on Isotopes	Adjusted Age Range Based on Superposition	Environment
Youngest								
Oldest								

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Sample observations chart: **Ages of Rock Layers** (answer key)**:**

	Layer/ Feature	Index Fossils	Age Range Based on Index Fossils	Adjusted Age Range Based on Superposition	%Parent Isotopes	Absolute Age Based on Isotopes	Adjusted Age Range Based on Superposition	Environment
Youngest	Layer F	Angiosperm	Jurassic - Present	Jurassic- Present			Paleogene (65 Ma) - Present	Terrestrial
	Layer C			Late Devonian-Present	96.45% K-40 99.575% Sm-147	65 Ma	65 Ma (Mesozoic-Cenozoic Boundary)	Terrestrial
	Unconformity K			Late Devonian-Present				Terrestrial
	Fault J			Late Devonian-Present				Terrestrial
	Layer M	Lycopod	Middle Silurian - Carboniferous	Late Devonian-Carboniferous				Terrestrial
	Layer H			Late Devonian-Carboniferous				Terrestrial
	Layer B	Calamites	Devonian - Permian	Late Devonian-Carboniferous				Terrestrial
	Unconformity I			Ordovician - Carboniferous			Silurian (425 Ma-Carboniferous	
	Fold			Ordovician - Carboniferous			Silurian (425 Ma-Carboniferous	
	Layer L	Phacopida trilobite	Ordovician - Devonian	Ordovician - Devonian			Silurian (425 Ma-Devonian	Marine
	Layer E			Ordovician - Devonian	66% U-235	425 Ma	425 Ma (Silurian)	Marine
	Layer D	Pentamerid brachiopod	Ordovician - Devonian	Ordovician - Devonian			Ordovician - Silurian (425 Ma)	Marine
	Layer G			Ordovician - Devonian			Ordovician - Silurian (425 Ma)	Marine
Oldest	Layer A	Orthid brachiopod Proetida trilobite	Ordovician - Permian	Ordovician - Devonian			Ordovician - Silurian (425 Ma)	Marine

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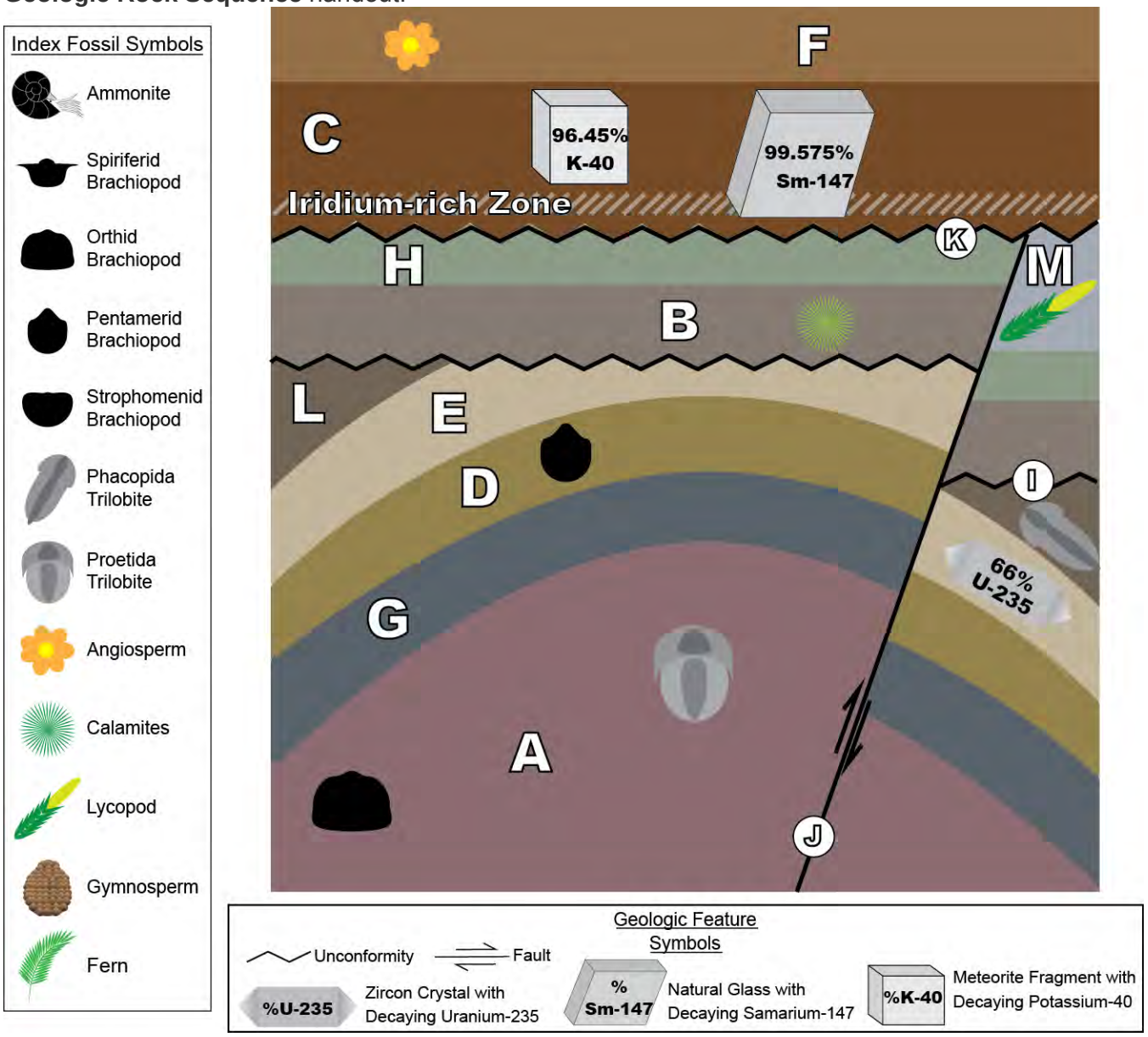
Geologic Rock Sequence handout:



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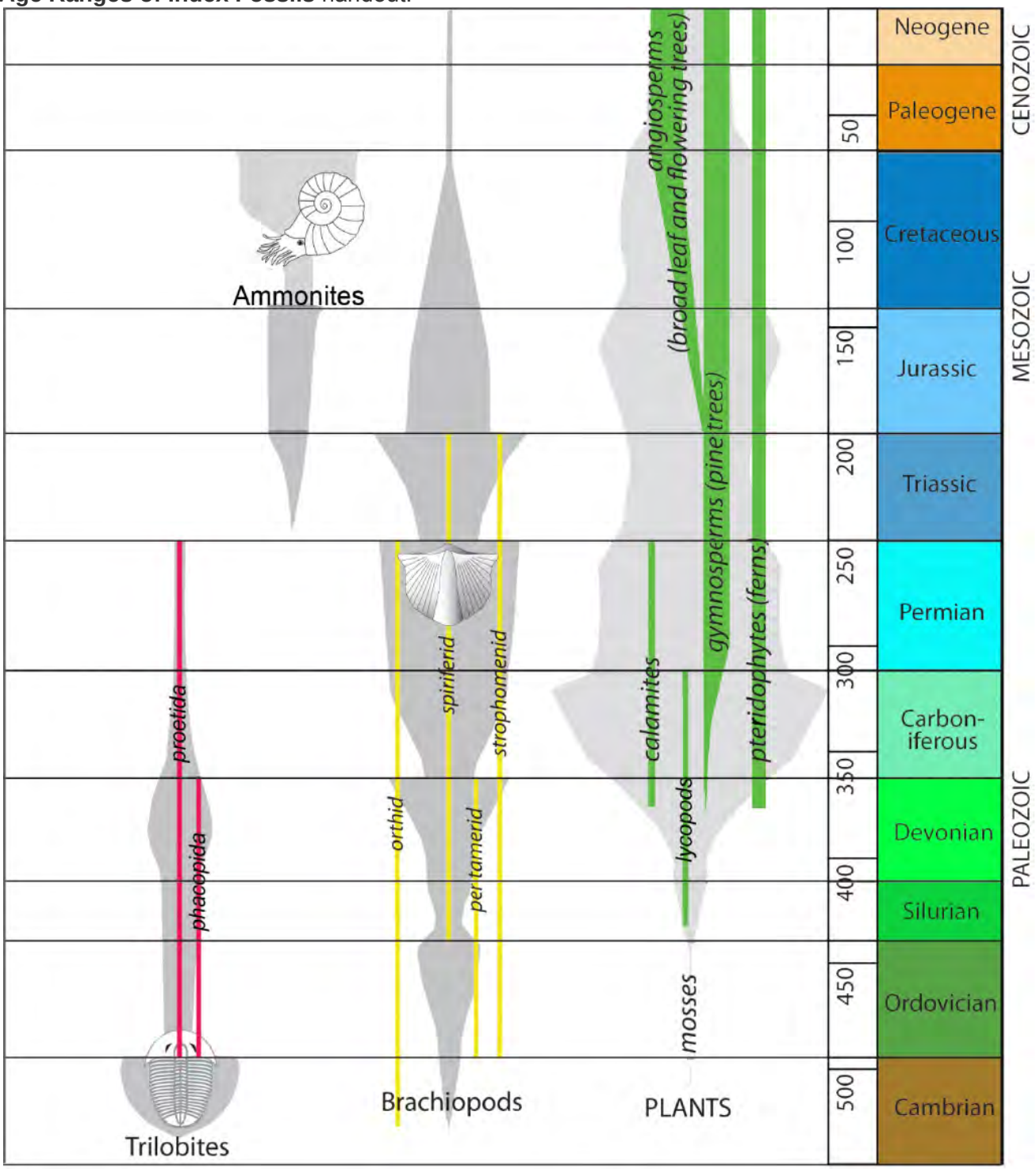
Age Ranges of Index Fossils handout:



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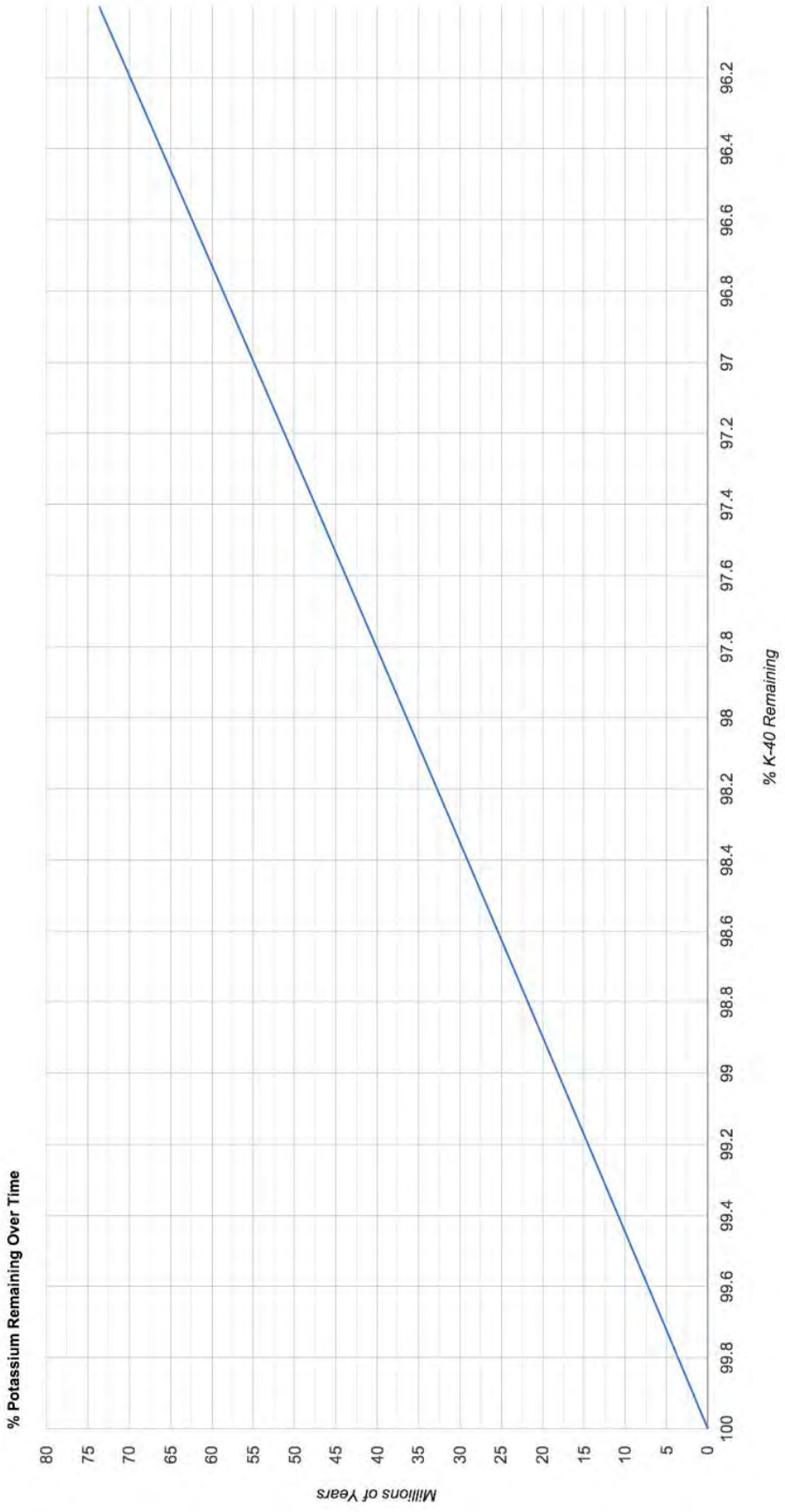

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Analysis and Conclusions

1. What can you infer about the environment in which the rock layers formed, based on the types of fossil organisms found in each layer?

   Sample answer: The layers below unconformity "I" contain marine organisms, while the layers above this unconformity contain terrestrial organisms. This indicates that a marine regression occurred.

2. What can you infer, based on the shape of the features of the layers, about the tectonic forces applied to the area in which the rock sequence formed? In what type of geologic setting would these forces be applied?

   Sample answer: Pressure was applied inward from either side of the rock layers, causing both the fold and the fault (although at different times). This type of pressure indicates a location near a convergent boundary. This also indicates that the entire sequence is in a continental setting, suggesting that the marine organisms lived in a shallow sea on a continent, rather than in an ocean or over oceanic crust.

3. What can you infer about other events that may have occurred during the formation of this rock sequence, based on the geologic features (such as the iridium-rich zone, natural glass, and meteorite fragments) found in the layers?

   Sample answer: Iridium is rare on Earth, but common in meteorites. K-40 is used to date glass from meteorite impacts. Sm-147 is used to date meteorites. This all implies that a meteorite impact occurred while layer C was forming. Since this layer is about 65 million years old, this was most likely the major meteorite impact that caused the mass extinction that marks the Cretaceous-Tertiary (Cretaceous-Paleogene, Mesozoic-Cenozoic) boundary.

4. Based on all the available information, what can you infer about the geological and biological history of the area in which this sequence formed?

   Students' answers will vary.

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Hands-On Activity

Bean Selection

Objective:
In this activity, students will work in pairs to simulate the processes of natural selection. Students will analyze and evaluate how natural selection produces changes in populations, not individuals, through an activity involving bean selection.

Estimated time to complete: 15 minutes

Materials:

For each student pair:

- black beans, 50
- lima beans, 50
- black construction paper
- light green construction paper
- timer

Procedure:

1. Spread out all of the beans on the light green construction paper.
2. Set the timer for 30 seconds and close your eyes until the timer rings.
3. Open your eyes and quickly grab the first bean you see and place it next to you. Then, immediately close your eyes again and count to 10.
4. Open your eyes again and quickly grab the first bean you see and place it in your pile.
5. Repeat the cycle in steps three and four 10 times, closing your eyes and counting to 10 each time.
6. Count the beans remaining on the construction paper and the ones in the piles. Record this data in the table.
7. Determine the percent of black beans picked versus the percent of lima beans picked. Record this data in the table.
8. Repeat the entire experiment on black construction paper.

Beans	# of black beans remaining	# of black beans in piles	# of lima beans remaining	# of lima beans in piles	% of black beans picked vs. % of lima beans picked
Light green environment					
Black environment					

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. Why did different beans survive better in different environments? (*Lima beans are larger and easier to see in the black environment so more were grabbed.)*

2. What do you predict would happen to the bean population with the worst survival rates if you continued the activity, using the remaining beans as your starting population each time? (*The unfavored population might become 'extinct'.)*

3. Analyze how your model demonstrated that natural selection produced change in the population, not the individual? *(The beans remained lima and black beans, the selection process didn't change the individual beans. However, over time, the selection process resulted in changes to the populations of beans.)*

4. How does this activity simulate the process of natural selection? *(The different environments presented a favorable condition for different populations of beans because it was easier to see the black beans in the green environment, and it was easier to see the lima beans in the black environment. In a real ecosystem, the organisms that stand out from the environment are easiest to see and thus more likely to be harvested and eaten. For this activity it is easy to understand what trait was more favorable because the population of the favorable bean would increase over time and the population of the unfavorable bean would decrease or become extinct. Black beans stood out against the light green background and were thus easier to harvest. The green beans remained in the light*

green environment and that population survived. The opposite is true for the black environment.)

5. What are the limitations of this model? (*The population is not reproducing and change occurs only within one generation. Natural selection in populations usually occurs over many generations.)*

6. 6. Use the data table given here to analyze a pool of results including your own. Average the survival rates for the black beans in each environment and the lima beans in each environment. Estimate how many generations it would take for the unfavored population in each environment to become extinct. *(Students' answers will vary slightly depending on individual results of the trials, but the average survival rate for black beans in the green environment will be near 20% and the survival rate for lima beans in the green environment will be near 80%. In the black environment, the opposite will be true. The survival rate of the black beans will be near 80% and the survival rate of the lima beans will be near 20%. With survival rates of 20% in the unfavored population, an estimate of three or four generations to extinction is reasonable. If students' results are very different from the three trials shown here, five or six generations to extinction might be reasonable.)*

Environment	# of black beans remaining	# of black beans in piles	# of lima beans remaining	# of lima beans in piles	% of black beans picked vs. % of lima beans picked
Light green, student 1	42	8	48	2	80/20
Light green, student 2	40	10	50	0	100/0
Light green, student 3	44	6	46	4	60/40
Black, student 1	50	0	40	10	10/90
Black, student 2	47	3	43	7	30/70
Black, student 3	48	2	42	8	20/80

Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
- Gather Data
  - Use senses to observe:
    - Seeing (color, shape, size, texture)
  - Use the appropriate format to record data:
    - Table
- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause effect relationship observed in the investigation
- Scientific Investigation
  - Scientific Data and Outcomes
    - Collecting and analyzing data is the best way to understand a changing pattern.
- Scientific Endeavor
  - Characteristics of Science
    - One way to make sense of something is to think of how it relates to something more familiar.

Calculating a Hardy-Weinberg Equation

Use the Hardy Weinberg equation to solve the problems below.

1. Suppose the frequency of the dominant allele in a population is 75%. What is the frequency of the recessive allele? [answer: 25%]

2. A population of salamanders has two colors, blue and white. Blue is the dominant color and white is recessive. The frequency of the white allele is 36%. What percentage of the salamander population is white? [answer: 13% of the salamander population is white.]

3. A population of 100 individuals has 49 individuals that are homozygous dominant for a certain trait. How many individuals are heterozygous dominant for a trait? How many are homozygous dominant for the trait?

RR	49 out of 100, or 0.49
Rr	?
rr	?

[answer: Rr = 42; rr = 9]

4. The frequency of a dominant allele (P) in a population is 60% and the frequency of the recessive allele (p) is 40%. Predict the probability of the possible genotypes in this population. [answer: PP = 36%; Pp = 48%; pp = 16%]

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5. The frequency of a dominant allele in a population is 85% and the frequency of the recessive allele is 35%. Is this population in equilibrium? Explain your answer.
   [answer: No, because p + q should equal 1, but .85 + .35 = 1.2]

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Hands-On Lab

The Evolution Game

Timing: one 90-minute class session

Objective:
Students will model scenarios that represent the mechanisms of evolution and practice calculating allele frequencies using the Hardy-Weinberg equation.

Safety Precautions:
Remind students to respect one another when they are hunting the flurbs and to use caution when using the tools.

Materials:
Per class:

- large piece of light-colored linoleum
- large piece of dark-colored, shaggy carpet/rug/blanket/material
- 10 mm pom-poms in three colors (black, yellow, and white are suggested), 200 of each color per class
- chopsticks (enough for 1/3 of the class)
- plastic forks (enough for 1/3 of the class)
- plastic spoons (enough for 1/3 of the class)
- stopwatch or timer

Per student:

- plastic cup
- graph paper
- calculator
- colored pencils

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Teacher Preparation:
Gather materials before students come to class. The carpet and linoleum should be large enough for half of the students in the class to gather around. Two of the pom-pom colors should blend in with the linoleum and with the carpet. The third color can stand out against both. Do not allow students to place the cups on the ground and shovel pom-poms into it. It may be best to tell them that they cannot touch the cup during hunting. Prepare a copy of the Student Investigation Sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>

Review the following steps with the class:

1. Divide the class into two groups and have them form small circles. If time allows, each group will run the simulation twice, once for each set of conditions.
2. Place the sheet of linoleum in the center of one group and the carpet in the center of the other group.
3. "Plant" about 90 pom-poms, 30 of each color, on each "habitat" (linoleum and carpet). Make sure students turn their backs or close their eyes while the pom-poms are being planted so the students do not have time to

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determine where all of the pom-poms are. The pom-poms will be a species called “flurbs.” Have students record the number of each color of flurb in a data table and determine its frequency: number of flurbs of a color / total number of flurbs. The answer will be a decimal and the sum of the decimals should equal 1.

4. Give each student (the hunters) a fork, a spoon, or a set of chopsticks. Also give each student a plastic cup. Record the number of each type of tool in a second data table and determine the frequencies of the tools: number of a specific tool / total number of tools. Students will use their hunting tools to pick up flurbs during the time allowed. During hunting, they must place their flurbs in their plastic cups, which represent their stomachs.
5. Allow the students to hunt in their respective habitats for 15–30 seconds and then call time. Let students know that competition is encouraged, but to be respectful. Also, once a flurb is picked up off the habitat, it is off limits to competition.
6. After time is up, have students count the number of flurbs of each color they have collected. Then, have each group of students determine how many total flurbs of each color were collected.
7. Multiply the number of surviving flurbs by 2 and add that number of pom-poms to the habitat. For example, if 15 yellow flurbs survived, then add 30 more yellow pom-poms to the habitat. This represents reproduction within the habitat.
8. Have students record the number of flurbs of each color in the appropriate data table and determine the frequencies.
9. In each group, the half who collected the greatest numbers will “survive and reproduce,” continuing with the activity. The other half will die and now be the children of the survivors (since the survivors reproduced). They will also continue with the activity as children. If there is an odd number of survivors, the surviving student with the least flurbs survives but does not reproduce.
10. The student with the lowest number of flurbs collected in step 5 gets the same tool to use next as the student with the highest number of flurbs collected in step 5.
11. Record the number of hunters with each tool for the next generation in the appropriate data table.
12. Repeat steps 5–11 two more times for a total of three generations.
13. Have students use the data in their tables to make bar graphs of the flurbs and of the hunters. On the *x*-axis, they should place the generations, and on the *y*-axis the frequencies (0–1). Each generation will have three bars, one for each color of flurbs and one for each hunter type.

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14. In addition to their bar graphs, have students create a line graph that models the relationship between generation and frequency.
15. If time allows, have the groups switch habitats and run the simulation again.
16. Have students use their data and graphs to help them to answer the Analysis and Conclusion questions.

Sample Data Tables:

Linoleum	Black flurbs	White flurbs	Yellow flurbs	Total
Generation 1 Population size				
Frequency				1
Generation 2 Population size				
Frequency				1
Generation 3 Population size				
Frequency				1

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Hunters	Forks	Spoons	Chopsticks	Total
Generation 1 Population size				
Frequency				1
Generation 2 Population size				
Frequency				1
Generation 3 Population size				
Frequency				1

Guided Inquiry

Students can work together to develop their own plans for simulating the concepts and collecting data, based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry:

- How will you model a population's gene pool?
- How will you model nature selecting traits?
- How many generations do you need to observe?
- How could you simulate a different set of predators with varying levels of skill?
- How could you simulate a different set of predators with varying levels of success?
- How will you calculate allele frequencies?
- How will you collect and organize your data?

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Allow students to design their model and the simulation process. Provide any additional materials they may need. Approve their procedures and provide helpful feedback before they get started. Share the sample data tables with the students and encourage them to organize their data so that they are able to graph it after the experiment. Circulate through the room and monitor group discussions throughout the investigation.

Analysis and Conclusions:
To help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. Did evolution through natural selection occur in each habitat? Explain your reasoning. *Sample: Yes, it did. In each generation, the allele frequencies of the colors changed. The color that stood out on the habitat became less frequent in each generation. Also, the hunter with the least effective tool began to die out in each generation.*

2. Were the results the same for each habitat? Why or why not? Compare results with the other group if necessary. *Sample: No, the results differed because the "environmental conditions" were different, so different traits were favored and selected for in each of the habitats. The selection for the hunter type was the same because this had nothing to do with the color of the flurbs.*

3. What predictions could you make about each of the populations if the simulation were run for 30 generations? *Sample: The alleles for traits that are least adapted to the habitat would die out, and those that were adapted would increase in frequency, eventually becoming stable, and the population would be in Hardy-Weinberg equilibrium.*

4. Using your investigation as a model, analyze how natural selection produces change in *q* population, not individuals. *Sample: A change may occur in an individual but unless that individual reproduces, that trait can't be passed on. If a change in a trait occurs, an individual can reproduce and pass on its trait. If offspring with that trait continue to be successful, each successful offspring will pass it on. It becomes a naturally selected trait in that population. The successful hunters in the model were able to reproduce and produce more predators of the same type. The population of successful predators grew, and the trait became apparent in all of the hunter offspring for that habitat.*

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Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
- Gather Data
  - Use senses to observe:
    - Seeing (color, shape, size, texture)
  - Use the appropriate format to record data:
    - Table
    - Graph
- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
- Scientific Investigation
  - Scientific Data and Outcomes
    - Collecting and analyzing data is the best way to understand a changing pattern.
- Scientific Endeavor
  - Characteristics of Science
    - Scientists are curious about how things work.
    - One way to make sense of something is to think of how it relates to something more familiar.
    - Scientific theories are based on accumulated evidence.
    - A theory is a well-supported and widely accepted explanation for what is observed in the natural world.
- Engineering and Technology
  - Scientific Discoveries
    - Darwin

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Exploration Teacher Guide: Evolution

Overview

Students will learn about natural and artificial selection by studying the evolution of a population of bugs. They will observe how bugs evolve to adapt to their surroundings over multiple generations.

Student Learning Objectives

- Investigate the differences between natural and artificial selection.
- Observe the evolution of a population of bugs for a number of generations.
- Examine the effects of changing the mutation rate of a population.
- Investigate the differences between the evolved population and the original population.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

Students can select the *Natural Selection* or *Artificial Selection* radio button to begin the Exploration. The leaf color can be selected by using the buttons provided under the Select Leaf Color section. Students can use the Select *Mutation Rate* slider to select a mutation rate between 0 and 1, for the population of white bugs.

For natural selection, students can use the *Simulate* button to examine the evolutionary changes in the color of the bugs, generation after generation. Twenty bugs move to the mating chamber from the bug population, for each generation.

For artificial selection, students have to click on any five bugs to move them to the mating chamber. As soon as the fifth bug is selected and clicked on, the next generation of bugs appears on the leaves. Students must continue to click and select five bugs for subsequent generations.

Students can observe the evolutionary changes in the bug population up to a maximum of ten generations. The *Pause* and *Continue* buttons can be used by the students to observe the variation in bug colors closely. Students can use the *Reset* button at any point to restart the Exploration.

The *Tracker* tab can be used to observe the total number of bugs that have mutated over a period of ten generations for each run of the Exploration.

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Answers to Questions in the Student Worksheet

1. Explain the difference between natural and artificial selection.

   Answer: Natural selection is a phenomenon, through which favorable characteristics are transferred from one generation to another. This process is entirely random and various natural factors play a role in the selection of these characteristics. On the other hand, artificial selection is a planned process through which various individuals of an organism are methodically bred to produce offspring that are genetically more advanced than their predecessors.

2. In the Exploration, the color of the bugs evolves over the course of a few generations. Give another real world example which can support Darwin's theory.

   Answer: A very well known example of evolution is displayed by peppered moths. Initially, peppered moths had a light coloration and used this to camouflage themselves against the light colored lichen on the bark of trees. However, due to the industrial revolution, when the lichen became covered with soot, the moths evolved to exhibit a darker color to avoid predation.

3. List any two factors that affect evolution.

   Answer:
   - Environmental factors such as temperature, rainfall, and availability of resources have a direct impact on the evolution of organisms.
   - The geographic distribution of different populations of the organism is also equally important in dictating the course of evolution.

4. Scientists experimenting on artificial selection use certain techniques to increase the rate of mutation. Explain why a higher mutation rate is desirable.

   Answer: A higher mutation rate diversifies the gene pool under study. Due to this, scientists can observe the dynamism exhibited by the organism and study extreme possibilities that may not be observed through natural selection.

5. Sometimes when organisms evolve, it gives rise to multiple species that can coexist simultaneously. Give an example supporting this statement.

   Answer: Dog breeders are known for breeding a very large number of varied dogs, exhibiting a gamut of characteristics. This gives rise to many hybrid varieties of dogs that are classified into different breeds. This is an example of coexistence of different types of the same organism.

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6. Explain why some species become extinct.

   Answer: Extinction is a natural process through which organisms that are unfit to survive on the planet are eliminated from the gene pool. Over a period of hundreds of thousands of years, the populations of species of organisms that are genetically inferior start dwindling until they become endangered and ultimately extinct.

7. Darwin's Theory of evolution suggests that fishes evolved into amphibians. If this statement is assumed to be true, explain why fishes still exist on the planet.

   Answer: Fossil evidence shows that some species of fish evolved towards settling in a more terrestrial environment. This branch of organisms was later classified as amphibians. However, it does not mean that other species of fish did not continue to evolve. It was only that instead of evolving towards a terrestrial conquest, they evolved to exhibit characteristics that better suited an aquatic habitat.

8. Explain the difference between adaptation and evolution.

   Answer: Adaptation is the ability of a specific individual of a group of organisms to outdo other individuals in performing functions that could aid its survival. On the other hand, evolution is a large scale change exhibited by the entire population due to genetic variations over a period of time.

9. Explain the role played by the rate of mutation in determining the course of evolution.

   Answer: The rate of mutation in a group of organisms determines how fast it will evolve to exhibit characteristics that are different from the parent generation. A higher mutation rate means that favorable characteristics may appear in the population relatively sooner than expected.

10. Describe how the process of evolution stops.

    Answer: Evolution is a continuous process which began the day the universe was created and will continue as long as life exists on Earth. This also means that human beings will also continue to evolve. However, this change may not be evident over the course of one's lifetime.

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Hands-On Activity

Investigating the Hardy-Weinberg Equation

In this investigation, students will examine the Hardy-Weinberg equation as it relates to the frequency of a heritable trait. They will use the equation to calculate allele frequencies.

Suggested Materials

Per Group:

- Internet access and/or library resources
- calculators

Procedure

1. Have students discuss the conditions needed in a population in order for it to be considered at Hardy-Weinberg equilibrium. These include:
    a. no mutations
    b. nonrandom mating
    c. no migration
    d. large population size
    e. no natural selection

2. Explain to students that although these "perfect" conditions do not exist, scientists use departures from the ideal conditions, using mathematical models to predict allele frequencies in a population. The Hardy-Weinberg equation predicts the frequencies of two alleles, p and q, for a population at equilibrium:

    $$p^2 + 2pq + q^2 = 1$$

    Punnett squares can also yield the Hardy-Weinberg equation. Demonstrate this by drawing a Punnett square on the board with genotypes Aa and aa, where A = p and a = q. Complete the square and note that the probability of each allele occurring is 50% (.5). Instruct students to complete the Hardy-Weinberg equation using these values and note that the total is 1.

3. Give students the following problem to practice their understanding of the Hardy-Weinberg equation:

    Many humans have an allele that allows them to taste a chemical called PTC (phenylthiocarbamide). Individuals who can taste this chemical have the dominant allele, T, with genotypes of TT or Tt. If 36% of the population cannot taste PTC, then what is the frequency of the T allele?

    Work through the problem with the students.

    Solution:

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a. The 36% of the population that cannot taste the chemical have the genotype tt. Because the frequency of t = q, this means that $q^2 = .36$ so $q = \sqrt{0.36} = 0.6$.
b. That is, the t allele has a frequency of 60%.
c. Since there are only two alleles for this trait (T and t), if 60% of the population has the t allele, that means that 40% has the T allele, so the answer is 0.4 (1 – t = 1 – 0.6 = 0.4).

4. Have students research other real-world heritable traits. They should focus only on those traits that are expressed by one allele. Those may include:
   a. widow's peak hairline
   b. attached or unattached earlobes
   c. cheek dimples
   d. tongue rolling
   e. cleft chin
   f. freckles
   g. naturally curly hair

5. You may wish to have students investigate traits of other organisms. (Plants are especially useful for explanations of genetics and gene frequencies.)

   a. Have students research the genes that make up their selected trait.
   b. Have students use the Hardy-Weinberg equation to calculate allele frequencies.

6. Imagine a population in which 20% has hereditary hemochromatosis (aa), a condition that results in the body absorbing too much iron. 67% are heterozygous for hemochromatosis (Aa), and 13% do not have the allele for hemochromatosis (AA). To test whether the population is in equilibrium, assume that:

   - $p + q = 1$, where p = frequency of the A allele and q = frequency of the a allele; and
   - $p^2 + 2pq + q^2 = 1$ (where p^2 = frequency of AA genotype, 2pq = frequency of Aa genotype, and q^2 = frequency of aa genotype)

   a. Ask students to use the frequency of hereditary hemochromatosis and the Hardy-Weinberg equation to predict the frequencies of the Aa and AA genotypes in a population at equilibrium.
   b. Have students determine whether the allele frequencies are at equilibrium. They should use a table to show results.

   Solution:
   a. The frequency of aa = 20%; therefore, $q^2 = 0.20$, so $q = \sqrt{0.20} = 0.45$.
      Since 1 – q = p, then 1 – 0.45 = p = 0.55. Therefore, $p^2 = 0.30$.
      If 20% is the frequency of the aa genotype (q^2) and 30% is the frequency of the AA genotype (p^2), the frequency of the Aa genotype (2pq) must be 50% or 0.50.
   b. No, it is not. The values predicted by the equation do not match the observed frequencies. The observed and expected frequencies are shown in the table below.
   c.

Genotype	Observed	Expected
aa	0.20	0.20
Aa	0.67	0.50
AA	0.13	0.30

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Analysis and Conclusions

1. What conditions must apply in order for a population to be in Hardy-Weinberg equilibrium?
   In order for a population to be in Hardy-Weinberg equilibrium, the following hypothetical conditions must apply:
   a. *There can be no mutation of genes.*
   b. *There can be no migration into or out of the population.*
   c. *There must be a very large population size.*
   d. *There can be no natural selection.*
   e. *There must be no random mating.*

2. What calculations did you use to show the frequencies of the alleles of your trait?
   Answers will vary, but students should have used the $p^2+2pq+q^2$ equation to calculate the frequencies of the alleles that express the traits they selected.

3. Was the population with hemochromatosis at Hardy-Weinberg equilibrium? Why or why not? Explain.
   It was not at equilibrium. The values predicted by the equation did not match the values observed in the population. By comparing the observed and expected values, you can see that this population contains more individuals with the Aa genotype and fewer individuals with the AA genotype in the population than one in equilibrium.

4. Sickle-cell disease is a disorder that occurs when mutations cause blood cells to develop in an abnormal shape. Recently, scientists have discovered that even one copy of the mutated gene responsible for sickle-cell disease also decreases susceptibility to malaria, a deadly infectious disease transmitted by mosquitoes. According to the World Health Organization, about 72,000 of 318 million Americans have sickle-cell disease (genotype AA). However, in some regions of Africa as much as 40% of the population has at least one copy of the mutated gene. In West Africa, where malaria is a significant danger, prevalence of sickle-cell disease is 4% of the population. Assuming both the American and West African populations are at equilibrium, use the Hardy-Weinberg equation to estimate population percentages then calculate the difference between prevalence of sickle-cell disease. What selective forces might have led to this difference?

   72,000 out of 318,000,000 is 0.022% of the population with the AA genotype in the United States.
   Therefore, $p^2 = 0.022\%$ or 0.00022 and $p = 0.015$ or 1.5%.
   $1 - p = q$, so $q = 1 - 0.015 = 0.985$
   $q^2 = 0.96$ or 96%
   $1 - (0.015 + 0.96) = 0.025 = 2.5\%$

   Considering the West African population:
   $p^2 = 4.0\% = 0.04$ and $p = 0.2 = 20\%$
   $1 - p = q = 1 - 0.20 = 0.80$
   $q^2 = 0.64$ or 64%
   $1 - (0.20 + 0.64) = 16\%$

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When the 0.022% American prevalence and the 4% West African prevalence are compared, we find:
(4 - 0.022) / 0.022) x 100
(3.978 / 0.022) x 100
180.818182 x 100
18081.8182% change

Because the mutation provides protection against malaria, individuals with the mutation may resist infection and live longer. Their children are also likely to carry the mutation and thus may survive for longer as well. In this case, the population is not at Hardy-Weinberg equilibrium because selection is favoring the presence of the a *allele.*

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
    - Make or use models that:
        - Simulate the real thing that cannot easily be studied or manipulated
        - Have as many details as possible replicated from the real thing
        - Function exactly like or similarly to the real thing.

- Patterns and Systems
    - Patterns and change:
        - Patterns in nature may be simple repeating patterns or complex changing patterns
        - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

- Evaluate Evidence
    - Drawing and Supporting a Conclusion by:
        - Using data to determine the cause effect relationship observed in the investigation
        - Report out trends and patterns in the data

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The Biotechnology Education Company ®

EDVO-Kit

140

Blood Typing

Store entire experiment at room temperature.

EXPERIMENT OBJECTIVE:

The objective of this experiment is to learn the concept of blood typing. A second objective is for students to differentiate between various types of cells found in blood and briefly provide an overview of their functions.

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All components are intended for educational research only. They are not to be used for diagnostic or drug purposes, nor administered to or consumed by humans or animals.

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This experiment is designed for 10 student groups.

No actual blood or blood products are used in this experiment.

Experiment Components

Store entire experiment at room temperature.

- Control ABO simulated blood samples (A, B, & O)**
- Unknown simulated blood samples from four patients (P1, P2, P3 & P4)

* Anti-A and Anti-B serum

- Transfer pipets
- Microtiter plates
- Microtest tubes

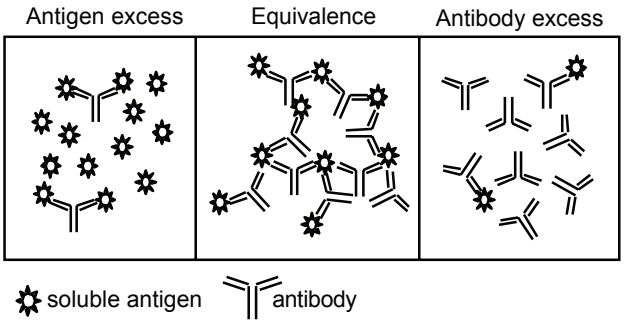
** NOTE: AB blood type will be prepared by instructor just prior to use.

Requirements

- Optional: Automatic micropipet (5 - 50 µl) and tips

Background Information

Precipitation reactions between soluble antigens and antibodies can be visible reactions if both components are in equivalence. Under this condition neither the antigen nor the antibody is in excess and antigen-antibody complexes form large networks that precipitate out of solution as diagrammed below.



When an antigen is attached to a red blood cell, the reaction is called an agglutination and the lattice of antigen and antibody that is visible at equivalence is called an agglutinate. Agglutination is a routine and cost-effective serological procedure because the agglutinate is very easily detectable.

Blood typing is an example of a clinical agglutination assay that is familiar to all of us. Since the specific blood antigens are on the surface of red blood cells (RBCs) they are termed hemagglutination reactions. Blood typing has various important medical applications. The most important use of hemagglutination blood typing is to ensure safe blood transfusions, which may be needed to replace blood lost during accidents or various medical procedures.

In the hemagglutination assay, blood types of both volunteer donors and recipients are tested. After the blood typing test, the recipient is matched to a donor from whom he will to be able to receive blood for a safe transfusion. The antigenic determinants on the surfaces of red blood cells (RBCs) are the A, B, and O blood group proteins, which are for convenience called A, B, and O antigens.

The two antigens provide for four possible types of blood; type A (only A antigen is on the surface of all RBCs from that person), type B (only B antigen is present); type AB (both A and B antigens are on each RBC); and O (neither A or B antigens are present). Based on the antigens on the surface of RBCs, there are four possible blood types in the ABO blood group system as listed below in Table A.

Blood Type	Antigen on Red Blood Cells
A	A
B	B
AB	both A and B
O	neither A nor B

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Background Information

Blood A and B antigens are common in the human population, as well as in nature, including bacteria to which we are exposed. When exposed to bacteria with the same blood group antigen, the immune system of the individual will recognize that antigen as "self" and no immune response will be mounted against it. By contrast, when exposed to bacteria with different blood group antigens, the human immune system will see that antigen as foreign and produce antibodies against it. These serum antibodies can then agglutinate RBCs from individuals with a different blood type. For example, anti-A antibodies from one individual's serum will agglutinate another person's RBCs that have the A antigen on their surface. Anti-B antibodies will agglutinate RBCs that have the B antigen on their surface as demonstrated below in Table B.

Blood Type	Antigen on Red Blood Cells	Antibody in Serum
A	A	anti-B
B	B	anti-A
AB	both A and B	neither anti-A nor anti-B
O	neither A nor B	both anti-A and anti-B

Type O blood is often referred to as the universal donor, and type AB blood is generally referred to as the universal recipient. Neither is correct. There is no universal donor nor a universal recipient in the case of whole blood transfusions. Type O blood is commonly said to be the universal donor because type O RBCs do not have either A or the B antigen on their surface. Thus Type O red blood cells were incorrectly assumed to be safe for transfusing individuals with Type A, B or AB blood. This assumption is incorrect and can have serious medical consequences where the anti-A antibodies from the donor would react with the recipient's red blood cells. Therefore, Type O blood is a universal donor only if red blood cells (and not serum) are being transfused.

If Type O blood was transfused into a person who has Type A blood, the following ABO antigens and antibodies would be present in various recipient's blood following transfusion.

- red blood cells with the A antigen (from recipient)
- red blood cells with neither A nor B antigen (from donor)
- anti-B antibodies (from recipient)
- anti-A and anti-B antibodies (from donor)

Therefore, in reality, only blood of the same type should be transfused into a patient. In fact, since there are subtypes of some of the blood groups and since there are other blood groups besides ABO which may cause transfusion problems, even this conservative approach is an oversimplification and may result in complications for the patient.

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Background Information

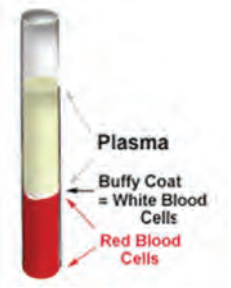
In this scenario, blood is needed in a small hospital for an emergency transfusion. A serious car accident occurred resulting in substantial blood loss and three friends quickly volunteered to serve as donors. The three donor and recipient blood samples are to be tested in the hospital serology laboratory by several technicians (student groups) to assure accuracy prior to the transfusion to occur. The three donors, two males and one female, are healthy and have recently been tested for blood infectious agents, including HIV, and were found to be free from all these agents and deemed candidates as blood donors. The recipient blood was quickly tested when she first arrived at the hospital and was found to be XX. The three donors do not know their blood types. The attending doctor ordered the blood of the recipient to be retested together with the three blood samples from the three donors, and all four sample were send to the laboratory.

ABOUT BLOOD AND BLOOD CELLS

Blood is a connective tissue that accounts for about 8% of an adult human's weight. It is composed of both fluid and cells. The fluid portion, called plasma is 90% aqueous (water) and is approximately 55% of normal total blood volume. Biological components in plasma amount to 10% and include different proteins and dissolved substances such as electrolytes and nutrients. Some of the proteins in plasma are involved in blood clotting; when these proteins are removed from the plasma, the resultant liquid is called serum. In effect, plasma is the fluid portion of whole blood, and serum is the fluid portion of clotted blood.

The remaining 45% of blood is composed of blood cells. There are three main types of blood cells: erythrocytes (also called red blood cells), thrombocytes (also called platelets), and leukocytes (also called white blood cells). All three of these cell types are produced in the red bone marrow from pluripotential stem cells called hemocytoblasts. ("Pluri" means "many"; thus, a pluripotential stem cell is one that can differentiate into many (but not all) types of cells; in this case, hemocytoblasts can differentiate into cells that ultimately give rise to all types of blood cells but not to other cells in the body.) About one billion new blood cells are produced each day by a process called either hemopoiesis or hematopoiesis.

When blood is centrifuged, it separates into 3 fractions (see Figure 1). The uppermost fraction consists of plasma, a straw-colored liquid. The 2 layers beneath the plasma consist of blood cells. Immediately below the plasma is a very thin white layer called the buffy coat; this layer, which represents less than 1% of whole blood, contains leukocytes and thrombocytes. The bottom layer consists of erythrocytes and accounts for about 45% of the blood volume.



Centrifuged blood

Plasma = ~ 55%

Buffy coat = < 1%
contains white blood cells
& blood platelets

Red Blood Cells = ~ 45%

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Background Information

By comparing the middle and bottom layers of centrifuged blood, it is easy to see that erythrocytes are the most numerous type of blood cell. Erythrocytes (seen in Figure 2) function in the transport of oxygen and, to a lesser degree, carbon dioxide. Adult human females have between 4.3 and 5.2 million erythrocytes per µl of blood (1 µl = 1 mm3 = 3.4 x 10-5 ounces = about 2.5 x 10-4 teaspoons); adult human males have between 5.1 and 5.8 million erythrocytes per µl of blood. Mature erythrocytes do not have a nucleus; as such, they are incapable of cell division. Erythrocytes are small, measuring about 7.5 µm in diameter (1 µm = 3.9 x 10-5 inches). The center of an erythrocyte is thinner than its periphery; thus, the center appears lighter than the periphery.

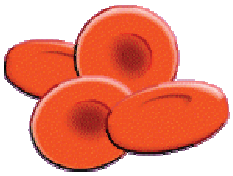

Figure 2: Erythrocytes

Thrombocytes (seen in Figure 3) are actually cytoplasmic fragments of large cells in the red bone marrow. Like erythrocytes, thrombocytes lack a nucleus and are thus incapable of mitosis. Adult humans have between 150,000 and 400,000 thrombocytes per µl of blood. Thrombocytes function mainly in hemostasis (i.e., stoppage of blood flow).

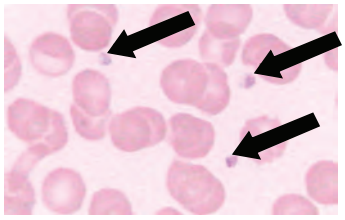

Figure 3: Thrombocytes.

Leukocytes function in defense. There are between 4,800 and 10,800 leukocytes per µl of blood in an adult human. Neutrophils, which function mainly in phagocytosis, account for 50-70% of circulating leukocytes in humans; they measure about 10 - 12 µm in diameter. The nucleus of a neutrophil appears as a band (in less mature neutrophils) or as a segmented structure with 2-6 lobes (in more mature neutrophils). Because of the variation in the shape of the nucleus, neutrophils are sometimes called polymorphonuclear leukocytes ("poly" means "many"; "morpho" means "shape") or simply polys or polymorphs. Because neutrophils are phagocytes, they are sometimes called microphages (meaning "small eaters"). The cytoplasm of neutrophils contains numerous small, indistinct granules that contain hydrolytic enzymes or other proteins that can function in defense. Because the granules of neutrophils stain with both an acid and a basic stain, they are considered neutral - thus, the name neutrophil. The granules of neutrophils appear light pink on a stained slide. Both band and segmented neutrophils can be seen in (Figure 4).

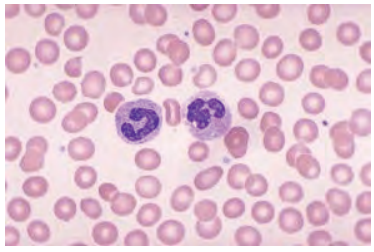

Figure 4: Band and Segmented Netrophils

Eosinophils (seen in Figure 5) account for only 2 - 4% of the circulating leukocytes in humans and are 10 - 14 µm in diameter. Their nucleus is usually bilobed. The cytoplasm of eosinophils contains relatively large granules (as compared to neutrophils); as the name of the cell implies, the granules stain with eosin. Thus, the granules are acidophilic (meaning "acid loving") and appear bright reddish-orange on a stained slide. Inside the granules are chemicals which function to destroy parasitic worms and to stop inflammatory reactions.

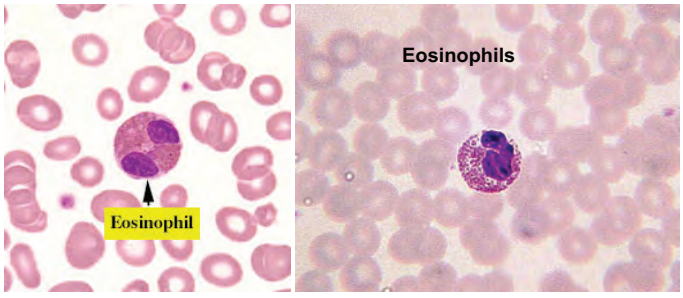

Figure 4: Eosinophils. In the image on the left, the 2 lobes of the nucleus look like 2 separate nuclei. In reality, they are 2 lobes of one nucleus that is constricted to form a thin, almost invisible central portion.

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Background Information

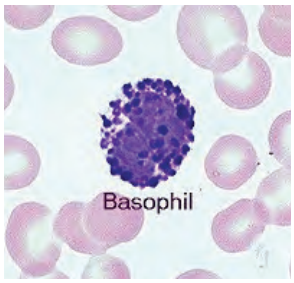

Figure 6: Basophil

Basophils (see Figure 6) are the least plentiful leukocyte in humans; they comprise less than 1% of circulating leukocytes. Generally smaller than neutrophils or eosinophils, basophils have a diameter of about 8-10 µm. The nucleus of the basophil, which is usually bilobed, is often not visible because of the numerous large dark blue staining (basophilic) granules in the cytoplasm. These granules contain many chemicals including heparin (an anti-coagulant) and histamine (a chemical which causes both constriction of bronchioles (air tubes within the lungs) and dilation of blood vessels). Basophils instigate some allergic reactions.

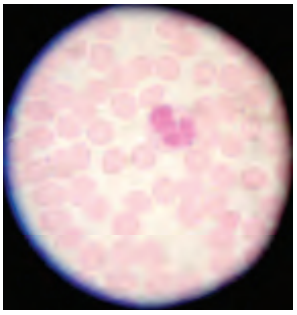
Figure 7: Monocyte

Monocytes (seen in Figure 7) are relative large blood cells, measuring between 14 and 24 µm in diameter. About 3 - 8% of circulating leukocytes are monocytes. The nucleus of a monocyte is large; either oval, indented, or folded; and appears foamy or spongy due to the arrangement of its chromatin. As the monocyte functions in phagocytosis, its cytoplasm contains many lysosomal granules. However, these granules are invisible using a light microscope; instead, the cytoplasm appears dirty gray. Monocytes that leave the blood and enter the tissues are called macrophages (meaning "big eaters"). Monocytes and macrophages are the major phagocytes in the body.

Lymphocytes (seen in Figure 8) constitute about 20 -40% of circulating leukocytes. These cells have a diameter of 5 – 17 µm and have a large nucleus which is round or nearly round. Often the nucleus takes up most of the cell, making visualization of cytoplasm minimal. Irregularly shaped clumps of chromatin are visible in the nuclei of stained lymphocytes. Lymphocytes function in immune responses.

Figure 8: Lymphocyte

There are 2 predominant types of lymphocytes - B cells and T cells. These cells are morphologically indistinguishable from each other, but each type is unique in function and location. In terms of function, B cells produce antibodies while T cells function in cell-mediated immunity and in controlling and regulating immune responses. Because of their differences in function, B and T cells express different cell surface receptors and thus can be separated from each other in the laboratory even though they appear identical. In terms of location, the majority of B cells home to specialized areas of the body called lymphoid tissues (such as red bone marrow, lymph nodes, the spleen, tonsils and the appendix); a lesser number of B cells are found in the blood. By contrast, most T cells circulate in the blood, while a minority of T cells home to lymphoid tissues.

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EXPERIMENT OBJECTIVE:

The objective of this experiment is to learn the concept of blood typing. A second objective is for students to differentiate between various types of cells found in blood and briefly provide an overview of their functions.

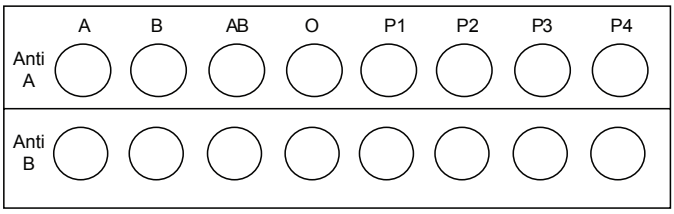
LABORATORY SAFETY

No human materials are used in this experiment. Gloves and safety goggles should be worn as good laboratory practice.

Student Experimental Procedures

Hemagglutination Reaction: Transfusion Testing

1. Place one microtiter plate piece as shown below. Across the top of the plate, label the 8 wells A, B, AB, O, P1, P2, P3, and P4 respectively, using a laboratory marking pen. Label the 2 rows Anti-A and Anti-B respectively. The plate should look like the one pictured below.



IMPORTANT! Avoid cross-contamination by using a new pipet or pipet tip for each blood sample.

PUT ON YOUR GLOVES NOW.

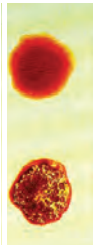
2. Using a different pipet or pipet tip for each sample, plate 3 drops of each control blood type and patient sample into each of the two corresponding wells. For example, control A blood type goes into the two wells under the letter A. Each well requires 3 drops or 50 µl.

3. Use a new pipet to add one drop or 20 µl of Anti-A serum into each of the wells in row #1.

4. Use a new pipet to add one drop or 20 µl of Anti-B serum into each of the wells in row #2.

5. Let the plate sit undisturbed on the lab bench for 5-10 minutes.

6. Observe the wells for the presence or absence of agglutination. Agglutination has occurred if the mixture appears to be granular rather than smooth. Record your results in the diagram in the Results section.



- (no agglutination)

+ (agglutination)

Experiment Procedure

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Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200. Standard must be consulted for specific requirements.

Control Type O
Unknown Simulated Blood Samples from Patient 2

IDENTITY (As Used on Label and List) — Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: EDVOTEK	Emergency Telephone Number: 301-251-5990
Address (Number, Street, City, State, and ZIP Code): 1121 5th Street NW	Telephone Number for information: 301-251-5990
Washington DC 20001	Date Prepared: 08/25/11
	Signature of Preparer (optional)

Section II - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
Proprietary mixture manufactured by Edvotek, Inc.				
CAS#: None Established				
Substance contains no blood or blood products.				

Section III - Physical/Chemical Characteristics

Boiling Point	NA	Specific Gravity (H2O = 1)	NA
Vapor Pressure (mm Hg.)	NA	Melting Point	NA
Vapor Density (AIR =1)	NA	Evaporation Rate (Butyl Acetate =1)	NA
Solubility in Water			
Appearance and Odor: red liquid, odorless			

Section IV - Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Extinguishing Media: Use appropriate extinguishing method for surrounding media.			
Special Fire Fighting Procedures			
Unusual Fire and Explosion Hazards			

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	Stable under normal temperatures and pressures.
Incompatiblity (Materials to avoid)			
Hazardous Decomposition or Byproducts			
Hazardous Polymerization	May Occur		
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes; Skin? Yes; Ingestion? Yes

Health Hazards (Acute and Chronic): None known. Not all health aspects of this substance have been thoroughly investigated

Carcinogenicity: NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: Eye irritant.

Medical Conditions Generally Aggravated by Exposure

Emergency and First Aid Procedures: Eye: Immediately flush with fresh water for 15 minutes. External: Wash with mild soap and water. Internal: Give large quantities of water. Call a physician or poison control at once.

Section VII - Precautions for Safe Handling and Use

Steps to Be Taken in case Material Is Released or Spilled: Ventilate area. Restrict unprotected personnel from area. Contain spill with sand or absorbant material. Deposit in sealed bag or container and hold for waste disposal

Waste Disposal Method: Follow federal, local, and state laws.

Precautions to be Taken in Handling and Storing: Avoid contact with eyes, skin and clothing. Wear chem. splash goggles, chem. resistant gloves and chem. resistant apron.

Other Precautions: Non hazardous for travel

Section VIII - Control Measures

Respiratory Protection (Specify Type)

Ventilation	Local Exhaust	Special
	Mechanical (General)	Other
Protective Gloves: None required	Eye Protection: None required	
Other Protective Clothing or Equipment		
Work/Hygienic Practices: Wear gloves and goggles as good laboratory practice.		

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200. Standard must be consulted for specific requirements.

Control Sample Type B
Unknown Simulated Blood Samples from Patients 1 and 4

IDENTITY (As Used on Label and List) — Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: EDVOTEK	Emergency Telephone Number: 301-251-5990
Address (Number, Street, City, State, and ZIP Code): 1121 5th Street NW	Telephone Number for information: 301-251-5990
Washington DC 20001	Date Prepared: 08/25/11
	Signature of Preparer (optional)

Section II - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
Proprietary mixture manufactured by Edvotek, Inc.				
CAS#: None Established				
Substance contains no blood or blood products.				

Section III - Physical/Chemical Characteristics

Boiling Point	NA	Specific Gravity (H2O = 1)	NA
Vapor Pressure (mm Hg.)	NA	Melting Point	NA
Vapor Density (AIR =1)	NA	Evaporation Rate (Butyl Acetate =1)	NA
Solubility in Water			
Appearance and Odor: red liquid, odorless			

Section IV - Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Extinguishing Media: Use appropriate extinguishing method for surrounding media.			
Special Fire Fighting Procedures			
Unusual Fire and Explosion Hazards			

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	Stable under normal temperatures and pressures.
Incompatiblity (Materials to avoid)			
Hazardous Decomposition or Byproducts			
Hazardous Polymerization	May Occur		
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes; Skin? Yes; Ingestion? Yes

Health Hazards (Acute and Chronic): None known. Not all health aspects of this substance have been thoroughly investigated

Carcinogenicity: NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: Eye irritant.

Medical Conditions Generally Aggravated by Exposure

Emergency and First Aid Procedures: Eye: Immediately flush with fresh water for 15 minutes. External: Wash with mild soap and water. Internal: Give large quantities of water. Call a physician or poison control at once.

Section VII - Precautions for Safe Handling and Use

Steps to Be Taken in case Material Is Released or Spilled: Ventilate area. Restrict unprotected personnel from area. Contain spill with sand or absorbant material. Deposit in sealed bag or container and hold for waste disposal

Waste Disposal Method: Follow federal, local, and state laws.

Precautions to be Taken in Handling and Storing: Avoid contact with eyes, skin and clothing. Wear chem. splash goggles, chem. resistant gloves and chem. resistant apron.

Other Precautions: Non hazardous for travel

Section VIII - Control Measures

Respiratory Protection (Specify Type)

Ventilation	Local Exhaust	Special
	Mechanical (General)	Other
Protective Gloves: None required	Eye Protection: None required	
Other Protective Clothing or Equipment		
Work/Hygienic Practices: Wear gloves and goggles as good laboratory practice.		

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200. Standard must be consulted for specific requirements.

Control Simulated Blood Sample Type A
Unknown Simulated Blood Sample from Patient 3

IDENTITY (As Used on Label and List) — Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: EDVOTEK	Emergency Telephone Number: 301-251-5990
Address (Number, Street, City, State, and ZIP Code): 1121 5th Street NW	Telephone Number for information: 301-251-5990
Washington DC 20001	Date Prepared: 08/25/11
	Signature of Preparer (optional)

Section II - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
Proprietary mixture manufactured by Edvotek, Inc.				
CAS#: None Established				
Substance contains no blood or blood products.				

Section III - Physical/Chemical Characteristics

Boiling Point	NA	Specific Gravity (H2O = 1)	NA
Vapor Pressure (mm Hg.)	NA	Melting Point	NA
Vapor Density (AIR =1)	NA	Evaporation Rate (Butyl Acetate =1)	NA
Solubility in Water			
Appearance and Odor: red liquid, odorless			

Section IV - Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Extinguishing Media: Use appropriate extinguishing method for surrounding media.			
Special Fire Fighting Procedures			
Unusual Fire and Explosion Hazards			

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	Stable under normal temperatures and pressures.
Incompatiblity (Materials to avoid)			
Hazardous Decomposition or Byproducts			
Hazardous Polymerization	May Occur		
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes; Skin? Yes; Ingestion? Yes

Health Hazards (Acute and Chronic): None known. Not all health aspects of this substance have been thoroughly investigated

Carcinogenicity: NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: Eye irritant.

Medical Conditions Generally Aggravated by Exposure

Emergency and First Aid Procedures: Eye: Immediately flush with fresh water for 15 minutes. External: Wash with mild soap and water. Internal: Give large quantities of water. Call a physician or poison control at once.

Section VII - Precautions for Safe Handling and Use

Steps to Be Taken in case Material Is Released or Spilled: Ventilate area. Restrict unprotected personnel from area. Contain spill with sand or absorbant material. Deposit in sealed bag or container and hold for waste disposal

Waste Disposal Method: Follow federal, local, and state laws.

Precautions to be Taken in Handling and Storing: Avoid contact with eyes, skin and clothing. Wear chem. splash goggles, chem. resistant gloves and chem. resistant apron.

Other Precautions: Non hazardous for travel

Section VIII - Control Measures

Respiratory Protection (Specify Type)

Ventilation	Local Exhaust	Special
	Mechanical (General)	Other
Protective Gloves: None required	Eye Protection: None required	
Other Protective Clothing or Equipment		
Work/Hygienic Practices: Wear gloves and goggles as good laboratory practice.		

Material Safety Data Sheets

Full-size (8.5 x 11") pdf copy of MSDS is available at www.edvotek.com or by request.

Material Safety Data Sheets
Full-size (8.5 x 11") pdf copy of MSDS is available at www. edvotek.com or by request.

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200. Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List)

Control Simulated Blood Sample Type A
Unknown Simulated Blood Sample from Patient 3

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: EDVOTEK	Emergency Telephone Number: 301-251-5990
Address (Number, Street, City, State, and ZIP Code): 1121 5th Street NW	Telephone Number for information: 301-251-5990
Washington DC 20001	Date Prepared: 08/25/11
	Signature of Preparer (optional)

Section II - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
Proprietary mixture manufactured by Edvotek, Inc.				
CAS#: None Established				
Substance contains no blood or blood products.				

Section III - Physical/Chemical Characteristics

Boiling Point	NA	Specific Gravity (H2O = 1)	NA
Vapor Pressure (mm Hg.)	NA	Melting Point	NA
Vapor Density (AIR = 1)	NA	Evaporation Rate (Butyl Acetate = 1)	NA
Solubility in Water			
Appearance and Odor: red liquid, odorless			

Section IV - Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Extinguishing Media: Use appropriate extinguishing method for surrounding media.			
Special Fire Fighting Procedures			
Unusual Fire and Explosion Hazards			

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	Stable under normal temperatures and pressures.
Incompatiblity (Materials to avoid)			
Hazardous Decomposition or Byproducts			
Hazardous Polymerization	May Occur		
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes | Skin? Yes | Ingestion? Yes

Health Hazards (Acute and Chronic): None known. Not all health aspects of this substance have been thoroughly investigated

Carcinogenicity: NTP? | IARC Monographs? | OSHA Regulation?

Signs and Symptoms of Exposure: Eye irritant.

Medical Conditions Generally Aggravated by Exposure

Emergency and First Aid Procedures: Eye: Immediately flush with fresh water for 15 minutes. External: Wash with mild soap and water. Internal: Give large quantities of water. Call a physician or poison control at once.

Section VII - Precautions for Safe Handling and Use

Steps to Be Taken in case Material Is Released or Spilled: Ventilate area. Restrict unprotected personnel from area. Contain spill with sand or absorbant material. Deposit in sealed bag or container and hold for waste disposal

Waste Disposal Method: Follow federal, local, and state laws.

Precautions to be Taken in Handling and Storing: Avoid contact with eyes, skin and clothing. Wear chem. splash goggles, chem. resistant gloves and chem. resistant apron.

Other Precautions: Non hazardous for travel

Section VIII - Control Measures

Respiratory Protection (Specify Type)

Ventilation	Local Exhaust		Special
	Mechanical (General)		Other
Protective Gloves: None required	Eye Protection: None required		
Other Protective Clothing or Equipment			
Work/Hygienic Practices: Wear gloves and goggles as good laboratory practice.			

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200. Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List)

Anti-B Serum, Kit 140

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: EDVOTEK	Emergency Telephone Number: 301-251-5990
Address (Number, Street, City, State, and ZIP Code): 1121 5th Street NW	Telephone Number for information: 301-251-5990
Washington DC 20001	Date Prepared: 08/25/11
	Signature of Preparer (optional)

Section II - Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
Proprietary mixture manufactured by Edvotek, Inc.				
CAS#: None Established				
Substance contains no blood or blood products				

Section III - Physical/Chemical Characteristics

N.D. = No Data

Boiling Point	1100°C	Specific Gravity (H2O = 1)	N.D.
Vapor Pressure (mm Hg.)	N.D.	Melting Point	800°C
Vapor Density (AIR = 1)	N.D.	Evaporation Rate (Butyl Acetate = 1)	N.D.
Solubility in Water: soluble in cold water			
Appearance and Odor: colorless or white, liquid, odorless			

Section IV - Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Extinguishing Media: Substance is nonflammable; use agent most appropriate to extinguish surrounding fire.			
Special Fire Fighting Procedures: As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear.			
Unusual Fire and Explosion Hazards: Substance not considered hazardous. However, not all health aspects of this substance have been thoroughly investigated.			

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid: Incompatible materials, dust generation, moisture, excess heat.
	Stable	X	
Incompatiblity (Materials to avoid): Strong oxidizing agents,aluminum, magnesium, potassium, mercury, lead, calcium, silver, barium, ammonium ions, strontium.			
Hazardous Decomposition or Byproducts			
Hazardous Polymerization	May Occur		
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes | Skin? Yes | Ingestion? Yes

Health Hazards (Acute and Chronic): May cause severe eye, skin and respiratory tract irritation with possible burns.

Carcinogenicity: NTP? | IARC Monographs? | OSHA Regulation?

Signs and Symptoms of Exposure: May cause eye, skin and respiratory tract irritation.

Medical Conditions Generally Aggravated by Exposure

Emergency and First Aid Procedures: Skin or Eyes: flush with plenty of water for at least 15 min. Get medical aid if irritation develops. Inhalation- move to fresh air. If not breathing, give artificial respiration. Ingestion: If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person.

Section VII - Precautions for Safe Handling and Use

Steps to Be Taken in case Material Is Released or Spilled: Restrict unprotected personnel from area and ventilate area. Contain spill with sand or absorbant material. Deposit in sealed bag or container.

Waste Disposal Method: Follow federal, local, and state laws.

Precautions to be Taken in Handling and Storing: Avoid contact with eyes, skin, and clothing. Wear chemical resistant splash goggles/gloves/apron. Non-hazardous for travel.

Other Precautions: Wear appropriate NIOSH/MSHA approved respirator

Section VIII - Control Measures

Respiratory Protection (Specify Type): Appropriate NIOSH/MSHA approved respirator

Ventilation	Local Exhaust: Yes		Special
X	Mechanical (General)		Other
Protective Gloves: Chemical resistant	Eye Protection: Chemical resistant		
Other Protective Clothing or Equipment			
Work/Hygienic Practices			

Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

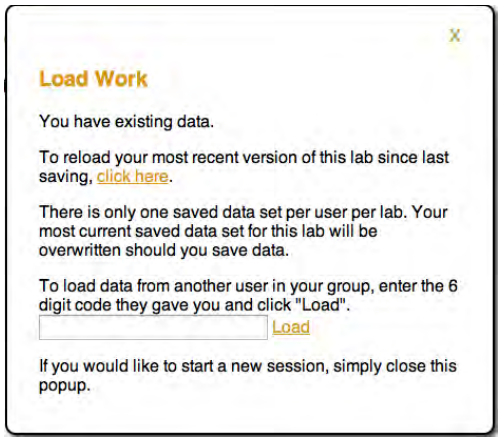
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

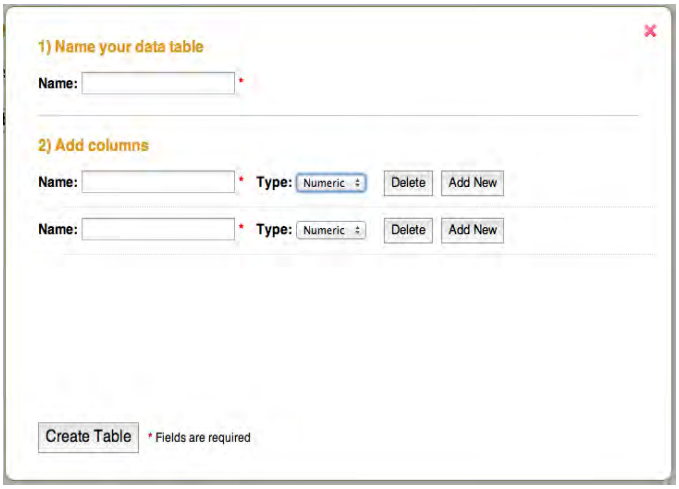
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



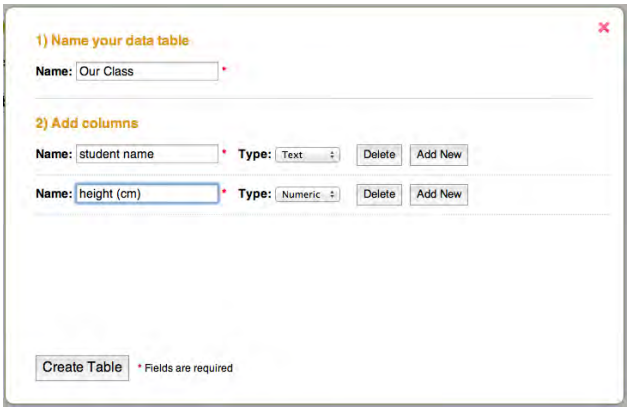
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

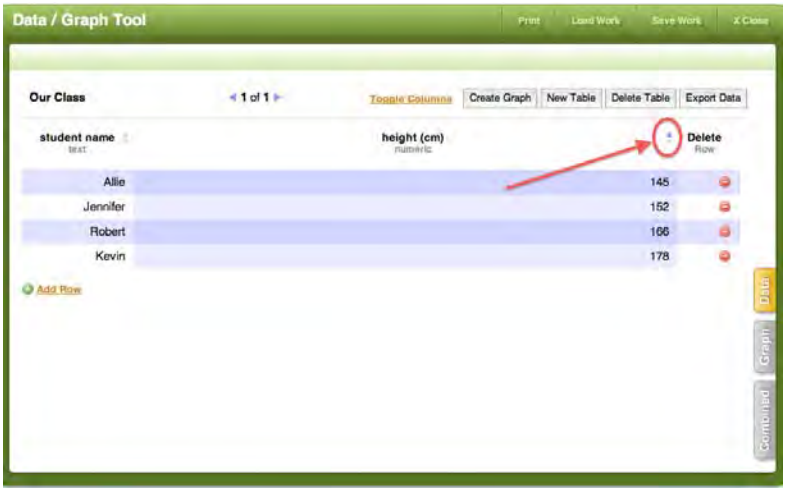
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

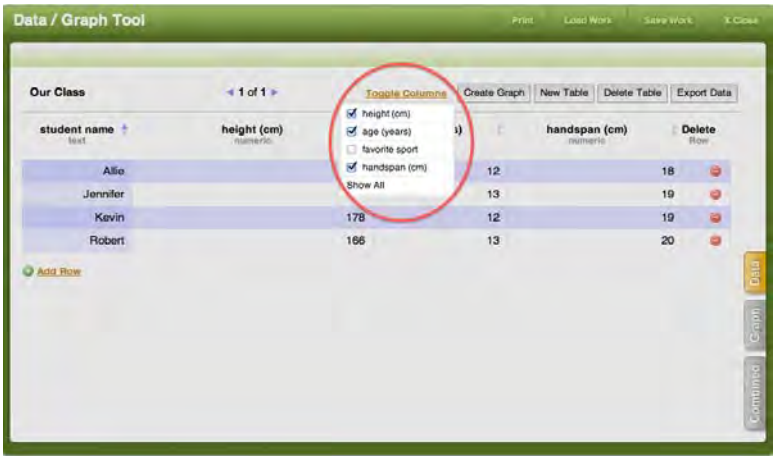


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

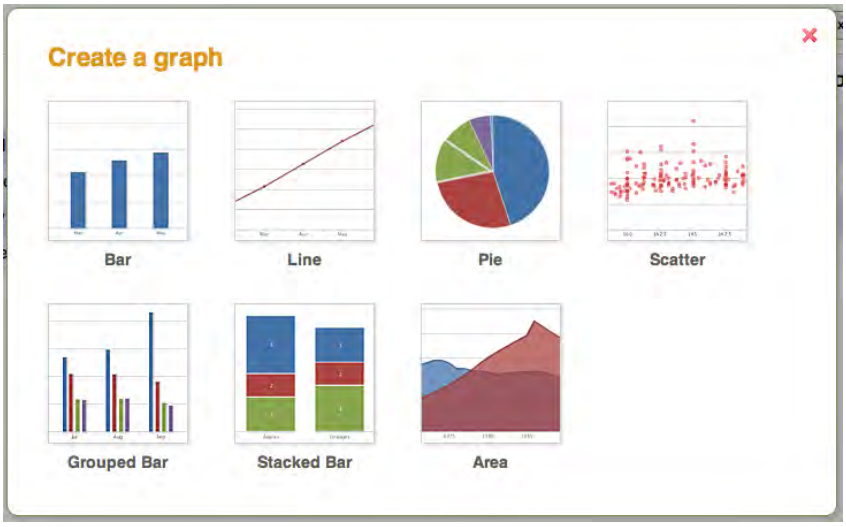
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

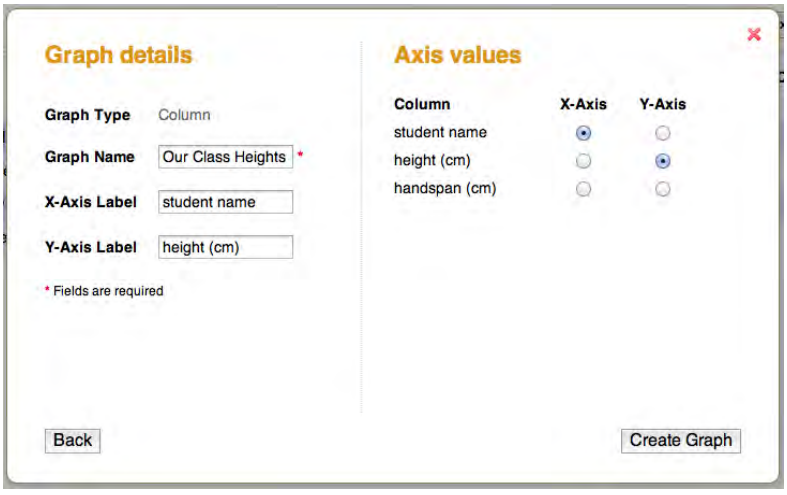
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

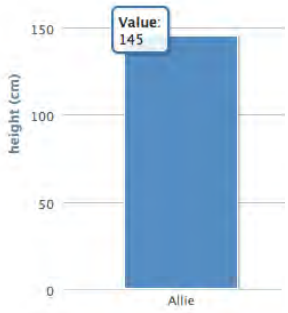


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

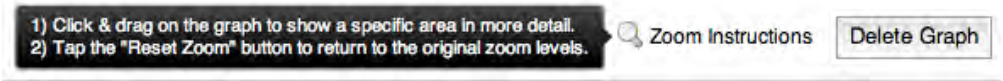
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Activity

Dominant vs. Recessive in a Sample Population

Objective:
Students will investigate a number of common human dominant and recessive alleles.

Estimated time to complete: 10 minutes

Materials:
For each student:

- Data table

Procedure:
Have the class agree to three or four traits that humans can have such as hair texture (straight), freckles, earlobe arrangement (attached), and the ability to roll their tongue. Have them write a hypothesis about which allele they think is dominant for each trait based on prior observation of society.

Students will survey each member of the class for the presence or absence of these traits and record tally marks in a data table such as the one below:

Trait (examples)	Trait present	Trait absent	Dominant allele
Straight hair			
Face freckles			
Attached earlobes			
Ability to roll tongue			
Other…			

After collecting the class data, students should predict which allele is dominant in the last column of the data table. (Answers for sample traits: Dominant traits include curly hair, the presence of freckles, free or non-attached earlobes, and the ability to roll one's tongue.)

Provide students with the correct answer for the dominant allele in each case. Then, have students answer the following questions in their notes. Invite students to discuss their responses with the class.

- *Was your hypothesis correct? Why do you think so?*
  This will depend on their initial hypothesis.
- *Were dominant alleles always the most common alleles in the sample population?*
  This will depend upon the alleles selected. However the chances are that at least one of the alleles that is most common in the sample will be recessive. The fact that an allele is dominant does not mean it is the most frequent allele in the population.
- *Why do you think some recessive alleles may be present in a population?*
  The frequency of alleles is determined through the process of natural selection. Those alleles that increase an organism's fitness will be selected for. Therefore the frequency of these alleles will increase within the population regardless of whether they are dominant or recessive..
- *What do you predict would happen if you repeated the same survey with your entire school or entire town? Why?*
  Emphasize the smallness of the sample size; remind students that surveying a larger group of people would likely produce more typical results.

Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Design and conduct field studies using:
    - Survey - collects multiple data points at one point in time
  - Design and conduct investigations using
    - Sample (if needed) - a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements.
- Gather Data
  - Use the appropriate format to record data:
    - Table
- Interpret Data
  - Sort and classify using scientific reasoning by:
    - Sorting objects, substances and organisms by characteristic
  - Identify and interpret patterns using:
    - Trends in data
    - Tables and graphs
    - Analysis of data collected during an investigation
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Reporting trends and patterns in the data
    - Extrapolating results beyond the investigation
- Scientific Investigation
  - Scientific Data and Outcomes:
    - Arguments and conclusions are invalid if based on very small samples of data, biased samples, or samples for which there was no control sample.

Hands-On Activity

Examining Flowers

Objective:
Students will use hand lenses to examine the reproductive structures of flowers.

Estimated time to complete: 20 minutes

Materials:

For each student or small group:

- Flowers (tulips and lilies)
- Hand lens or magnifying glass
- Tweezers or small dissecting scissors

Procedure:
Provide each student with a flower with large stamens and pistils, such as lilies or tulips. Have the students examine the flowers with a hand lens, paying special attention to the reproductive parts. Have students use the various tools such as the hand lens and tweezers to collect their data. After examining the intact flower, have students break the pistils and stamens apart to examine these parts more closely. In order to collect qualitative data, students need to create a data table or chart to record their observations about the size, location, and other characteristics of the plant reproductive parts.

Give students about ten minutes to sketch their observations, then invite students to share what they have discovered about how plants are fertilized from their observations. Ask students to define cross-pollination and self-pollination from their observations.

Analysis and Conclusions:

1. What new information did you learn about how flowers are fertilized by examining them?
   Sample Response: *Now I understand that the same basic structures are involved in the fertilization of flowers, even though they look very different from one species to another.*

2. What do you now understand about cross-pollination and self-pollination?
   Sample Response: *Now I understand that the plants cannot necessarily detect from where pollen is coming from, so any pollen, from the same plant or from a different one, can pollinate a flower.*

3. How would fertilization be different in nature and in a lab setting?
   In nature, cross-pollination takes place when insects, wind, or animals carry pollen from one plant to another, while self-pollination occurs when wind or some minor disturbance transfers pollen from the stamen to the pistil of the same plant. In a lab, researchers place pollen where it is needed for their experiments, either on a different plant or the same one.

4. How do you think traits in offspring differ between plants that are self-pollinated and those that are cross-pollinated?
   There is greater opportunity for varied traits when plants are cross-pollinated.

5. How did the qualitative data you collected on the flowers help you understand how flowers cross-pollinate or self-pollinate? (By collecting qualitative data on the flower's reproductive parts, it was easier to determine if the plant was cross- or self-pollinated.)

Inquiry and Nature of Science Skills in this Activity:

- Gather Data
  - Choose appropriate tools to conduct an investigation:
    - Magnifying Glass
    - Lenses
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
  - Use the appropriate format to record data:
    - Sketch

Exploration Teacher Guide: Genetics

Overview

Genetics is the science of heredity. In this Exploration, students carry out monohybrid and dihybrid crosses and observe the genotypic and phenotypic ratios of the offspring. While carrying out a cross, they explore how some genes are dominant for a given trait. Students identify the different allele pair combinations that can be used to make these crosses. They also explore how gametes are formed in a monohybrid and a dihybrid cross.

Student Learning Objectives

- Analyze how Punnett squares indicate the outcome of monohybrid and dihybrid crosses.
- Model the phenotype and genotype of the offspring.
- Model the process of formation of gametes using the Punnett square.
- Observe dominant and recessive characteristics of different traits in pea plants and humans.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students carry out monohybrid and dihybrid crosses between individuals with different traits. Students use the *Monohybrid* and *Dihybrid* radio buttons to select the type of cross they wish to investigate. They use the *Select Species* dropdown list to select the species for which they want to study the cross. Students then select the trait they wish to study using the options in the *Select Trait* dropdown list. They select the allele pairs using the options in the *Select Allele Pair* dropdown list.

This is a two-step activity. In the first step, students make gametes, by arranging allele pairs along the sides of the Punnett square. To do this, alleles are dragged and dropped on the slots on top and on the left side of the Punnett square. After the allele pairs have been made correctly, students click on the *Continue* button to move on to the second step of this activity.

In this step, students drag each allele that they made in step 1 and drop them into the corresponding boxes within the Punnett square to simulate the cross. After the allele pairs are positioned correctly, images representing each offspring appear.

Students may use the *Hint* button see an animation of how the allele pairs are arranged.

They use the *Reset* button to reset the activity area using the same selections. The may use the *Start Over* button to start the Exploration again.

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In the *Tracker* tab, students track the various crosses created by them successfully. The also note the selected traits and the genotypic and phenotypic ratios.

Answers to Questions in the Student Worksheet

1. List the genotypes of a homozygous tall pea plant and a heterozygous tall pea plant, assuming that the dominant allele is T and the recessive allele is t.

   Answer: The genotype of a homozygous tall pea plant is TT. The genotype of a heterozygous tall pea plant is Tt.

2. Explain why Mendel selected pea plants to study genetics.

   Answer: Mendel chose pea plants to study genetics because of their characteristic features including:
   a. Pea plants have short life cycles, so it is possible to study several generations in a short time.
   b. Pea plants have distinctive observable features such as height and color of flower, making them relatively easy for the study of phenotypes.
   c. Self-pollination and self fertilization is possible in pea plants, allowing the development of lines that breed true.
   d. Hybrids of pea plants are fertile.

3. A pea plant with round and yellow seeds has an allele pair combination of *RrYy*. Identify the allele combinations possible in the gametes that can be formed from this parent.

   Answer: The allele pair combinations possible in the gametes are RY, Ry, rY, and ry.

4. List the heterozygous offspring that may be obtained if one parent is homozygous and the other heterozygous for a single trait. Include the trait you are using in the explanation.

   Answer: This question can have multiple answers. One of the answers is as follows:

   Consider a homozygous tall pea plant (TT) crossed with a heterozygous tall pea plant (Tt). The offspring of this cross would be TT, Tt, and TT. The possible heterozygous offspring obtained would be Tt (heterozygous tall). The alternative answer is a cross of tt x Tt with offspring heterozygous tall to homozygous short in a 1:1 ratio.

5. Explain the difference between a monohybrid and a dihybrid cross.

   Answer: A monohybrid cross is a genetic cross in which alleles of a single trait are studied, such as a dwarf pea plant crossed with a tall pea plant. Height is the single trait. Dihybrid cross is when two traits with two alleles each are studied, such as a dwarf pea plant with

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white flowers crossed with a tall pea plant with red flowers. Height and flower color are the two traits.

6. Explain how you would use a Punnett square to study phenotypic characteristics.

   Answer: A Punnett square is used to determine the genotype and phenotype of an offspring obtained by crossing two parents. For a monohybrid cross, it is a 2 × 2 checkerboard. Alleles of each parent are written on the sides of the square. Later, the alleles are assigned to corresponding boxes of the square and the resulting offspring genotypes are interpreted as phenotypes.

7. Use gametes BB and Bb (B: brown eye color; b: blue eye color) to carry out a monohybrid cross. List all the possible outcomes. Compare these outcomes to those when gametes BB and bb are crossed.

   Answer:
   Cross 1: Genotypes and phenotypes are BB- homozygous brown, Bb- heterozygous brown.
   Cross BB x Bb = BB, Bb, BB, Bb
   Offspring genotypic ratio = 2:2
   Offspring phenotypic ratio (brown: blue) = 1:0

   Cross 2: Genotypes and phenotypes are BB- Homozygous brown, bb- Homozygous blue
   BB x bb = BB, Bb, Bb, bb
   Offspring genotypicratio = 1:2:1
   Offspring phenotypicratio: 3 = 1

8. Explain how Mendel's law of segregation is different from Mendel's law of independent assortment.

   Answer: Mendel's law of segregation states that for any particular trait, every individual has a separate pair of alleles. During a cross, each parent passes a randomly selected allele to its offspring. The dominant allele in the offspring expresses that trait. The law of independent assortment states that separate alleles for separate traits are passed independently of one another from parents to offspring.

9. In a certain plant, purple flowers are dominant over red flowers. Identify the genotype of the parent plants if a cross between two purple-flowered plants produces some purple-flowered plants and some red-flowered plants. Assume the dominant and recessive are alleles are P and p respectively.

   Answer:
   Possible genotypes of purple flowered plants are PP and Pp.
   Possible genotype of red flowered plants is pp.

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Since some offspring have red and some have purple flowered plants, their genotypes could be PP or Pp (purple flowers), and pp (red flowers). Both parent plants are purple flowered but cannot both be homozygous purple (PP) since the cross yields some red flowered plants. Nor can one parent be PP and the other be Pp since all offspring would still be purple. Hence the genotype of both parent plants would be Pp.

10. A monohybrid cross was carried out to study flower color in pea plants. The phenotypic ratio was 3:1 for pink flowers to white flowers. The genotypic ratio was 1:2:1 for PP:Pp:pp. Use the phenotypic and genotypic ratios to determine the dominant trait. Identify the allele pair combination of the parents used to produce this cross.

    Answer: Since the offspring ratio is 1:2:1 for PP:Pp:pp and the phenotype is 3:1 for pink flowers to white flowers, the dominant trait is pink flower color. The genotypic ratio of the offspring indicates that the allele pair combination of parent plants is Pp and Pp.

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Hands-On Activity

Investigating DNA

During meiosis, chromosomes pair up. These pairs are called *homologous chromosomes*. These chromosomes can twist around each other, leading to an exchange of genetic information called *crossing over*. In this activity, students will model how homologous chromosomes pair up and exchange genetic material.

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should use care when handling scissors.

Suggested Materials:
Per group:

- scissors
- paper, cut into 4 strips
- colored pencil, red
- colored pencil, blue
- tape

To introduce the activity, have students read the Reading Passage titled **How DNA Works.** Introduce the term *homologous chromosomes* and ask them to identify references to homologous chromosomes in that passage.

Procedure:

1. Direct students to write *A* and *B* on a strip of paper with the red pencil. Then, students should write *A* and *B* on a second strip of paper, also with the red pencil. For each strip, write the *A* at the bottom of the strip and *B* close to the center.
2. On a third strip of paper, students should write *a* and *b* with the blue pencil. Then, students should write *a* and *b* with the blue pencil on a fourth strip of paper. For each strip, write the *a* at the bottom of the strip and *b* close to the center.
3. Direct students to use tape to create homologous chromosomes.
4. Next, instruct students to model crossing over using their chromosome models.

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Analysis and Conclusions

1. How did you model homologous chromosomes?
   Answers should indicate that the strips with A *and* B *were joined together (likely with tape) and the strips with* a *and* b *were joined together.*

2. What did the letters on the strips of paper represent?
   The letters represented genes.

3. What did you do to represent crossing over between the homologous chromosomes?
   Answers should indicate that students at least crossed strips with the same letters—that is, B *with* b *or* A *with* a*. Some students may have actually cut the "genes" from strips and taped them to the other chromosome.*

4. The "arms" of a chromosome are called the *chromatids*. A chromosome consists of sister chromatids. The chromatids are attached to each other with a structure called a *centromere*. What represented the centromere in your model?
   Students likely used tape to join the chromatids (strips of paper) together. Students should at least understand that the centromere is the location where the chromatids are attached to each other, even if they did not physically attach the strips of paper with tape.

5. How does the exchange of DNA through crossing over increase genetic variation?
   Crossing-over results in unique combinations of genes from the parent organisms. This recombination of genetic material results in more variation in a population.

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing

- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)

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Hands-On Activity

Modeling Mendel's Laws

In this activity, students will use colored beads to model and better understand Mendel's laws.

Materials

Per Pair:

- beads, at least four different colors (20 of each color)
- small jars or cups
- masking tape
- permanent marker

To introduce the activity, review with students the terms *phenotype*, *genotype*, *allele*, *gene*, *trait*, *dominant*, *recessive*, *homozygous*, and *heterozygous*. Also review Mendel's two laws:

- The first law is called the law of **segregation.** The two alleles of a gene segregate, or separate, from each other in the formation of gametes, so that half of the gametes carry one allele and half carry the other.
- The second law is called the law of **independent assortment**. Alleles for different traits separate independently of each another when gametes form.

Part 1: Principle of Segregation

Procedure

Distribute all materials to each pair. Review the objective of the activity, and answer any questions students may have.

1. Explain that students will use the given materials to model the first of Mendel's two laws—the principle of segregation.
2. Review Mendel's experiment in which he crossed tall pea plants with short pea plants, using homozygous parent plants. This experiment is the basis for Mendel's first law.
3. Explain that students will create a model that represents Mendel's experiment. Give each pair 20 red beads and 20 blue beads. Have them put the red beads in one jar and use the masking tape and marker to label the jar "Parent 1 Gamete." Students can place the blue beads in the other jar and label it "Parent 2 Gamete."
4. Explain that the beads represent the original pea plants in one of Mendel's experiments (with red as the dominant tall trait and blue as the recessive short trait). To model the experiment, students should first "breed" the pea plants by randomly selecting one bead from each jar to produce a new genotype (i.e., one bead from each parent). To ensure that selection is random, students should choose the beads without looking: one partner may hold the jar while the other covers his or her eyes and chooses.
5. Students should record data for the offspring in a table such as the one below. Each new pairing of beads (one from each jar) is one trial.

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Trial	Offspring Genotype	Offspring Phenotype
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

6. Next, students will continue the model to show how Mendel discovered the principle of segregation by breeding the first generation offspring to make a second generation. Because there are more possible outcomes, students should mix 20 of each color bead from the previous section and randomly choose from this assortment. They should complete 100 trials, returning the beads to the jar after each trial. They may record their results using tally marks in a table such as the one below:

Genotype	TT	Tt	tt
Number of offspring			

7. Discuss how Mendel's results after the second generation show that there must be multiple alleles for each trait.

Part 2: Principle of Independent Assortment

1. Explain that students will continue to work with their partners, using what they learned in Part 1 to design a model of a dihybrid cross. Have students recall that Mendel studied a cross between plants with yellow, round seeds and plants with green, wrinkled seeds. (The yellow and round traits were dominant.) Students' models should demonstrate the principle of independent assortment. Encourage students to brainstorm ways to ensure the independent assorting of the allele pairs. (For example, a group may use the jar of red and blue beads from Part 1 to represent the yellow and green seeds, and add a second jar that has 20 beads each of two new colors to represent the smooth or wrinkled seeds.)

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Analysis and Conclusions

1. Create a Punnett square for the first generation of your model in Part 1. How did your model's percentages compare to the percentages predicted by the Punnett square?
Sample Response: Predicted and actual percentages were the same, as suggested by this Punnett square:

		Parent 1 (Red Beads)	
		T	***T***
Parent 2 (Blue Beads)	***t***	*Tt (tall)*	*Tt (tall)*
	t	*Tt (tall)*	*Tt (tall)*

2. Create a Punnett square for the second generation of your model in Part 1. How did your model's percentages compare to the percentages predicted by the Punnett square?
Sample Response: Predicted and actual percentages of genotype and phenotype may vary but should be similar, as suggested by this Punnett square:

		Parent 1 (Red/Blue)	
		T	***T***
Parent 2 (Red/Blue)	***T***	*TT (tall)*	*Tt (tall)*
	t	*Tt (tall)*	*tt (short)*

3. How did your model in Part 1 demonstrate the law of segregation?
Sample Response: In the second generation, some of the offspring were short. This showed that the short allele was carried by the first generation plants, though it was not expressed. In the second generation, some of the short alleles separated from the tall ones and came together in pairs without tall alleles, allowing the plants to express this trait.

4. How did your model in Part 2 demonstrate the law of independent assortment?
Sample Response: In my model, I kept beads for each allele pair in a separate jar. This meant that when I modeled crossing the plants by choosing from the jars, I chose only one allele for each trait.

5. Create a Punnett square for the dihybrid cross you modeled in Part 2.
Sample Response:

		TtYy			
		TY	***Ty***	***tY***	***ty***
TtYy	***TY***	*TTYY*	*TTYy*	*TtYY*	*TtYy*
	Ty	*TTYy*	*TTyy*	*TtYy*	*Ttyy*
	tY	*TtYy*	*TtYy*	*ttYY*	*ttYy*
	ty	*TtYy*	*Ttyy*	*ttYy*	*ttyy*

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Hands-On Activity

Punnett Squares

Objectives:
Diagram and predict the results of monohybrid crosses.

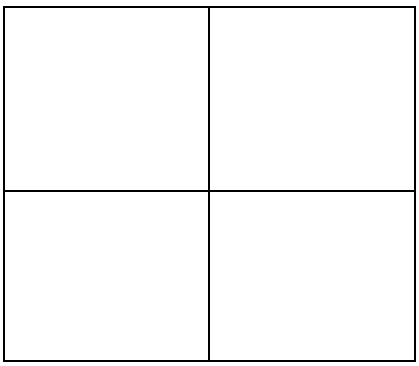
Estimated time to complete: 10 minutes

Materials:
For each student:

- Pencil and paper

Procedure:

1. Write the last four digits of a phone number on the paper. These four numbers represent the alleles for a gene that determine a person's ability to roll his or her tongue. In this activity, even digits represent the allele of the dominant trait (can tongue roll) and the odd digits represent the recessive trait (cannot tongue roll).
2. Draw a vertical line between the first two digits and the last two digits. The first two will represent the mother's alleles and the last two are the father's. Use the letters *T* and *t* to write the genotype of each parent based on the digits.
3. Use the blank Punnett square below and place the mother's genotype across the top squares. Place the father's genotype along the left side of the squares.
4. Complete the Punnett square. Then, determine the probability that this child will have the ability to tongue roll.
5. Share your information with the class to determine the average number of children that will be able to roll their tongue. Does the class data align with the fact that tongue rolling is a dominant trait? Why or why not?



Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Design and conduct investigations using:
    - Sample (if needed) - a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements
- Interpret Data
  - Sort and classify using scientific reasoning by:
    - Sorting objects, substances and organisms by characteristic
  - Identify and interpret patterns using:
    - Tables and graphs
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Reporting trends and patterns in the data
    - Extrapolating results beyond the investigation
- Patterns and Systems
  - Patterns and Change
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

Hands-On Lab

Creating and Evaluating Scientific Models of DNA

Timing: two 90-minute class sessions

Objective(s):
Students will create a model of DNA and then evaluate their model to determine its limitations.

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should be careful using sharp objects such as scissors and other modeling equipment. Remind students to wear proper safety attire including lab coats or aprons, and gloves if necessary. Students should follow proper disposal and cleaning procedures after the lab.

Materials:
Per group:

- variety of modeling materials, such as:
  - modeling clay
  - styrofoam
  - colored paper
  - colored pens
  - toothpicks
- glue
- box cutter and/or scissors
- notebook
- lab apron, one per student
- paper towels

Teacher Preparation:

- Gather materials in advance of students performing the lab.

Procedure

1. Have students research the structure and function of DNA, in particular reviewing images that represent the molecule in different ways. A good resource to start with is Crick and Watson's original paper in the science journal *Nature (*http://www.nature.com/nature/dna50/watsoncrick.pdf*)*.
2. Instruct students to create a simple plan, including the goals of the model as well as proposed techniques to create the model.
3. Students may choose to build 3D models, but also encourage students to think of models that are not simple 3D representations, including more abstract models such as flowcharts and mathematical representations. Also encourage students to consider models of details of molecules such as ribose sugars, bases or phosphate groups. Creating the models of the building blocks of DNA may help students build the more complex 3D DNA model.
4. When students have completed their models, encourage them to explore the benefits and limitations of their models. For example, you can guide students with questions such as:
    a. What does your model show that cannot be seen directly?
    b. Can your model be used to make predictions?
    c. How does your model help communicate the structure and function of DNA?
    d. Does your model omit details or processes that scientists know about?
    e. Is your model an exact representation of DNA?

Analysis and Conclusions

1. What new information did you learn about DNA by creating a model?

Answers may vary. Some examples of student answers may be: I learned what DNA molecules look like. I learned the different molecules that make up a DNA molecule. I learned the different atoms that are found in DNA. I learned about the shape of a DNA molecule. I learned about the types of bonds that hold a molecule of DNA together. I learned about the structure and components of DNA.

2. What predictions did you make about using your model to understand DNA structure and function?

Answers may vary. Some examples of student answers may be: I predicted I would learn what DNA molecules look like and how they work. I predicted I would learn the different types of bonds within DNA molecules and how they hold DNA together. I predicted I would learn the different types of molecules found within DNA and how they are necessary for DNA to function. I predicted I would learn about the atoms found in DNA and how they help DNA function.

3. How does creating a model of DNA, rather than reading about it or looking at pictures about it, provide you with a better idea about its structure and function?

It is more engaging process that helps you better visualize and understand the different components of DNA and how DNA functions. When you just read about the structure and function of DNA or just see pictures, you may forget about them more easily than if you take the time needed to incorporate all the details you do when making an actual model of DNA and learning about how it functions. By building a model, it helps me understand how the how all of the parts of the cell work and interact with each other.

4. Models are always an imperfect representation of reality. Think about the model you created. What aspects of DNA could your model not show? Evaluate the limitations of your model, and how they could be overcome with an improved model or different approach. Learning kinesthetically helps to better retain what you have learned.

Answers may vary. Some examples of student answers may be: My model does not show how copies of DNA are made through the process of DNA replication. This could be overcome by making multiple models showing the different stages of replication or using a computer model to show how replication occurs. My model does not show how DNA is transcribed into mRNA through the process of transcription. This could be overcome by making multiple models showing the different stages of transcription or using a computer model to show how transcription occurs. My model does not show the whole process of how proteins are assembled based on the information contained in the genetic code of DNA through the process of translation. This could be overcome by making multiple models to show different steps of the process of translation or by using a computer model to show how translation occurs.

Inquiry skills

In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

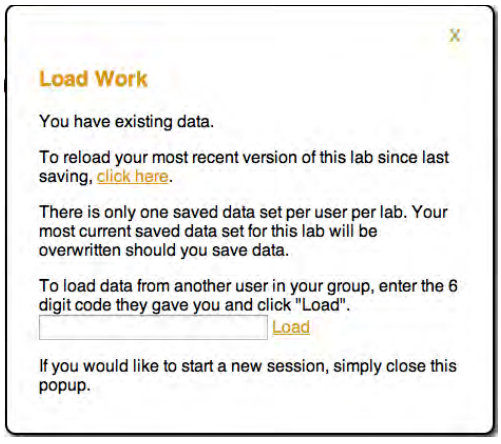
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

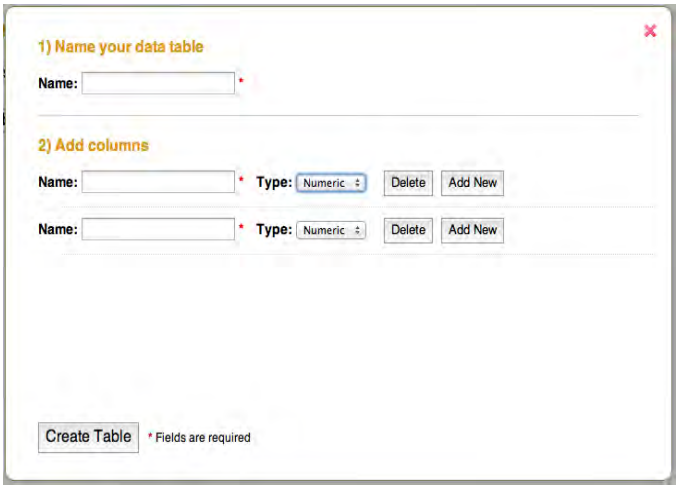
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



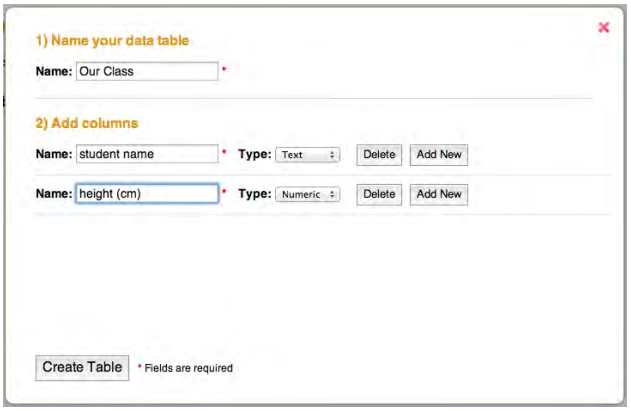
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

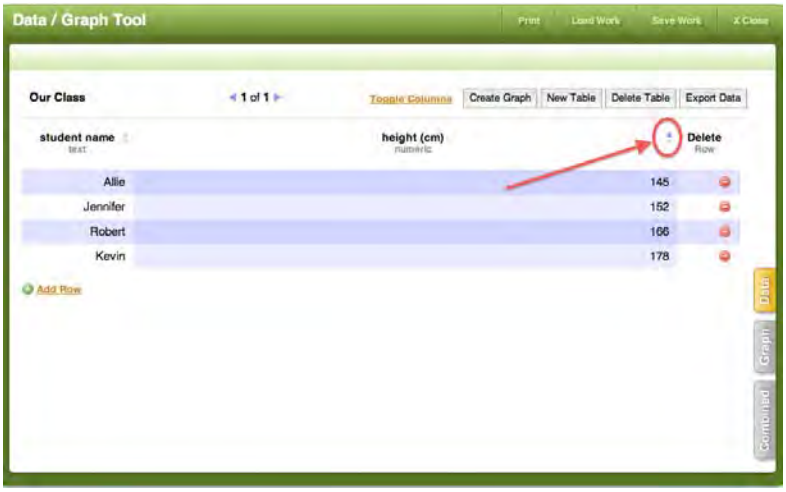
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

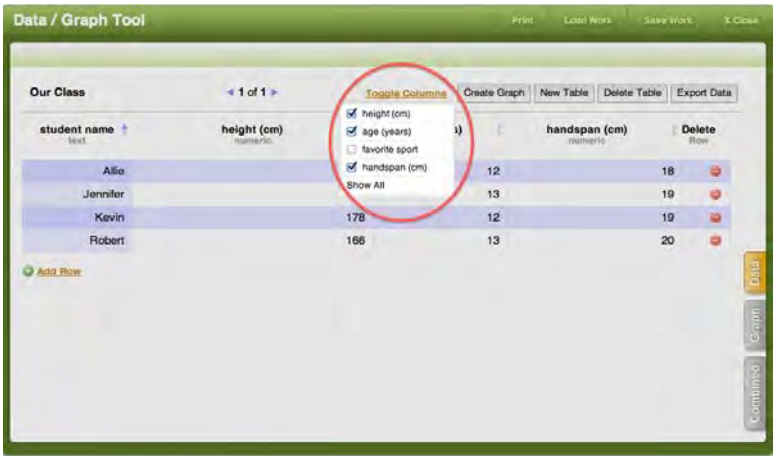


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

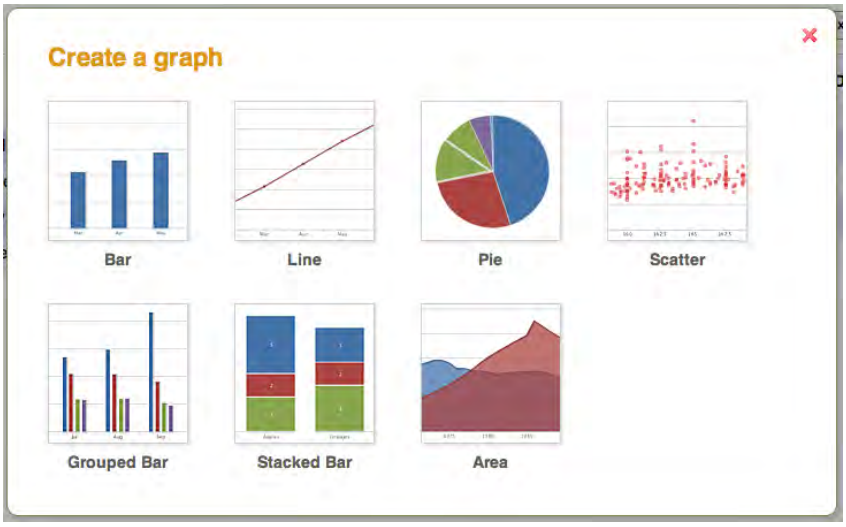
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

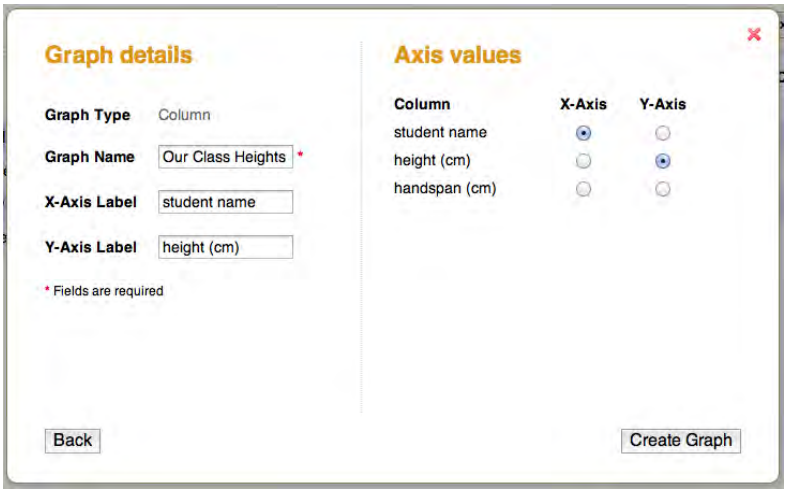
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

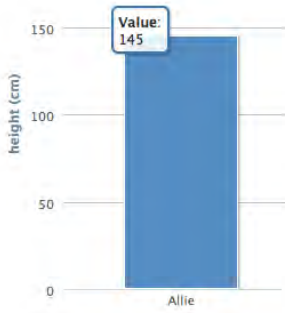


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

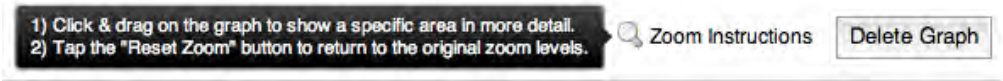
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Exploration Teacher Guide: DNA

Overview

The polynucleotide DNA is the basic replicating molecule of life. In this Exploration, students develop a model of the structure of the DNA and simulate the DNA replication process. In developing the DNA structure, they learn how the four chemical bases pair up and are positioned. To complete the structure, they identify how sugar molecules and phosphate groups form a part of this structure. During the DNA replication process, students perform steps in the correct order to unwind the DNA double helix structure. They then replicate the molecule by building the complementary strands for the leading and lagging strands.

Student Learning Objectives

- Learn how the chemical bases, adenine (A), guanine (G), cytosine (C), and thymine (T), pair up to form the base pairs.
- Construct the DNA structure by linking the bases to the phosphate groups using the sugar molecules.
- Observe the double-helix structure of DNA.
- Simulate the DNA replication process.
- Follow the sequence in which the enzymes are released to start the replication process.
- Understand the role of helicase and polymerase in the replication process.
- Create the complementary strands for the leading and lagging strands to complete the DNA replication process.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Build* tab, students develop a model of the DNA structure. This is a two-step activity. In the first step, students position the four chemical bases adenine (A), guanine (G), cytosine (C), and thymine (T) to form base pairs horizontally. Bases are positioned in any of the slots and complementary bases are positioned in adjoining slots. Students use the rotate buttons to rotate the base so that it forms hydrogen bonds between hydrogen attached to a nitrogen base on one strand and an electronegative atom such as nitrogen or oxygen on the other. The *Remove* button is used to remove the base from the current slot. Students use the *Hint* button at any time during the step. The *Show Me!* button shows students the correct arrangement of the base pairs. Students may use the *Reset* button to reset the screen. Clicking the *Link* button validates if the user has positioned the bases correctly. When the arrangement is not correct, feedback is provided. After the bases are positioned correctly, clicking the *Proceed* button takes the user to the second part of this activity.

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The user has to link each of the bases to the sugar molecule and then connect the sugar molecules to the phosphate groups.

In the *Replicate* tab, students click on the enzymes in the correct order and then observe the DNA unwind and splitting into lagging and leading strands. Students then build the complementary strands by dragging and dropping the bases in their correct position so that they form base pairs. The order in which the base pairs are formed is important. An *Alert!* message is displayed with an incorrect attempt.

Answers to Questions in the Student Worksheet

1. If the DNA double helix is a twisted ladder, what are the rungs of the ladder and what holds the rungs together?

   Answer: DNA double helix is a long chain polymer of nucleotides. The rungs of the ladder are paired bases of adenine and thymine, and of guanine and cytosine. These rungs are held together by hydrogen bonds between the base pairs.

2. The sequence of bases on a strand of DNA is AATCGACCGACTA. What is the sequence of bases on its complementary strand?

   Answer: The sequence of bases on the complementary strand would be TTAGCTGGCTGAT.

3. What is the role of enzymes helicase and polymerase during DNA replication?

   Answer*:* Helicase enzyme is involved in separation and unwinding of nucleic acid strands (double helix of DNA). This enzyme breaks hydrogen bonds between the base pairs of the double stranded DNA. Polymerase, on the other hand, is involved in adding free nucleotides to the 3' end of a newly forming DNA strand.

4. How do the nucleotides pair up?

   Answer: Nucleotides pair up due to hydrogen bonds.Adenine and thymine are held together by two H-bonds while guanine and cytosine are held together by three H-bonds.

5. Explain how DNA is able to make an exact copy of itself.

   Answer: DNA makes an exact copy of it by semi-conservative replication. In this type of replication, each strand of the parent DNA molecule acts as a template for the synthesis of a new complementary DNA molecule. Enzymes break the DNA double helix and "unzip" it into two separate strands. The strands act as templates for the formation of two new daughter strands with sequences of bases determined by complementary base pairing. This results in the formation of exact copies of parent DNA.

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6. Explain why AT pairs are easier to pull apart than GC pairs during the unwinding process.

   Answer: Adenine and thymine are held together by two H-bonds while guanine and cytosine are held together by three H-bonds. Thus adenine and thymine are separated more easily than guanine and cytosine.

7. Although A pairs with T, merely placing them next to each other is not enough to create a bond between them. Explain.

   Answer: In a DNA molecule, base pairing takes place due to stacking interactions. Factors like short-range exchange repulsion and electrostatic interactions help in the stability of base pairs. Thus merely placing A and T bases together will not create a bond between them.

8. If you were to create a model of a DNA structure, what objects would you use? Describe how you would build this structure.

   Answer: This question could have multiple answers. One of the answers is as follows:

   To make a structural model of DNA, use copper wires, beads of four different colours, toothpicks, and gum. First, bend the two copper wires in the form of a circular coil and place them parallel to each other. Then, stick four different coloured beads in a consecutive fashion on one of the wire. Each colour would represent adenine, thymine, guanine and cytosine, respectively. Now, attach complimentary beads on the other copper wire. (In complementary base pairing, A is paired with T and G is paired with C). Once both the wires have beads attached to them, place two toothpicks to show hydrogen bonding between A-T and three toothpicks to show hydrogen bonding between C-G.

9. The double helix structure of DNA is the same in all organisms. What are the main differences in the DNA of plants, mammals and bacteria?

   Answer: The major difference between bacterial DNA and the DNA of plants and animals is that bacterial DNA is circular and is not organized into chromosomes. The difference between plant DNA and animal DNA is in the size of total genome. Plants in general have much larger genomes compared to animals.

10. Could DNA be in the form of a helix, rather than a double helix? Explain.

    Answer: Yes, DNA exists in the form of a single helix, since it can still replicate. Certain viruses have single stranded DNA.

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Hands-On Activity

Modeling DNA

Objective:
In this two-part activity, students will create models that show how DNA carries genetic information and replicates.

Estimated time to complete: Part I: 50 minutes; Part II: 30 minutes

Materials:
For each small group:

- colored paper
- colored pencils
- glue sticks
- paper clips
- tape
- wire
- wire cutters
- modeling clay
- digital camera (optional)

Procedure: Part I
Divide students into groups of three or four. Distribute the materials to each group. Students will use the materials to create a model that shows how DNA carries genetic information. First, each group should plan its model on paper; once you have approved a group's plan, the group may begin building its model.

One possible design is to cut two equal lengths of wire to represent the sugar and phosphate "backbones" of the complementary strands in a DNA molecule. Students may use colored paper, modeling clay, paper clips, or other small objects to represent the four nucleotide bases; each base should be a different object or color. Students may arrange their "bases" in any order along one strand, but the order of the bases in the complementary strand must mirror the order of the bases in the first strand: Each guanine base in one strand must pair with a cytosine base in the other strand; each adenine base in one strand must pair with a thymine base in the other strand.

Allow groups to present their models to the class when they are finished. As they watch each presentation, students should point out any errors in their classmates' models and suggest fixes.

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Procedure: Part II

Instruct students to return to their small groups from Part I. Return each group's DNA model and distribute the materials as needed. Students will use the materials to revise their models—or create new models—show the process of DNA replication. Explain that groups may need to create several models to represent the major steps in the process. Rather than creating multiple models, groups may use digital cameras, if available, to photograph the process of revising a single model to represent each step; students can then turn their photographs into a slideshow presentation.

For example, to represent the creation of a replication fork, a group might begin by photographing its original DNA model. The group could then separate the joined strands of wire at one end of the model to represent the unraveling of the molecule by the enzyme helicase. After photographing this version of the model, students would further revise their model to represent the synthesizing of the leading and lagging strands, photographing each revision to create a record of the successive changes.

First, each group should plan its model on paper; once you have approved a group's plan, the group may begin building or revising its model. Allow groups to present their models to the class when they are finished. As they watch each presentation, students should point out any errors in their classmates' models and suggest fixes.

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Analysis and Conclusions

1. What is the significance of the different nucleotide bases in your models? *Sample answer: The different nucleotide bases are the basis of the triplet genetic code.*

2. How did your model demonstrate the carrying of genetic information by DNA? *Sample answer: Most model triplets of bases on the model strand of DNA represent the code for an mRNA base pair triplet. This RNA triplet in turn codes for an amino acid. The nature and order of nucleotides in a DNA triplet therefore determines the amino acid added to a polypeptide chain during translation.*

3. How did your model demonstrate the replication process of DNA? *Sample answer: The answer will depend upon the approach taken by the group. For example students may have modeled a replication fork. Students may wish to add labeled images to explain their answer to the question.*

4. Were there any errors in your model when you shared it with the class? How did you fix these errors? *Sample answer: Answers will depend on the individual models constructed by the students. If errors were present then the answer should include a suggested fix.*

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Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
- Gather Data
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
    - Touching (temperature, texture, shape, size, vibration, motion)
- Communication in Science
  - Report results using:
    - Peer presentation
- Patterns and Systems
  - Patterns and Change:
    - Patterns in nature may be simple repeating patterns or complex growing or changing patterns

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S-51

EDVO-Kit #

Whose DNA was Left Behind?

Storage:
Store the entire experiment at room temperature.

EXPERIMENT CONTENT OBJECTIVE

- Students will learn how restriction enzymes cut DNA molecules at specific base sequences producing DNA fragments of varying lengths.
- Students will learn how agarose gel electrophoresis separates different sizes of DNA fragments.
- Students will learn how these fragments form unique patterns for each person's DNA, which is the basis for DNA fingerprinting analysis.

All components are intended for educational research only. They are not to be used for diagnostic or drug purposes, nor administered to or consumed by humans or animals.

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Experiment Components

Storage:
Store this experiment at room temperature.

This experiment is designed for 10 groups.

Contents

A Crime Scene Simulated DNA Sample 1
B Crime Scene Simulated DNA Sample 2
C Suspect One Simulated DNA Sample 1
D Suspect One Simulated DNA Sample 2
E Suspect Two Simulated DNA Sample 1
F Suspect Two Simulated DNA Sample 2

Transfer pipets
UltraSpec-Agarose™
50x Electrophoresis Buffer
Practice Gel Loading Solution

None of the experiment components have been prepared from human sources. Simulated DNA samples are non-toxic, water-based dyes.

Experiment Requirements

Experiment Requirements

- Electrophoresis Apparatus, M-12 or equivalent
- D.C. Power Supply
- Heat Source
- 500 ml Beaker or Flask
- Hot Gloves
- Distilled Water (used to make buffer solutions)
- Balance
- Automatic Micropipet and tips (optional)

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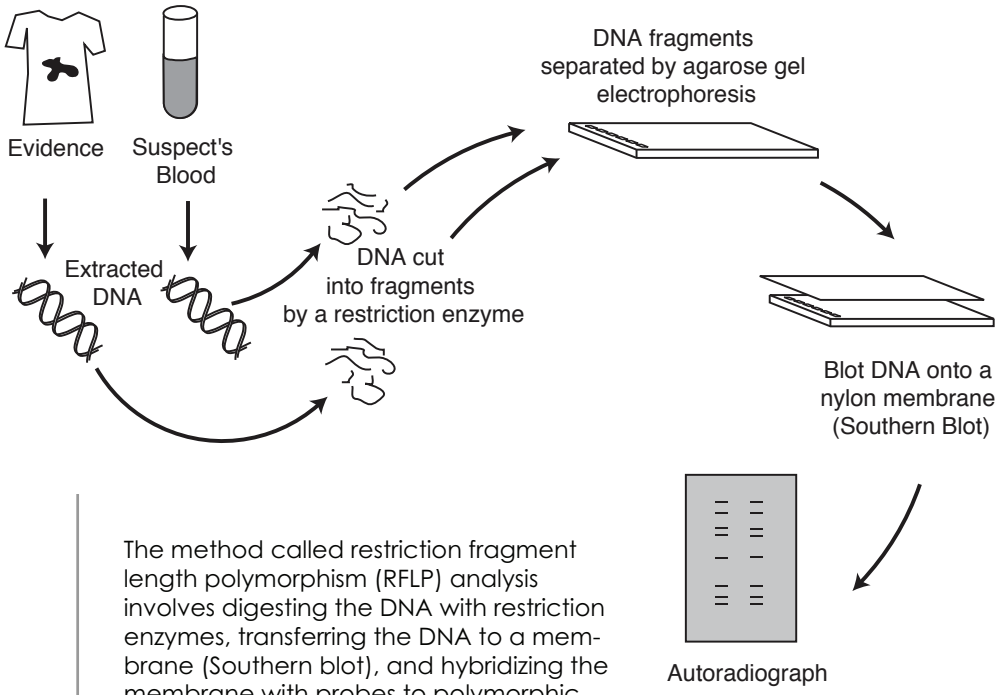
Background and Introduction

DNA fingerprinting allows for the identification of the source of a DNA sample, which is very important in many forensic cases. DNA fingerprinting can provide positive identification with great accuracy by matching DNA obtained from a crime scene to individual suspects.

Several steps are involved in DNA fingerprinting. First, a suitable sample must be obtained. Forensic scientists use great care obtaining evidence from crime scenes so that the DNA will not be damaged. DNA is then isolated from the evidence, such as blood or hair samples. Once the DNA isolated, it is either digested with special enzymes called restriction endonucleases, or submitted to the Polymerase Chain Reaction (PCR).



The method called restriction fragment length polymorphism (RFLP) analysis involves digesting the DNA with restriction enzymes, transferring the DNA to a membrane (Southern blot), and hybridizing the membrane with probes to polymorphic regions (autoradiography). This method requires relatively large amounts of DNA and takes several weeks. It is, however, statistically very accurate.

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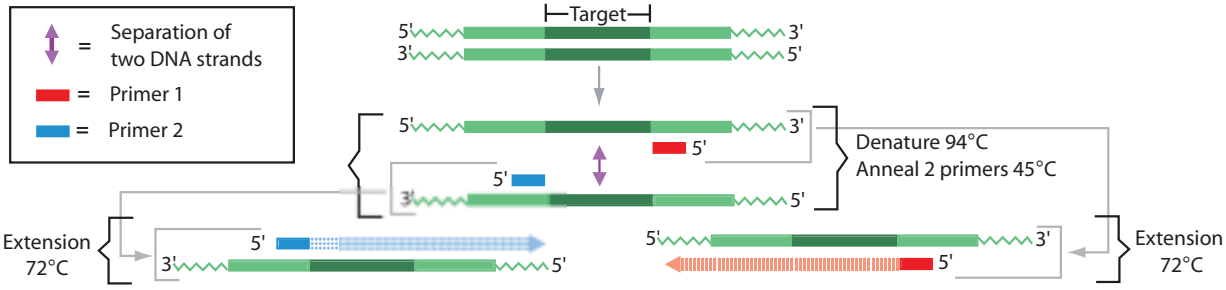
Background and Introduction

More recently, the Polymerase Chain Reaction (PCR) has been used in forensics to analyze DNA. This technique requires much less (500-fold) DNA than RFLP analysis and is much less time-consuming. PCR amplification uses an enzyme known as *Taq* polymerase, which was originally purified from a bacterium that inhabits hot springs. It is stable at very high (near boiling) temperatures. The PCR reaction mixture also includes two (15-30 nucleotide) synthetic oligonucleotides, known as "primers". These items are mixed with the extracted DNA, known as the "template".

The region of DNA to be amplified is known as the "target". In the first step of the PCR reaction, the template's complimentary DNA strands are separated (denatured) from each other at 94°C, while the *Taq* polymerase remains stable. In the second step, known as annealing, the sample is cooled to an intermediate temperature, usually 40°-65°C, to allow hybridization of the two primers, one to each of the two strands of the template DNA. In the third step, known as extension, the temperature is raised to 72°C and the *Taq* polymerase adds nucleotides to the primers to complete the synthesis of the new complementary strands.



These three steps - denaturation, annealing, and extension - constitute one PCR "cycle". This process is typically repeated for 20-40 cycles, amplifying the target sequence exponentially. PCR is performed in a thermal cycler, an instrument that is programmed to rapidly heat, cool and maintain samples at designated temperatures for varying amounts of time.

In this experiment, you will analyze DNAs (represented by colored dyes) using aspects of RFLP analysis. In this hypothetical case, the dyes represent DNAs obtained from a crime scene and two suspects which have been cut by restriction enzymes and the fragmentation patterns serve as the individual fingerprint. The DNA (dye) fragmentation patterns are simple enough to analyze directly in the agarose gel. The objective is to analyze and match the DNA fragmentation patterns after agarose gel electrophoresis and determine if Suspect 1 or Suspect 2 was at the crime scene.

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Experiment Overview

BEFORE YOU START THE EXPERIMENT

1. Read all instructions before starting the experiment.

2. Write a hypothesis that reflects the experiment and predict experimental outcomes.

EXPERIMENT CONTENT OBJECTIVE

- Students will learn how restriction enzymes cut DNA molecules at specific base sequences producing DNA fragments of varying lengths.
- Students will learn how agarose gel electrophoresis separates different sizes of DNA fragments.
- Students will learn how these fragments form unique patterns for each person's DNA, which is the basis for DNA fingerprinting analysis.

WORKING HYPOTHESIS

If a DNA sample collected at the crime scene is cut with two different restriction enzymes and compared with DNA samples obtained from two suspects' DNA cut with the same two restriction enzymes, then one should be able to identify the real killer by the DNA fingerprint method.

MATERIALS FOR THE EXPERIMENT

Each Lab Group should have the following materials:

Activity One

- Electrophoresis Buffer
- Practice gel loading sample
- Sample delivery instrument
  Automatic micropipet and tips, or
  Transfer pipet and beaker of distilled water

Activity Two

- Agarose gel
- Electrophoresis apparatus
- DC power source
- Dye Samples (A - F) representing DNA
- Sample delivery instrument
  Automatic micropipet and tips, or
  Transfer pipet and beaker of distilled water

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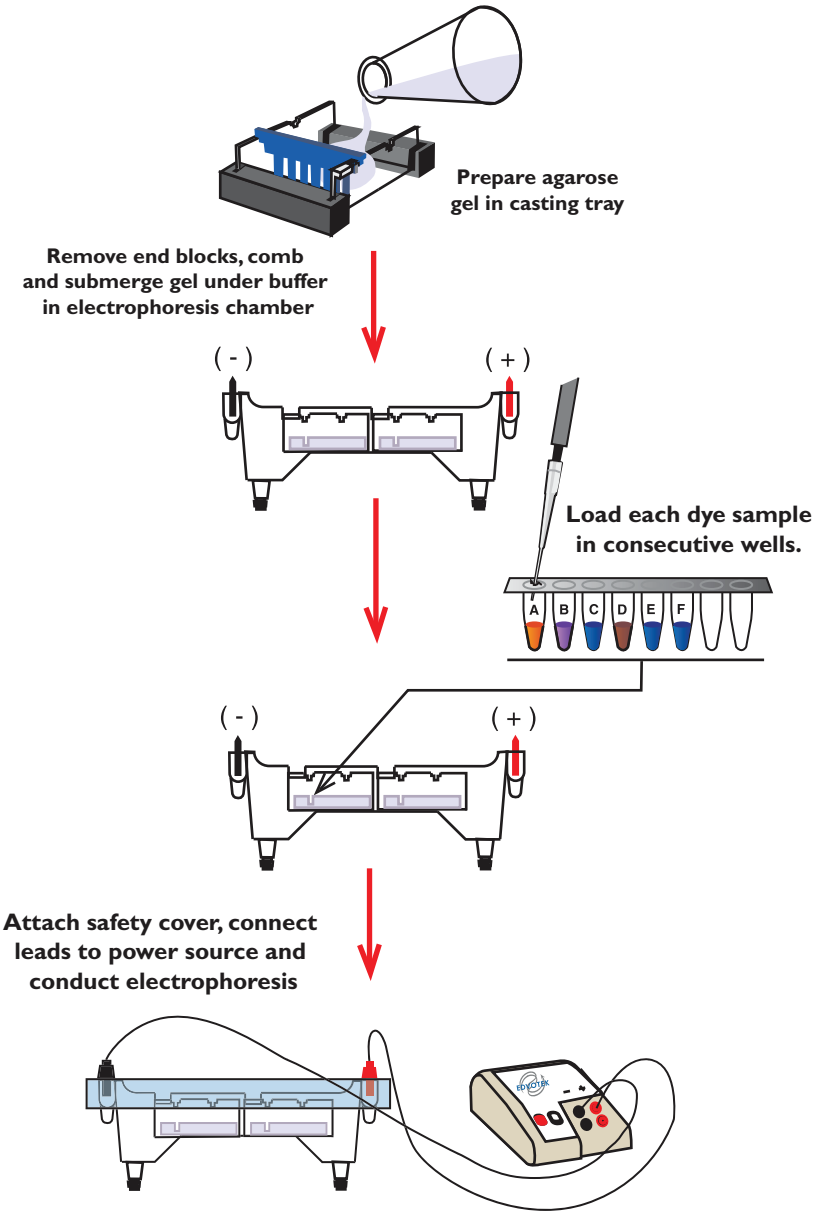
Experiment Overview



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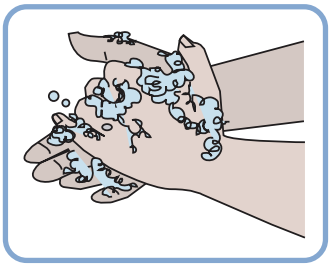
Laboratory Safety

1. Gloves and goggles should be worn routinely as good laboratory practice.
2. Exercise extreme caution when working with equipment that is used in conjunction with the heating and/or melting of reagents.
3. DO NOT MOUTH PIPET REAGENTS - USE PIPET PUMPS.

Wear gloves and safety goggles

4. Exercise caution when using any electrical equipment in the laboratory.
   - Although electrical current from the power source is automatically disrupted when the cover is removed from the apparatus, first turn off the power, then unplug the power source before disconnecting the leads and removing the cover.
   - Turn off power and unplug the equipment when not in use.
5. EDVOTEK injection-molded electrophoresis units do not have glued junctions that can develop potential leaks. However, in the unlikely event that a leak develops in any electrophoresis apparatus you are using, IMMEDIATELY SHUT OFF POWER. Do not use the apparatus.
6. Always wash hands thoroughly with soap and water after handling reagents or biological materials in the laboratory.



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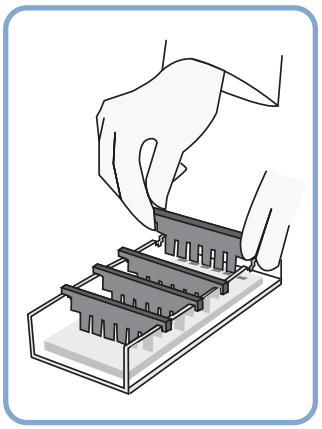
Activity One - Practice Gel Loading

Accurate sample delivery technique ensures the best possible gel results. Pipeting mistakes can cause the sample to become diluted with buffer, or cause damage to the wells with the pipet tip while loading the gel.

If you are unfamiliar with loading samples in agarose gels, it is recommended that you practice sample delivery techniques before conducting the actual experiment. EDVOTEK electrophoresis experiments contain a tube of practice gel loading solution for this purpose. Casting of a separate practice gel is highly recommended. One suggested activity is outlined below:



1. Cast a gel with the maximum number of wells possible.
2. After the gel solidifies, place it under buffer in an electrophoresis apparatus chamber.

   Alternatively, your teacher may have cut the gel in sections between the rows of wells. Place a gel section with wells into a small, shallow tray and submerge it under buffer or water.

Note: The agarose gel is sometimes called a "submarine gel" because it is submerged under buffer for sample loading and electrophoretic separation.

3. Practice delivering the practice gel loading solution to the sample wells. Take care not to damage or puncture the wells with the pipet tip.
   - For electrophoresis of dyes, load the sample well with 35-38 microliters of sample.
   - If using transfer pipets for sample delivery, load each sample well until it is full.
4. If you need more practice, remove the practice gel loading solution by squirting buffer into the wells with a transfer pipet.
5. Replace the practice gel with a fresh gel for the actual experiment.

Note: If practicing gel loading in the electrophoresis chamber, the practice gel loading solution will become diluted in the buffer in the apparatus. It will not interfere with the experiment, so it is not necessary to prepare fresh buffer.

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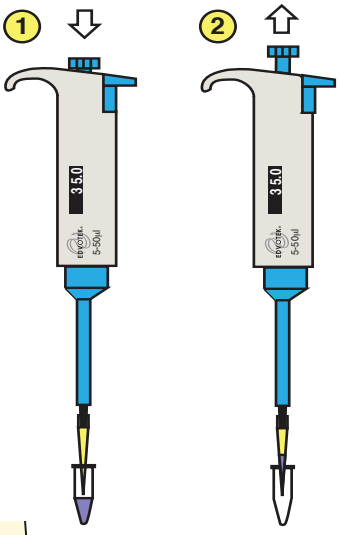
Activity One - Practice Gel Loading

SAMPLE DELIVERY WITH VARIABLE AUTOMATIC MICROPIPETS:

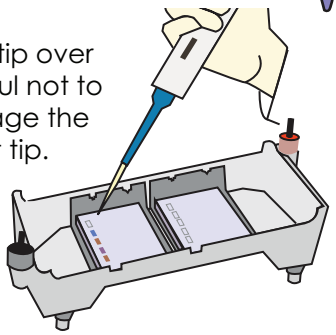


1. Set the micropipet to the appropriate volume and place a clean tip on the micropipetor.

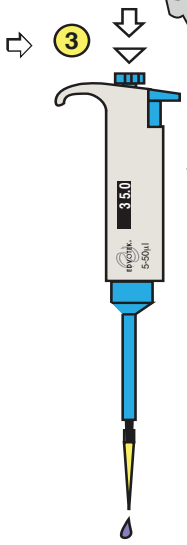
Press the top button down to the first stop. then immerse the tip into the sample.

2. Once the tip is immersed in the sample, release the button slowly to draw sample into the tip.

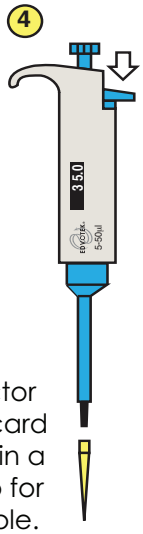
3A. Position the pipet tip over the well. Be careful not to puncture or damage the well with the pipet tip.



3B. Deliver the sample by pressing the button to the first stop - then empty the entire contents of the tip by pressing to the second stop.



3C. After delivering the sample, do not release the top button until the tip is out of the buffer.



4. Press the ejector button to discard the tip. Obtain a new clean tip for the next sample.

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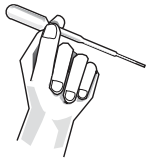
Activity One - Practice Gel Loading

SAMPLE DELIVERY WITH PLASTIC TRANSFER PIPETS:

1. Gently squeeze the pipet stem to slowly draw the sample up into the pipet. The sample should remain in the lower portion of the pipet.

   If the sample is overdrawn and becomes lodged in the bulb or on the walls, tap until the sample moves down into the lower stem of the pipet. Eject it back into the tube. Try step 1 again.

To control the delivery of small sample volumes with transfer pipets, gently squeeze the pipet stem, instead of the bulb.



2. While holding the pipet tip above the sample tube, slowly squeeze until the sample is nearly at the opening of the pipet tip.

3. Place the pipet tip in the electrophoresis buffer so it is directly above barely inside the sample well.

   Avoid placing the pipet tip all the way inside the well - this will minimize the chances of inadvertently piercing the bottom of the well.

4. MAINTAIN STEADY PRESSURE on the pipet stem to prevent buffer from being drawn in and diluting the sample.

5. Slowly squeeze to eject the sample. Stop squeezing when the well is completely full. Put any remaining sample in the pipet back into the sample tube.

6. Rinse the pipet with distilled water before obtaining the next sample for gel loading.

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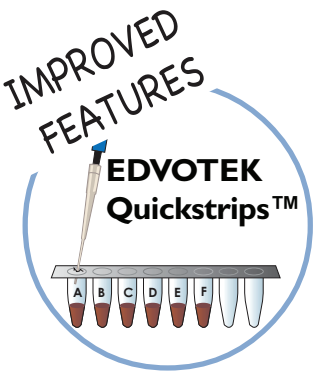
Activity Two - Conducting Agarose Gel Electrophoresis

ELECTROPHORESIS SAMPLES

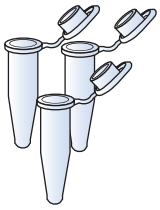
Samples in EDVOTEK Series 100 and S-series electrophoresis experiments are packaged in one of two different formats:

1. Pre-aliquoted Quickstrip™ connected tubes (new format)

   To remove samples from the Quickstrip™ tubes, simply pierce the foil top with the micropipet tip and withdraw the sample.

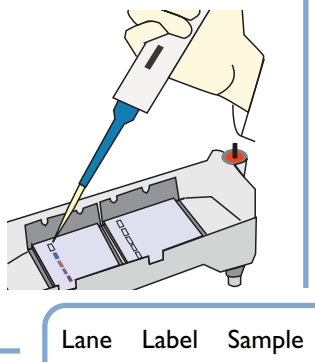


Quickstrips
patent pending



2. Individual 1.5 ml or 0.5 ml microtest tubes

   Your instructor may have aliquoted these into a set of sample tubes for each lab group. Alternatively, you may be required to withdraw the appropriate amount from the experiment stock tubes.



LOADING THE SAMPLES

1. Check the Sample Volumes

   Sometimes a small amount of sample will cling to the walls of the tubes. Make sure the entire volume of sample is at the the bottom of the tubes before starting to load the gel.

   - If your samples are in Quickstrip™ connected tubes, tap the foil top of the strip so samples fall to the bottom of the tubes.
   - If your samples are in individual 1.5 ml or 0.5 ml microtest tubes, briefly centrifuge the sample tubes, or tap each tube on the tabletop to get all the sample to the bottom of the tube.

2. Load Samples

   Load each of the dye samples in tubes A - F into the wells in consecutive order. The amount of sample that should be loaded is 35-38 µl.

Lane	Label	Sample
1	A	Crime scene DNA 1
2	B	Crime scene DNA 2
3	C	Suspect 1 DNA 1
4	D	Suspect 1 DNA 2
5	E	Suspect 2 DNA 1
6	F	Suspect 2 DNA 2

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Activity Two - Conducting Agarose Gel Electrophoresis

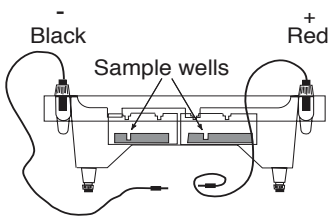
RUNNING THE GEL

3. After the samples are loaded, carefully snap the cover down onto the electrode terminals.

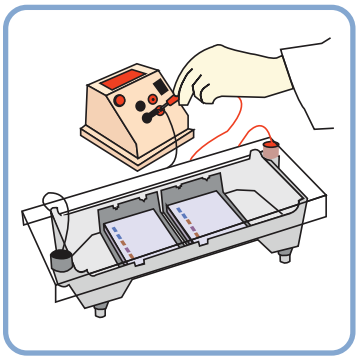
Make sure that the negative and positive color-coded indicators on the cover and apparatus chamber are properly oriented.

Reminders:

During electrophoresis, the samples will migrate through the agarose gel towards the positive electrode. Before loading the samples, make sure the gel is properly oriented in the apparatus chamber.



4. Insert the plug of the black wire into the black input of the power source (negative input). Insert the plug of the red wire into the red input of the power source (positive input).



5. Set the power source at the required voltage and conduct electrophoresis for the length of time determined by your instructor. General guidelines are presented in Table C.

6. Check to see that current is flowing properly - you should see bubbles forming on the two platinum electrodes.

Table C Time and Voltage

Electrophoresis of Dyes

Volts	Recommended Time
125	20 min
70	45 min
50	1 hr 30 min

7. After approximately 10 minutes, you will begin to see separation of the colored dyes.

8. After the electrophoresis is completed, turn off the power, unplug the power source, disconnect the leads and remove the cover.

9. Document the gel results.

   A variety of documentation methods can be used, including drawing a picture of the gel, taking a photograph, or scanning an image of the gel on a flatbed scanner.

Staining is not required for Experiment # S-51, but results must be analyzed upon completion of the electrophoretic separation. Because dye molecules are extremely small they will diffuse out of the gel. Therefore, the gel cannot be saved.

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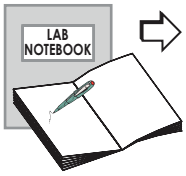
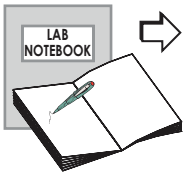
Critical Thinking and Hypothesis Development



Record the following in your Laboratory Notebook or on a separate sheet of paper:

1. Based on the evidence obtained from analysis of the gel, which suspect committed the crime? Explain.
2. What is the variable in this experiment?
3. What would you change in the experiment if you had to do it over again?
4. Write a hypothesis that would reflect these changes.

Study Questions



Record the answers to the following Study Questions in your Laboratory Notebook or on a separate sheet of paper, as instructed by your teacher:

1. Why is it important to position the sample wells near the negative electrode?
2. What kind of evidence would you look for at a crime scene to obtain DNA?
3. Why is it important to wash the pipet between uses?
4. How will you be able to tell who committed the crime?
5. Who is the suspect that committed the crime?
6. What determines that each person has a unique pattern within their DNA?
7. Can you think of a case when two people will have identical DNA patterns?

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Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): Agarose

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive, Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: 07/01/03

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard. CAS #9012-36-6				

Section III - Physical/Chemical Characteristics

Boiling Point (For 1% solution)	194° F	Specific Gravity (H_2O = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	No data
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Insoluble - cold

Appearance and Odor: White powder, no odor

Section IV - Physical/Chemical Characteristics

N.D. = No data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		N.D.	N.D.

Extinguishing Media: Water spray, dry chemical, carbon dioxide, halon or standard foam

Special Fire Fighting Procedures: Possible fire hazard when exposed to heat or flame

Unusual Fire and Explosion Hazards: None

Section V - Reactivity Data

Stability			Conditions to Avoid
	Unstable		None
	Stable	X	

Incompatibility: No data available

Hazardous Decomposition or Byproducts:

Hazardous Polymerization			Conditions to Avoid
	May Occur		None
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Inhalation: No data available Ingestion: Large amounts may cause diarrhea

Carcinogenicity: NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: No data available

Medical Conditions Generally Aggravated by Exposure: No data available

Emergency First Aid Procedures: Treat symptomatically and supportively

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Sweep up and place in suitable container for disposal

Waste Disposal Method: Normal solid waste disposal

Precautions to be Taken in Handling and Storing: None

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type): Chemical cartridge respirator with full facepiece.

Ventilation		
	Local Exhaust	Special
	Mechanical (General) Gen. dilution ventilation	Other

Protective Gloves: Yes Eye Protection: Splash proof goggles

Other Protective Clothing or Equipment: Impervious clothing to prevent skin contact

Work/Hygienic Practices: None

EDVOTEK®

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): **50x Electrophoresis Buffer**

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive, Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: 07/01/03

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard.				

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_2O = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	No data
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Appreciable, (greater than 10%)

Appearance and Odor: Clear, liquid, slight vinegar odor

Section IV - Physical/Chemical Characteristics

N.D. = No data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		N.D.	N.D.

Extinguishing Media: Use extinguishing media appropriate for surrounding fire.

Special Fire Fighting Procedures: Wear protective equipment and SCBA with full facepiece operated in positive pressure mode.

Unusual Fire and Explosion Hazards: None identified

Section V - Reactivity Data

Stability			Conditions to Avoid
	Unstable		None
	Stable	X	

Incompatibility: Strong oxidizing agents

Hazardous Decomposition or Byproducts: Carbon monoxide, Carbon dioxide

Hazardous Polymerization			Conditions to Avoid
	May Occur		None
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): None

Carcinogenicity: None identified NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: Irritation to upper respiratory tract, skin, eyes

Medical Conditions Generally Aggravated by Exposure: None

Emergency First Aid Procedures: Ingestion: If conscious, give large amounts of water

Eyes: Flush with water Inhalation: Move to fresh air Skin: Wash with soap and water

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Wear suitable protective clothing. Mop up spill and rinse with water, or collect in absorptive material and dispose of the absorptive material.

Waste Disposal Method: Dispose in accordance with all applicable federal, state, and local enviromental regulations.

Precautions to be Taken in Handling and Storing: Avoid eye and skin contact.

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type):

Ventilation				
	Local Exhaust	Yes	Special	None
	Mechanical (General)	Yes	Other	None

Protective Gloves: Yes Eye Protection: Safety goggles

Other Protective Clothing or Equipment: None

Work/Hygienic Practices: None

EDVOTEK®

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): **Practice Gel Loading Solution**

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive, Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: 07/01/03

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)

This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard.

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_20 = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	No data
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Soluble

Appearance and Odor: Blue liquid, no odor

Section IV - Physical/Chemical Characteristics

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		No data	No data

Extinguishing Media: Dry chemical, carbon dioxide, water spray or foam

Special Fire Fighting Procedures: Use agents suitable for type of surrounding fire. Keep upwind, avoid breathing hazardous sulfur oxides and bromides. Wear SCBA.

Unusual Fire and Explosion Hazards: Unknown

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	None

Incompatibility: None

Hazardous Decomposition or Byproducts: Sulfur oxides, and bromides

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	None

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Acute eye contact: May cause irritation. No data available for other routes.

Carcinogenicity: No data available NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: May cause skin or eye irritation

Medical Conditions Generally Aggravated by Exposure: None reported

Emergency First Aid Procedures: Treat symptomatically and supportively. Rinse contacted area with copious amounts of water.

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Wear eye and skin protection and mop spill area. Rinse with water.

Waste Disposal Method: Observe all federal, state, and local regulations.

Precautions to be Taken in Handling and Storing: Avoid eye and skin contact.

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type)

Ventilation	Local Exhaust	Yes	Special	None
	Mechanical (General)	Yes	Other	None

Protective Gloves: Yes Eye Protection: Splash proof goggles

Other Protective Clothing or Equipment: None required

Work/Hygienic Practices: Avoid eye and skin contact

EDVOTEK®

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): B-1: Food Dye

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive, Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: **07/01/03**

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)

This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard.

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_20 = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	N/A
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Soluble

Appearance and Odor: Blue color, liquid, no odor

Section IV - Physical/Chemical Characteristics

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		No data	No data

Extinguishing Media: N/A

Special Fire Fighting Procedures: N/A

Unusual Fire and Explosion Hazards: None

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	Unknown

Incompatibility: None

Hazardous Decomposition or Byproducts: Sulfur oxides and bromides

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	None

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? No Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Acute eye contact: may cause irritation

Carcinogenicity: None NTP? No data IARC Monographs? No data OSHA Regulation? No

Signs and Symptoms of Exposure: May cause skin or eye irritation

Medical Conditions Generally Aggravated by Exposure: None reported

Emergency First Aid Procedures: Rinse contacted areas with copious amounts of water

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Wear eye and skin protection and mop/wipe spill area. Rinse with water.

Waste Disposal Method: Can be disposed in the trash or down the sink

Precautions to be Taken in Handling and Storing: Avoid eye and skin contact

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type): NIOSH/MSHA - approved respirator

Ventilation	Local Exhaust	No	Special	None
	Mechanical (General)	No	Other	None

Protective Gloves: Yes Eye Protection: Splash prof goggles

Other Protective Clothing or Equipment: None required

Work/Hygienic Practices: Avoid eye and skin contact

EDVOTEK®

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): R-40 Food dye

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: **07/01/03**

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard.				

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_20 = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	N/A
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Soluble

Appearance and Odor: Red color, liquid, no odor

Section IV - Physical/Chemical Characteristics

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		No data	No data

Extinguishing Media: N/A

Special Fire Fighting Procedures: N/A

Unusual Fire and Explosion Hazards: None

Section V - Reactivity Data

Stability			Conditions to Avoid
	Unstable		
	Stable	X	Unknown

Incompatibility: None

Hazardous Decomposition or Byproducts: Sulfur oxides and bromides

Hazardous Polymerization			Conditions to Avoid
	May Occur		
	Will Not Occur	X	None

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? No Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Acute eye contact: may cause irritation

Carcinogenicity:	NTP?	IARC Monographs?	OSHA Regulation?
None	No data	No data	No

Signs and Symptoms of Exposure: May cause skin or eye irritation

Medical Conditions Generally Aggravated by Exposure: None reported

Emergency First Aid Procedures: Rinse contacted areas with copious amounts of water

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Wear eye and skin protection and mop/wipe spill area. Rinse with water.

Waste Disposal Method: Can be disposed in the trash or down the sink

Precautions to be Taken in Handling and Storing: Avoid eye and skin contact

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type): NIOSH/MSHA - approved respirator

Ventilation				
	Local Exhaust	No	Special	None
	Mechanical (General)	No	Other	None

Protective Gloves: Yes Eye Protection: Splash prof goggles

Other Protective Clothing or Equipment: None required

Work/Hygienic Practices: Avoid eye and skin contact

EDVOTEK®

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): Xylene Cyanol

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: **07/01/03**

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard. CAS # 2650-17-1				

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_20 = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	N/A
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Soluble

Appearance and Odor: _____ color, liquid, no odor

Section IV - Physical/Chemical Characteristics

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		No data	No data

Extinguishing Media: N/A

Special Fire Fighting Procedures: N/A

Unusual Fire and Explosion Hazards: None

Section V - Reactivity Data

Stability			Conditions to Avoid
	Unstable		
	Stable	X	Unknown

Incompatibility: None

Hazardous Decomposition or Byproducts: Sulfur oxides and bromides

Hazardous Polymerization			Conditions to Avoid
	May Occur		
	Will Not Occur	X	None

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? No Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Acute eye contact: may cause irritation

Carcinogenicity:	NTP?	IARC Monographs?	OSHA Regulation?
None	No data	No data	No

Signs and Symptoms of Exposure: May cause skin or eye irritation

Medical Conditions Generally Aggravated by Exposure: None reported

Emergency First Aid Procedures: Rinse contacted areas with copious amounts of water

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Wear eye and skin protection and mop/wipe spill area. Rinse with water.

Waste Disposal Method: Can be disposed in the trash or down the sink

Precautions to be Taken in Handling and Storing: Avoid eye and skin contact

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type): NIOSH/MSHA - approved respirator

Ventilation				
	Local Exhaust	No	Special	None
	Mechanical (General)	No	Other	None

Protective Gloves: Yes Eye Protection: Splash prof goggles

Other Protective Clothing or Equipment: None required

Work/Hygienic Practices: Avoid eye and skin contact

Hands-On Lab

Changes in DNA

Timing: one 90-minute class session

Objective(s)
In this lab the student will identify and illustrate different types of mutations, showing which nitrogen bases have been affected. The mutations they are responsible for include: deletion, duplication, and inversion. Using the template strand provided by your teacher, they will write the sequence of nitrogen bases that best exemplifies the type of mutation.

Safety Precautions:

- Follow general lab safety rules and do not eat or drink in the lab.

Objective(s):
In this activity, students will illustrate different types of changes in DNA and evaluate the significance of these changes. Students will identify the type of nitrogen base changes that cause the mutations in their illustrations.

Materials:
Per student:

- Original DNA template strand
- Colored markers or pencils

Teacher Preparation:
Write the following DNA template strand on the board, being sure to highlight the area for student to use in their mutations.

CGGTTAATCGA

Then instruct the students to use the highlighted portion of the strand and write down possible outcomes of the following mutations:
Deletion
Duplication
Inversion

Procedure

Students will write down the template strand provided by their teacher. They will then illustrate possible answers to the different types of mutations. Students can use different colored pencils or markers for each nitrogen base. Have students use different colors to highlight the different types of changes to the DNA strand, one color per type of mutation: deletion, duplication, and inversion.

The original DNA template strand had the nitrogen base sequence:

ATTGCC**CGGTTA**ATCGA

Analysis and Conclusions

1. Using the bolded underlined segment of the DNA strand, what would be a possible base sequence for a deletion mutation?

A deletion mutation removes one or more of the nitrogen bases from the strand. Possible answers could be:

ATTGCC GGTTAATCGA – the empty space represents the C that was deleted. Other answers are appropriate as long as one of the bolded nitrogen bases is removed.

2. Using the same segment of DNA, what would be a possible base sequence after a duplication mutation?

A duplication mutation causes one or more of the nitrogen bases to be repeated. Possible answers be:

*ATTGCCCG**G**GTTAATCGA, where the bolded G is are bases that have been duplicated.*

3. Using the same segment of DNA, what would be a possible base sequence after an inversion mutation?

An inversion mutation is when a series of nitrogen bases are removed from the template strand and then reattached in the opposite order. Possible answers would be:

*ATTGCC **ATTGGC** ATCGA, where the bolded nitrogen bases are in the opposite order from the original segment.*

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
    - Make or use models that:
        - Have as many details as possible replicated from the real thing.
        - Simulate a real thing that cannot easily be studied or manipulated.

Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

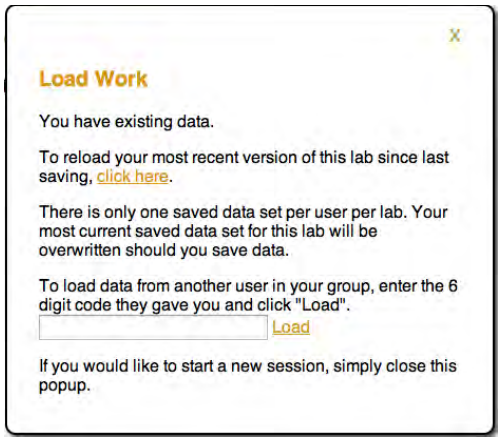
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

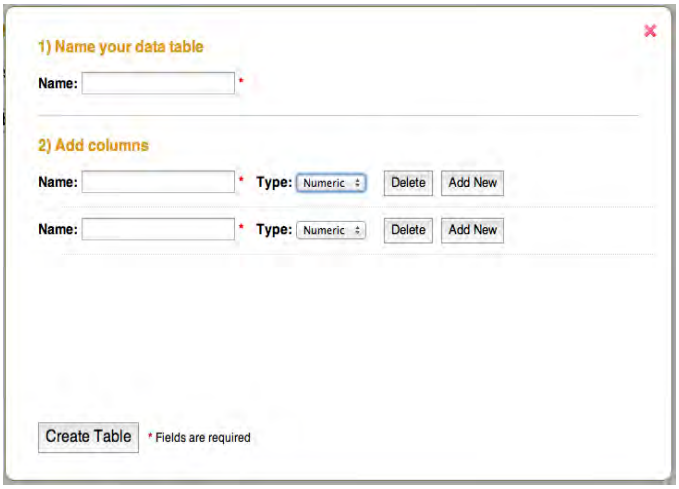
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



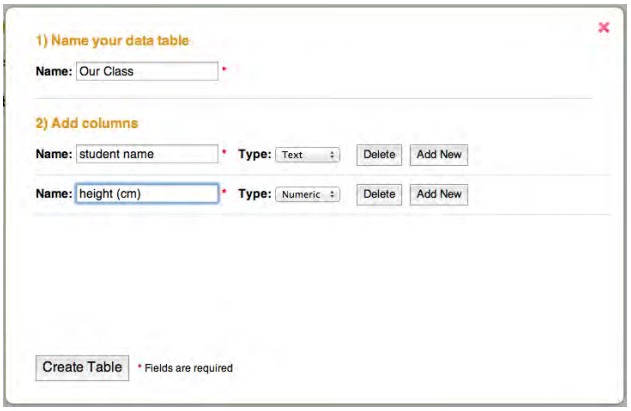
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

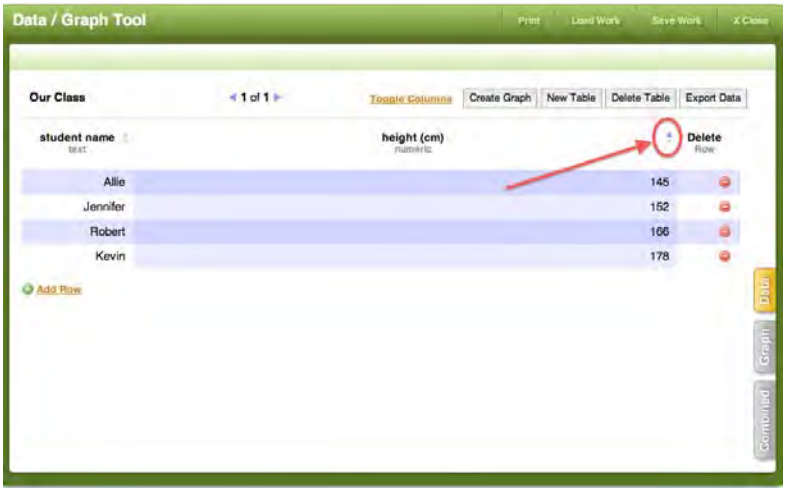
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

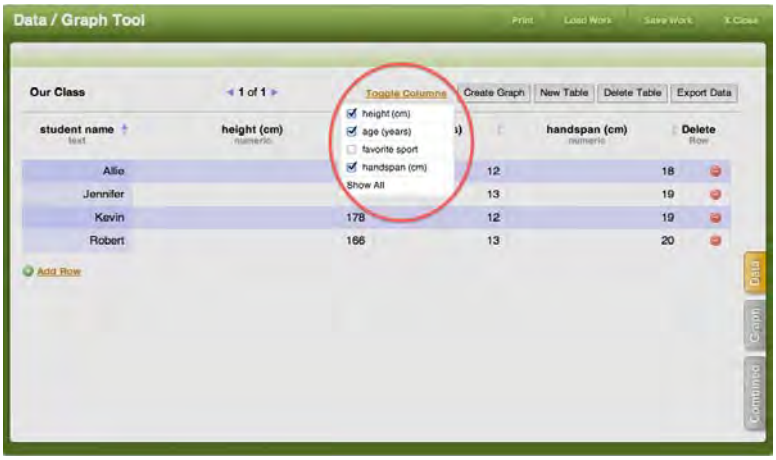


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

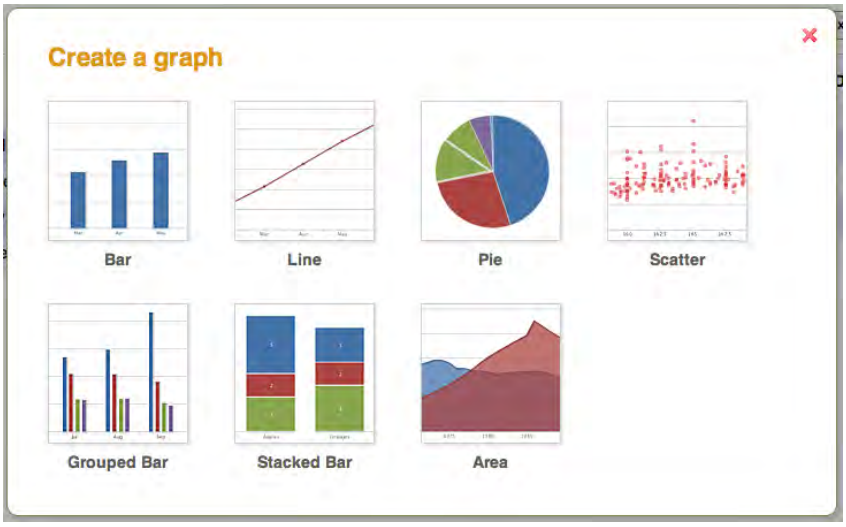
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

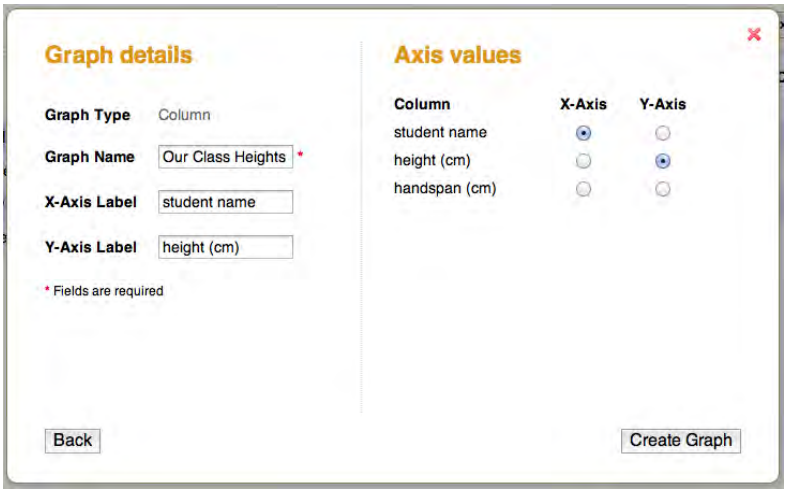
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

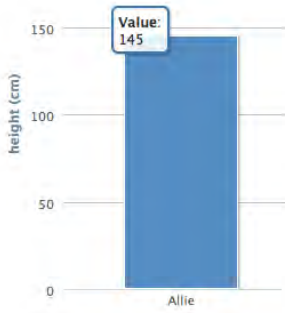


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

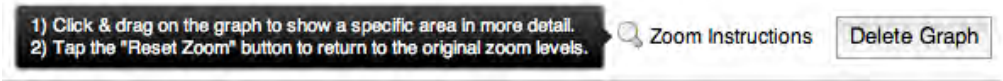
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Activity

Investigating DNA

In this activity, students will use the reading passage titled **How DNA Makes Us** and various Internet sources to determine how genes result in traits. Students will also determine whether a mutated gene directly causes the symptoms of a genetic disorder or if the symptoms are correlated with the presence of the mutation.

Suggested Materials

Per group:

- reading passage titled **How DNA Makes Us**
- Internet access

To introduce the activity, assign each team of students a genetic disorder to research. The disorder can be one that produces visually apparent symptoms (e.g., Down syndrome) or one that does not (e.g., Alzheimer's disease). Pass out the reading passage **How DNA Makes Us** or direct students to locate it online. Have students summarize the differences between cause and correlation before you begin.

Procedure

Part 1: Reading Passage and Research

1. Ask students to read **How DNA Makes Us.**
2. Direct students to investigate the genetic disorders assigned to them, paying particular attention to the change in genes which results in the disorder and the characteristic symptoms associated with it.
3. Guide students in constructing a data table that lists each symptom and whether they think each symptom is directly caused by the genetic disorder or a correlated effect of the genetic disorder.
4. Allow students to discuss their findings with other groups. Then, bring the entire class back together for a large group discussion about the different disorders and their symptoms.

Part 2: The Role of Genes

Students will continue to investigate their assigned disorder but should now focus on the disorder's discovery and connection to DNA. They should keep in mind the following questions when doing their research:

1. When was the disease discovered?
2. How did the researchers identify it as a disease?
3. What empirical evidence can you find in connection with the disease? Why is it important? Examples include data from studies (number of subjects, trials, etc.) and scientific publications.
4. What symptoms of this disease likely result from the genetic disorder and what symptoms are correlated to the gene disorder? Why?
5. How do the concepts of cause and correlation lead to our understanding of how genes result in the expression of traits?

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Analysis and Conclusions

1. What is the difference between a cause and a correlation?
   A cause *is the reason something happened. This means that if A happens, it will produce B. A* correlation *indicates that there are connections between two events or occurrences, but there is no causal relationship between them.*

2. Explain how the traits expressed as a result of the genetic disorder you studied are related to changes in DNA.
   Answers will vary depending on the disorder being investigated but should indicate that genes are expressed as traits. A mutation causes a gene to express incorrectly or not at all, and some traits depend directly on specific genes while others are correlated to genetic expression but not directly connected.

3. Explain why some symptoms connection with the disorder you researched might be correlated with a genetic mutation and not directly caused by it.
   Some mutations affect more than the trait for which it codes. These mutations may cause changes in how other traits not directly connected with the disorder are expressed. For example, a mutation in a gene might mean the trait being coded for will not be expressed, but that change might affect another trait coded somewhere else on the chromosome. The expression of traits also differs between individuals; certain traits may be expressed in one person and not in another.

4. How does the carrying of traits from one generation to the next relate to genetic disorders?
   ` *If a mutated copy of a gene is passed from a parent to their offspring, there is a chance that the genetic disorder could be inherited by the next generation. Not all traits are the direct result of a mutation, however, and some may not be expressed or may be expressed normally.*

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Evaluate Evidence
  - Identifies and Interprets Patterns
    - Trends in data

- Evaluate Evidence
  - Drawing and Supporting Conclusions By:
    - Reporting out trends and patterns in the data

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Hands-On Activity

Nature Versus Nurture

In this investigation, students will analyze one or more scientific studies that research the influences of genetics and the environment ("nature versus nurture"). The students' investigation will focus on studies of twins who have been raised separately. Students will use empirical evidence to determine which factors caused the twins to develop differences or similarities in various traits and behaviors. Students will also identify correlations between traits and behaviors with the environments where the twins were raised.

Suggested Materials

Per group:

- scientific studies that research the influence of nature versus nurture on twins
- Internet access

Introduce this activity by asking students if they know anyone who is a twin. If necessary, remind students about the difference between fraternal and identical twins. Ask students if they have heard of studies of twins who were raised separately that compared the similarities and differences in physical and behavioral traits.

Procedure

1. Ask students to identify the differences between fraternal and identical twins, and discuss how these two kinds of twins arise and develop.
2. Have students compare a set of identical twins they know personally or they have researched online.
3. Have students write down all of the traits that may be similar or different between the twins, distinguishing between physical and behavioral traits.
4. Ask students to define the terms *nature* and *nurture* in the phrase "nature vs. nurture." Emphasize that "nature" refers to genetic influences, whereas "nurture" means environmental influences. Have students create a T-chart. Have them list traits in one column or the other according to whether they think the trait is determined by "nature" or "nurture."
5. Have small groups of students brainstorm how twin studies help scientists understand the roles of genetics and environmental factors in determining physical and behavioral traits.
6. Show students the video segment **Identical Twins: Influence of Genetics versus Environment** found at http://app.discoveryeducation.com/player/view/assetGuid/B8EBDD99-B341-44E3-9834-F7C198E0786C.
7. Have students identify which aspects of the twin are predominantly determined by genetics (nature) and which are influenced by environment (nurture). Have students make a T-chart to show their results, and then compare this chart with the one made before watching the video.
8. Provide students with information about empirical studies of twins who were separated at birth and about twins who were raised together, such as Bouchard's study and the Minnesota Twin Family Study.

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9. Students should collect evidence about the studies and then consider the statement, “Physical traits of twins raised separately are determined entirely by their genes, but behaviors are determined entirely by environmental factors.” Have students collect evidence to establish the causes of different physical traits and behaviors. Encourage students to correlate traits and behaviors to the environments where the twins were raised.
10. Students will then discuss their findings. This can be done as an entire class or in small groups, or you can organize a formal debate.

Analysis and Conclusions

1. What does the phrase “nature versus nurture” mean?
   Nature has to do with an organism’s genetic makeup. The traits and behaviors that are the result of nature are those that are inbred. For example, a monarch butterfly’s desire to migrate to warmer climates during the winter is an example of an innate behavior that is programmed into its genes. Nurture has to do with the environment in which an organism is raised. Certain traits and behaviors happen because of where an organism grows up. For example, children growing up in a house where their parents smoke are likely to have more respiratory problems than children who grow up in nonsmoking homes.

2. What did the scientific studies on twins you researched present as the causes of specific genetic traits and behaviors of the twins?
   Answers will vary depending upon what studies the students found.

3. Do you think that the genetic traits and behaviors of twins are caused by nature or nurture? Provide examples to support your argument.
   Answers will vary depending upon the information the students find and what their personal opinions are about the topic.

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Observational Study
    - Compare changes in data points over time

- Interpret Data
  - Identify and Interpret Patterns:
    - Trends in data

- Scientific Investigation
  - Scientific Data and Outcomes
    - Scientific claims are based on data and reliable scientific sources

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Hands-On Activity

Researching Genetic Traits

In this investigation, students will research a genetic trait. They will formulate an argument, based on evidence, to explain how this trait arises. Sources of genetic variation may include new genetic combinations that result from meiosis, mutations caused by errors during replication, and environmental factors.

Suggested Materials

Per group:

- Internet access

To introduce the activity, ask students how they think variations of traits arise. Write their responses on the board or on an overhead projector.

Procedure

1. Have students form small groups.
2. Ask each group to choose one of the following scenarios to investigate:
   a. A hairless Sphynx cat is born to parents with normal coats.
   b. A frog with five legs hatches in a polluted river.
   c. Two siblings have the same parents but different appearances.
   d. A child is born with color blindness in a family without a history of the trait.
3. Before beginning, ask the class whether they think this trait arises due to new genetic combinations through meiosis, viable errors occurring during replication, or mutations caused by environmental factors. Record the class responses on the board.
4. Instruct students to further investigate their scenarios in their groups, identifying the source of the variation in traits including the trait(s) affected (if known).
5. After students have completed their research, ask them to present their findings to the class. Encourage students to compare the results of the class poll to the groups' findings and examine the evidence to see if they agree.
6. Discuss with students whether they think most variations in traits arise when organisms are in development or fully developed, based on the class' findings.

Trait	Origin
Hairlessness in Sphynx cats	Viable mutation in Keratin 71 (KRT71) gene
5-legged frog	Environmental mutation due to pollutants
Siblings with differing appearances	New genetic combinations through meiosis
Spontaneous color blindness	Viable mutation in one of several genes

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Analysis and Conclusions

1. What are the different ways by which a new trait can arise?

   New traits can arise from new genetic combinations that occur during meiosis, from mutations that result from various environmental factors, and from errors that happen during the replication of DNA.

2. How does the source of the trait you selected compare with those investigated by the rest of the class?

   Answers will vary depending on the trait selected.

3. What other examples of trait variations can you think of with the same source as the one you investigated?

   Answers will vary depending on the scenario selected.

4. When do you think new traits are most likely to be expressed in an organism? Explain your answer.

   Students may note that new traits are most likely to be expressed during an organism's development. Changes such as errors in replication or variation due to meiosis are likely to be expressed when the majority of genetic development is occurring. Although changes can occur after birth, such as environmental mutations, they are less likely to result in variation of traits.

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In this activity, students will demonstrate the following Inquiry Skills:

- Interpret Data
  - Identify and Interpret Patterns
    - Trends in data
    - Analyze data collected during an investigation

- Evaluate Evidence
  - Drawing and Supporting a Conclusion by:
    - Reporting out trends and patterns in the data

- Engineering and Technology
  - Societal Issues
    - Scientific discoveries have benefited people in many ways

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Hands-On Lab

Transcription and Translation

Timing: one 90-minute class session

Objective(s)
Students will model the processes of transcription and translation by creating the structures involved and reenacting the processes. Students will model the introduction of a mutation into the sequence and trace it through the steps of transcription and translation to see how it affects the final protein.

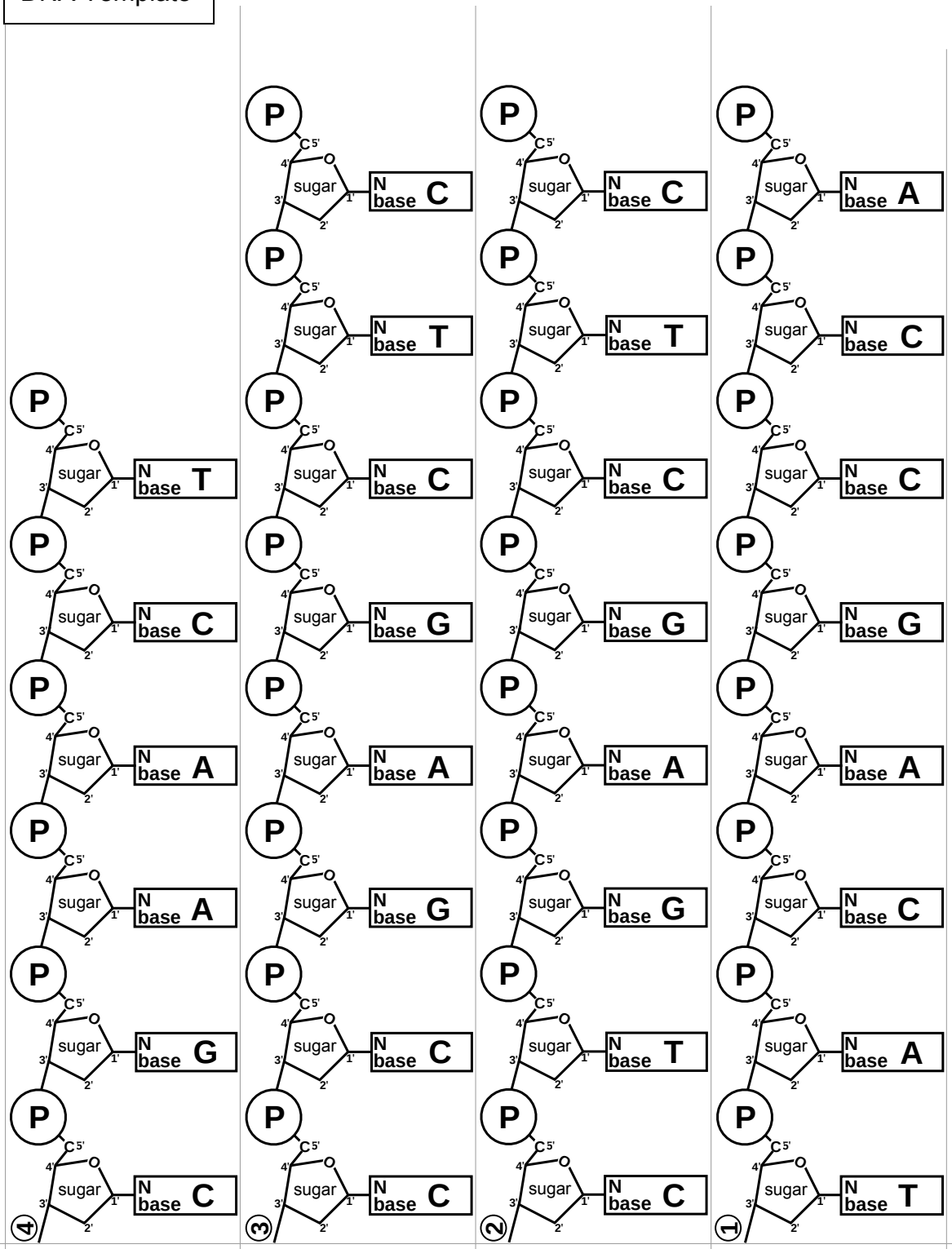
Safety Precautions:
Remind students to follow general lab safety rules, use scissors safely and not to eat or drink in the lab.

Materials:
Per group:

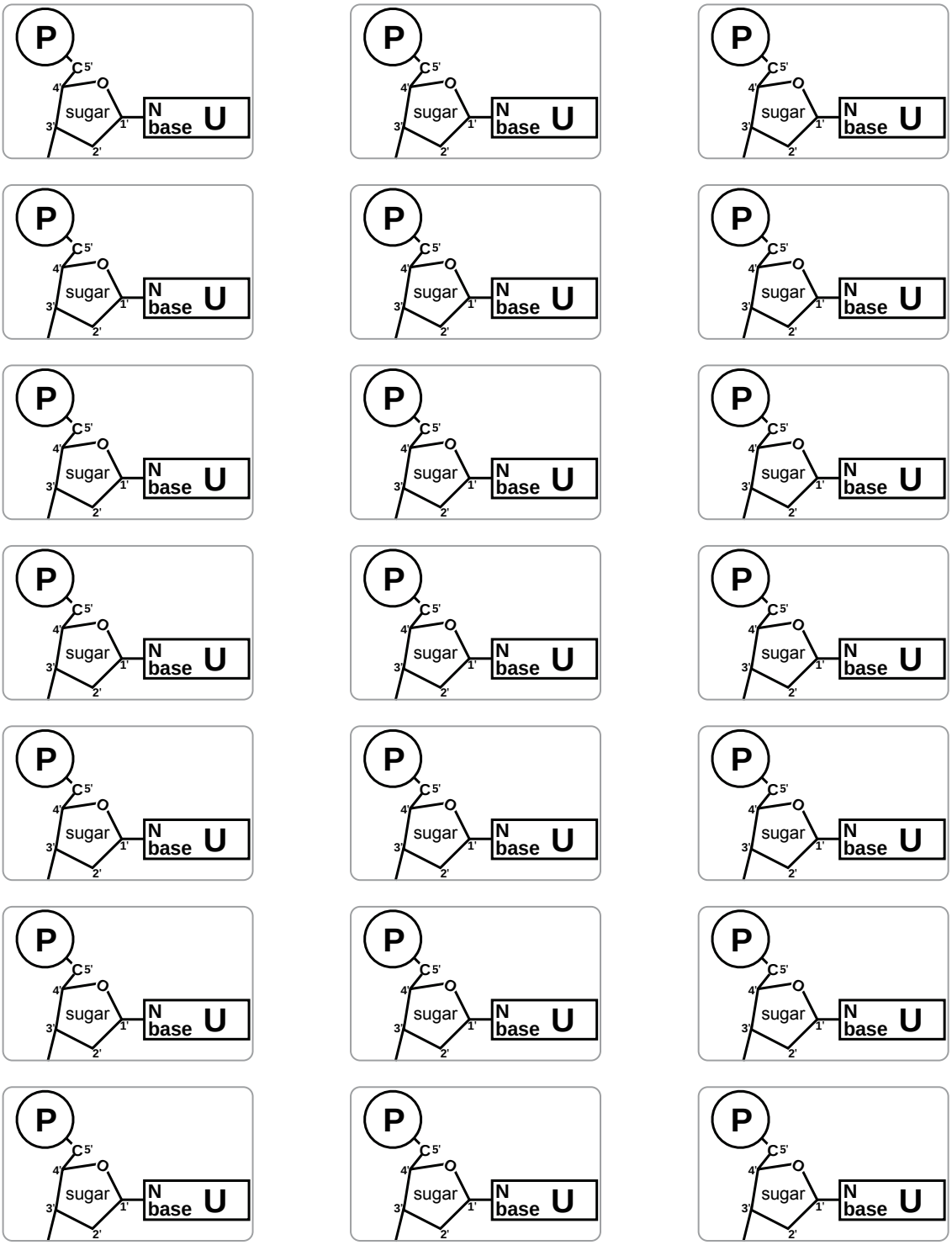
- codon amino acid chart showing mRNA codons
- templates for DNA, four nucleotides (mRNA bases), and tRNA
- scissors
- transparent tape

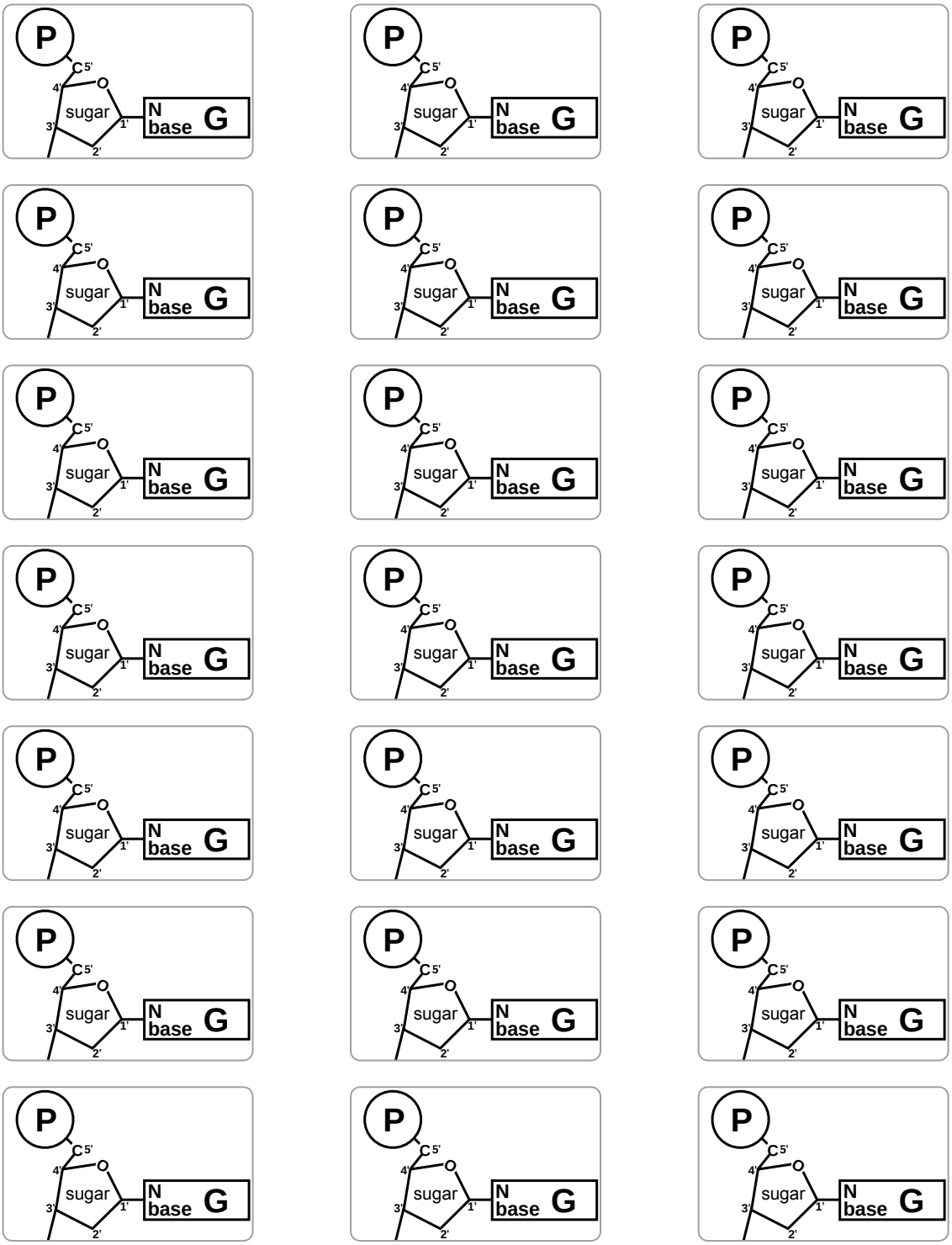
Teacher Preparation:
Prepare the DNA template, nucleotides, and tRNA by copying the masters onto cardstock for sturdiness. It is a good idea to copy each nucleotide on a different color cardstock. Copy the tRNA on light-colored cardstock because students will need to write on it. Make enough copies for every group to have one copy of the DNA, one copy of each nucleotide page, and multiple copies of tRNA. Make student copies of the Student Investigation Sheet.

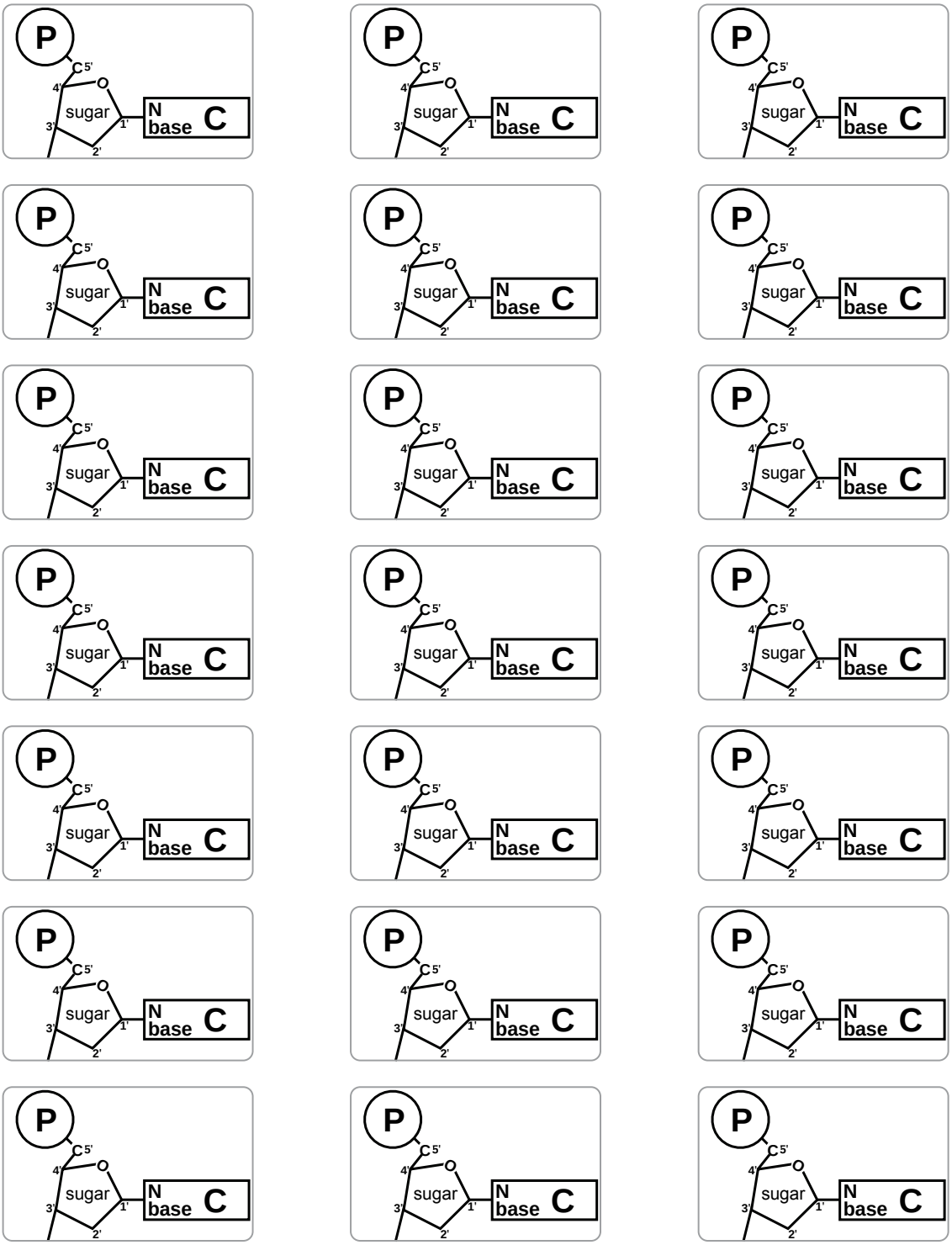
DNA Template

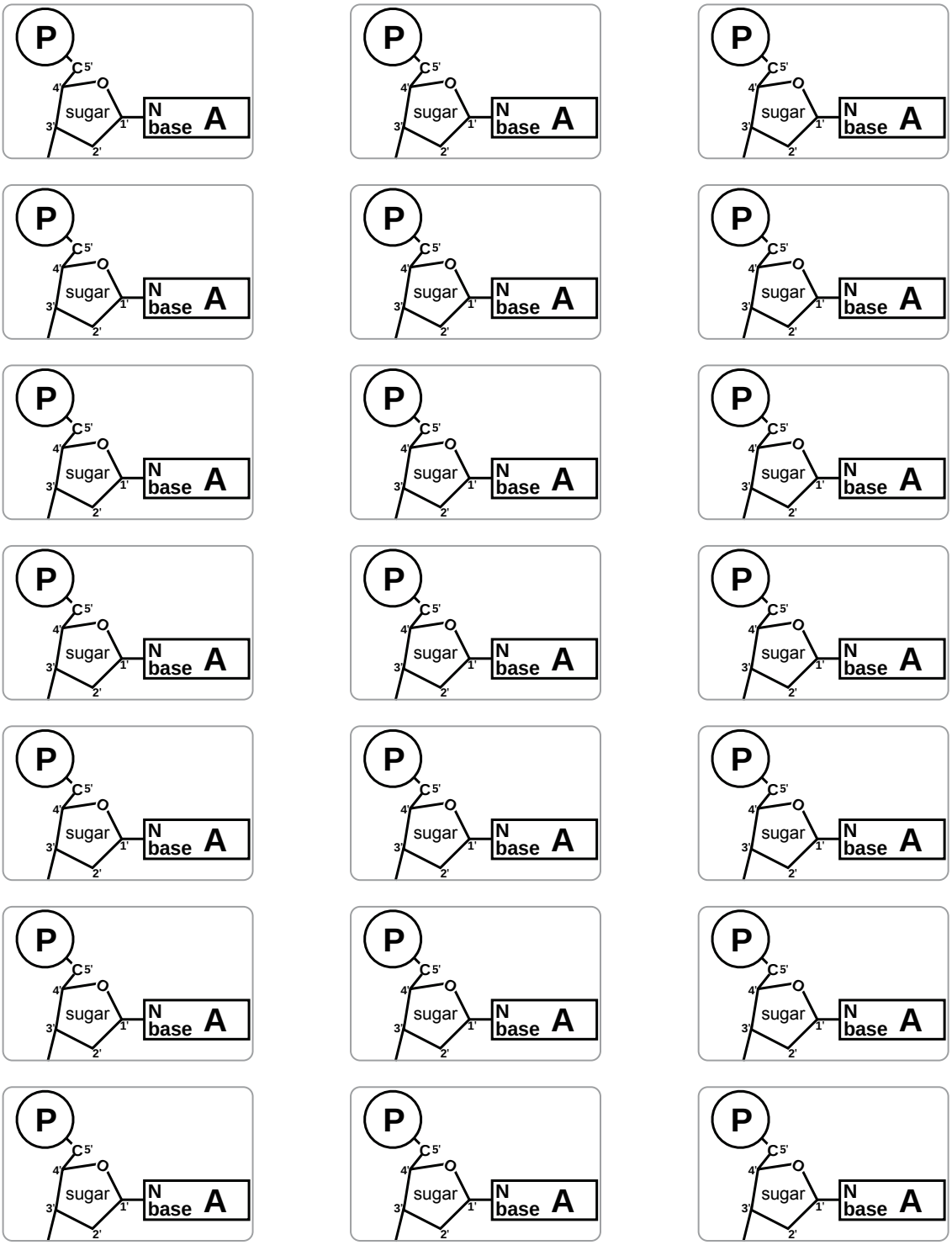


Nucleotides

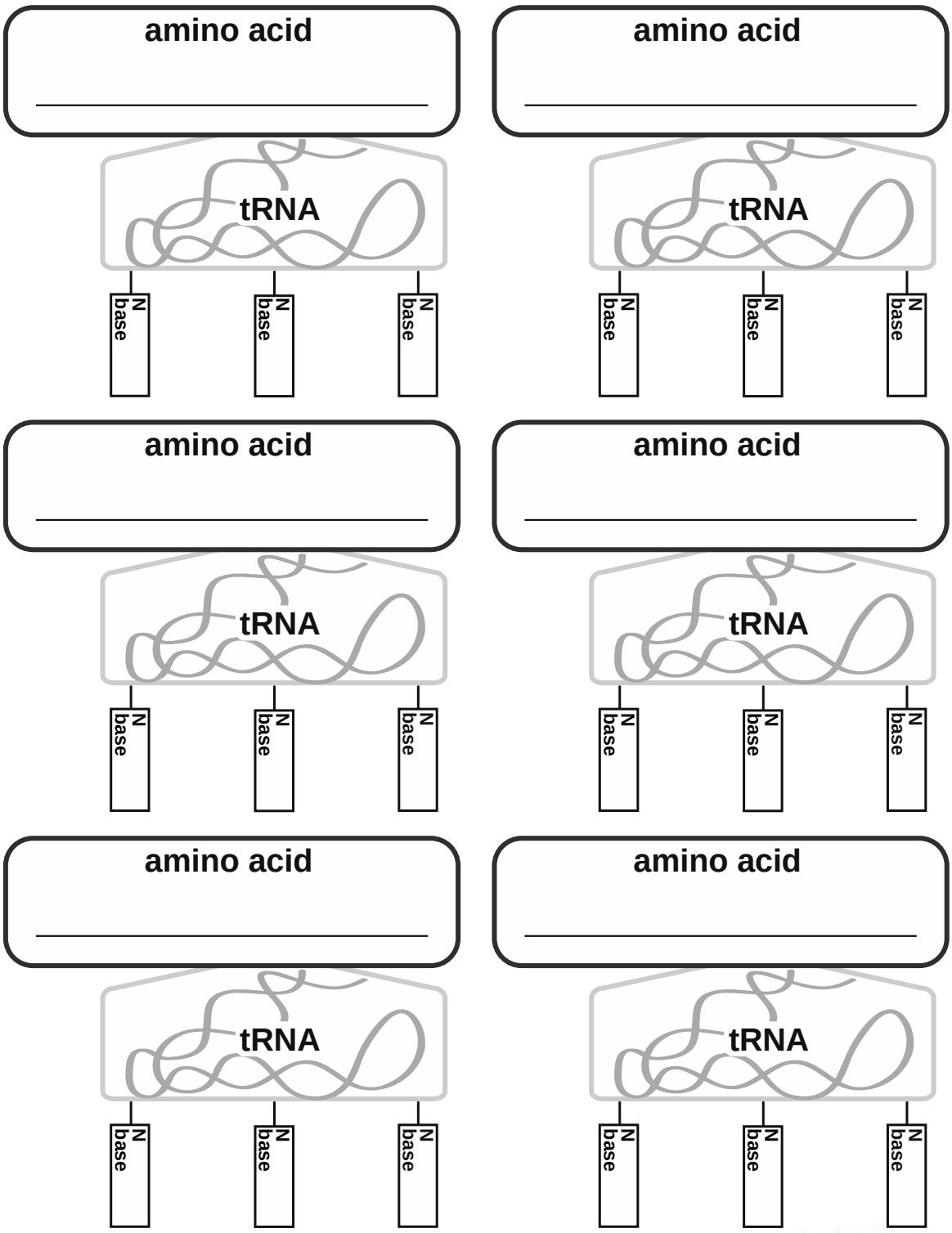



P
C 5'
4'
O
sugar
3'
1'
2'
N base G


P
C 5'
4'
O
sugar
3'
1'
2'
N base
C


P
C 5'
4'
O
sugar
3'
1'
2'
N base A

tRNA


amino acid
tRNA
N base
N base
N base
amino acid
tRNA
N base
N base
N base
amino acid
tRNA
N base
N base
N base
amino acid
tRNA
N base
N base
N base
amino acid
tRNA
N base
N base
N base
amino acid
tRNA
N base
N base
N base

Procedure

The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Students will complete the following steps. Read each step aloud and ask students if they have any questions after you have read through them. You may wish to model some or all of the steps to get them started. Circulate among the students to make sure they are completing the steps correctly.

1. Cut the DNA strips from the cardstock along the straight lines and attach them together lengthwise according to the numbers at the top. From left to right, start with the strip numbered 1, then 2, then 3, and finally, 4. This is your DNA template strand for the gene whose protein will be synthesized. Record its sequence nucleotides on your data sheet.
2. Cut out the nucleotide bases from the colored cardstock pages. Using these, transcribe a molecule of mRNA by matching the complementary base with the DNA template strand. Be sure to work on one base at a time. Tape the bases together to simulate the bonds formed between bases of an mRNA molecule, but do not tape the mRNA strand to the DNA template. Record the mRNA sequence on your data sheet.
3. Once formed, the mRNA strand is ready for translation. You must move it out of the "nucleus" and away from the DNA. Simulate this by moving to another work area in the classroom.
4. Use a pen or pencil to lightly divide the mRNA sequence into codons by drawing a line between each codon. Record the codons on your data sheet.
5. Cut out the tRNA molecules from the cardstock pages. Fill in the anticodon on each tRNA molecule and begin bringing the correct amino acid by adding its complete name to the opposite end of the tRNA

molecule. Use the codon amino acid chart to identify amino acids. Be sure you pay attention to the START and STOP codons. Start codons code for the amino acid methionine (Met).
6. As each tRNA matches the mRNA codon, use scissors to cut off the amino acid portion from the tRNA and bond it to its neighboring amino acid with tape forming the protein chain. Record the amino acid sequence on your data sheet. At the end of translation, show your completed chain to your teacher.
7. Review the data collected on your data sheet. As a group, choose one nucleotide in your original DNA strand to change. For example, change an A to a C or a G to a T.
8. On your data sheet only, transcribe the DNA into mRNA with the mutation. Record the mRNA sequence.
9. Translate the mRNA strand into a protein. Record the codons and amino acids with the mutation.

Guided Inquiry

Students can develop their own plans for designing their model transcription and translation processes based on their knowledge of the procedure and available materials. Ask the students some guiding questions to help them focus their inquiry:

- How will you form the mRNA strand?
- How can you represent the migration of mRNA from the nucleus to the cytoplasm for translation?
- How will you model a mutation and how it manifests in the protein?

Allow students to design their model process and provide any additional materials they may need. Circulate through the room, and monitor group discussions to be sure they are on the right track.

Analysis and Conclusions:

1. Which steps of the investigation modeled transcription? Which steps modeled translation? (Steps 1 and 2; Steps 3 through 6.)

2. What role(s) did your hands play in the models of transcription and translation? Explain. (*In the transcription model our hands played the role of RNA polymerase because they moved down the DNA template and assembled the mRNA strand. In the translation model, our hands were the ribosome. They moved along the mRNA and attached amino acids using tRNA. They also detached the tRNA and the protein from the mRNA strand.)*

3. The model did not include the step of RNA processing. What activity could you add to the model to demonstrate RNA processing? (*After transcription, we could have cut sections of the mRNA strand out and then spliced it back together.)*

4. In Step 7, what kind of mutation did you model? How do you know? At each step of the transcription and translation process, what impact did this mutation have? (*I modeled a point mutation in a gene. I*

know because only one nucleotide was changed in the gene sequence. The mutation changed the codon and so changed the amino acid coded for. This, in turn, changed the protein assembled.

Additional Questions:

1. What were the effects of the mutation in the protein? How might this manifest in a real organism? (*Answers will vary, but the protein should have come out differently. A different protein may cause the cell to malfunction and a disorder could appear, such as cystic fibrosis. The mutation may also lead to an advantage for the organism.)*

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
    - Make or use models that:
        - Have as many details as possible replicated from the real thing.
        - Simulate a real thing that cannot easily be studied or manipulated.

Exploration Teacher Guide: Translation

Overview

Translation is the process by which cells decode mRNA to make proteins. In this Exploration, students model translation to make proteins from an mRNA strand and tRNA molecules. They investigate how different codons on the mRNA strand pair up with anticodons on the tRNA molecule. Students also observe how anticodons of a tRNA molecule specify different amino acids and how these amino acids form peptide bonds to produce a protein. During the translation process, students translate the mRNA strand in the correct order to make a peptide chain.

Student Learning Objectives

- Observe how the chemical bases, adenine (A), guanine (G), cytosine (C), and uracil (U), form codons that match anticodons according to base pairing rules.
- Explore the structure of the mRNA strand and tRNA molecules.
- Model the translation process for a part of the amino acid sequence for the selected protein.
- Review which amino acids carried by tRNA molecules with specific codons.
- Observe the structure and function of the protein formed.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Translate* tab, students create a section of the amino acid sequence for different proteins. Students select one of four proteins that they want to build using the options in the *Select Protein* dropdown list. The mRNA sequence required to build the selected proteins appears in the activity area. Students add tRNA molecules sequentially from the 5'end to the 3' end. They click and drag the tRNA molecule with the correct anticodon and drop it on the corresponding codon triplet of the mRNA molecule. They repeat this for successive tRNA molecules to obtain an amino acid chain. The process always begins with the start codon. Students will encounter a stop codon in the middle of the mRNA sequence for one protein and at the end of the mRNA sequence for a different protein. They will not be able to add tRNA molecules to the codons that appear after the stop codon. Negative feedback is displayed if the students do not add tRNA molecules with anticodons sequentially or try to add a tRNA molecule with an incorrect anticodon. Once all the tRNA molecules are correctly assigned to their corresponding codon, students use the *Translate* button to get positive feedback. They may use the *View Image* button to observe the structure and function of the protein. A *Hint* button will be available at all times to remind students of the base pairing rule that A pairs with U and G pairs with C. Students use the *Reset* button to reset the Exploration at any time and make a new protein.

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In the *Tracker* tab, students observe all the proteins they successfully synthesize. They also review the amino acid sequence and structure of the proteins.

Answers to Questions in the Student Worksheet

1. Define the term translation. Explain how it is different from replication.

   Answer: Translation is a process in which cells synthesize proteins by decoding mRNA to form peptide chains from amino acids. Replication involves the synthesis of nucleotides and replication of the DNA or RNA strand.

2. Differentiate between a codon and an anticodon. Also, describe their functions.

   Answer: A triplet of bases present on the mRNA strand is the codon. A triplet of bases present on the tRNA molecule is the anticodon. The bases in the anticodons are complementary to thoseon the codon.

3. The sequence of bases on an mRNA strand is AAUCGACGCCCGAGCACU. List the codons present in this sequence.

   Answer: The codons present in the sequence mentioned above areAAU, CGA, CGC, CCG, ACG, ACU.

4. List the tRNA anticodons that would pair with the codons present in the above sequence of mRNA.

   Answer: The tRNA anticodons that would pair with the codons present in the sequence mentioned above are UUA, GCU, GCG, GGC, UGC, UGA.

5. Determine the translated amino acid sequence obtained from the mRNA strand given in question 3. You may use the codon table to translate.

   Answer: The translated amino acid sequence obtained from the mRNA strand given in question 3 is leucine, alanine, alanine, glycine, cysteine, STOP.

6. A tRNA anticodon has the base sequence CCG. Identify the DNA base sequence that was used to produce the codon that will bind it to this anticodon.

   Answer: With the tRNA anticodon as CCG, the mRNA codon must be GGC. Therefore the DNA base sequence used to produce the mRNA codon is CCG.

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7. Explain how you would determine whether a single chain of nucleotides is RNA or DNA.

   Answer: A single chain of nucleotides is RNA if it contains the nucleotide uracil. The chain is DNA if it contains the nucleotide adenine.

8. Describe all the elements required to carry out the process of translation after transcription is completed.

   Answer: Elements required to carry out the process of translation after transcription is completed are:
   a. mRNA
   b. tRNA
   c. ribosomes

9. Describe the importance of DNA in determining the structure of a protein.

   Answer: DNA determines the primary structure of a protein because the nucleotides on a DNA strand serve as a template for transcription – the synthesis of a complimentary mRNA strand. The mRNA strand, in turn, gets translated to produce a protein.

10. Identify the site of protein synthesis in a cell. Is the site for protein synthesis same as that for DNA replication? Explain your answer.

    Answer: The site of protein synthesis in a cell is the ribosome. It contains binding sites for the mRNA and enzymes required for translation.DNA replication occurs in the nucleus. DNA unwinds in the nucleus to be transcribed into mRNA. The mRNA migrates out of the nucleus to be translated. Replication of DNA, on the other hand, occurs in the nucleus.

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Hands-On Lab

Variation and Distribution of Expressed Traits

Timing: one 50-minute class session

Objective(s):
Students will investigate the frequencies at which different types of mutations occur in a population and will use statistical analysis to make conclusions about their causes.

Safety Precautions:
Students should follow all safety guidelines and not eat or drink in the laboratory.

Materials:
Per group:

- dice, six-sided
- calculators
- paper

Teacher Preparation:

- Gather materials in advance of students performing the lab.
- Prepare blank data tables (provided in the Appendix) for students to record their findings.

Procedure
Part I: How Do Mutations Occur?

1. Divide the class in half.
2. Play the "telephone" game with the first group of students by directing students to sit in a circle. Using a whisper that cannot be heard by others, tell the first student the following phrase: **"Stand up. Jump two times. Spin around. Pat your knee. Cough."**
3. Have students in this group pass the message along by whispering the phrase to the person to their right until it reaches the first student. This final student must act out the whispered actions. Have students compare the original and final phrases and make note of any errors.
4. With the second group of students, do the same activity. This time the whispered message is: **"Go to the board, draw a circle, draw a plus sign below it, draw a triangle above it, and draw a squiggly line at one tip of the triangle."**
5. Ask the students how the two games relate to the passing on of genetic information. Lead the discussion towards mutations, emphasizing the concept of replication errors.
6. Use the errors that may have occurred with the first group to describe point mutations (rubbing the stomach instead of the knee, clapping instead of coughing, etc.).
7. Use the errors that occurred with the second group to discuss deletions. Point out that the longer a message is, the more likely it is that parts will be omitted.

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Part II: Frequencies of Different Mutations

1. Give each team of students a six-sided die.
2. Have each team roll the die and record the number. Explain to students that each roll of the die simulates a reproductive event in a population, and the number rolled indicates the type of mutation that occurs in the resulting organism. Using the result from their first roll, have students identify the corresponding type of mutation in the list below, then repeat 49 more times for a total of 50 rolls:
   1: substitution
   2: insertion
   3: deletion
   4: translocation
   5: amplification
   6: substitution
   Students should record their results in a data table titled "Types of Mutation" (see Appendix).
3. Have students repeat the process using the following corresponding events:
   1, 6: DNA replication
   2, 4: environmental impact
   3, 5: error during meiosis
   Students should record their results in another data table titled "Causes of Mutation" (see Appendix).

Part III: Statistical Analysis and Conclusions

1. Students should examine their data and determine which type of mutation occurred most frequently based on their data. They should calculate the percentage of each type of mutation as it occurred during their investigation.
2. Students should calculate the frequency of the different causes of mutations using the same process as in Step 1.

Analysis and Conclusions

1. Based on your results, which type of mutation is most likely to occur in this population? What is the most likely cause? Support your answers.
   Answers will vary depending upon the data the students obtained from their dice rolling.

2. What effect does the mutation type have on base sequence or chromosome structure? Provide one example of a change of this type.
   Answers will vary, but students should demonstrate a clear understanding about how mutations can determine the expression of traits.

3. How do your data support the hypothesis that variation and distribution of traits allow some members of a population to reproduce successfully?
   Answers will vary, but students should recognize that mutations cause new traits to arise and that those traits give may give some individuals an advantage over others. If the environment

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selects for those traits, organisms may survive to reproduce and pass on those favorable traits. If the new trait does not confer an advantage, organisms may die before reproducing. Then the trait will not be passed on.

4. What were the limitations of the “telephone-game” model when compared with the actual variation and expression of expressed traits?
   Students should recognize that organisms have many more traits than are represented by each phrase in the game. Some mutations also affect the expression of more than one gene and trait. Another limitation is the presence of DNA mechanisms that typically correct the vast majority of actual mutations.

5. How do the results of the “dice-rolling” model compare statistically with “real-world” mutations and environmental conditions? How well does this model work as a quantitative or qualitative representation?
   Students should recognize that the numbers represented in the model are much too small to provide statistically relevant information about the variation and expression of traits. It is not a good quantitative model. It does, however, provide a good qualitative representation about the randomness of mutations.

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Appendix

Types of Mutation

Roll	Number	Corresponding result	Roll	Number	Corresponding result
1			26		
2			27		
3			28		
4			29		
5			30		
6			31		
7			32		
8			33		
9			34		
10			35		
11			36		
12			37		
13			38		
14			39		
15			40		
16			41		
17			42		
18			43		
19			44		
20			45		
21			46		
22			47		
23			48		
24			49		
25			50		

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Causes of Mutation

Roll	Number	Corresponding result	Roll	Number	Corresponding result
1			26		
2			27		
3			28		
4			29		
5			30		
6			31		
7			32		
8			33		
9			34		
10			35		
11			36		
12			37		
13			38		
14			39		
15			40		
16			41		
17			42		
18			43		
19			44		
20			45		
21			46		
22			47		
23			48		
24			49		
25			50		

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In this lab, students will demonstrate the following Inquiry Skills:

- Identify
  - Develop Predictions/Hypotheses
    - State what may happen in an investigation based on prior knowledge or experience
    - State the expected cause and effect in an investigation

- Gather Data
  - Choose appropriate format to record data
    - Graph or chart
    - Table

- Evaluate Evidence
  - Draw and supporting a conclusion by:
    - Reporting out trends and patterns and trends in the data

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

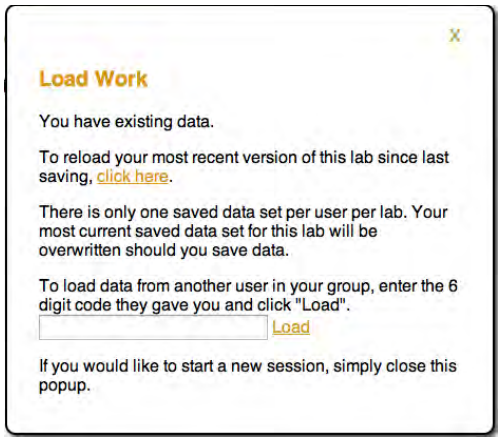
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

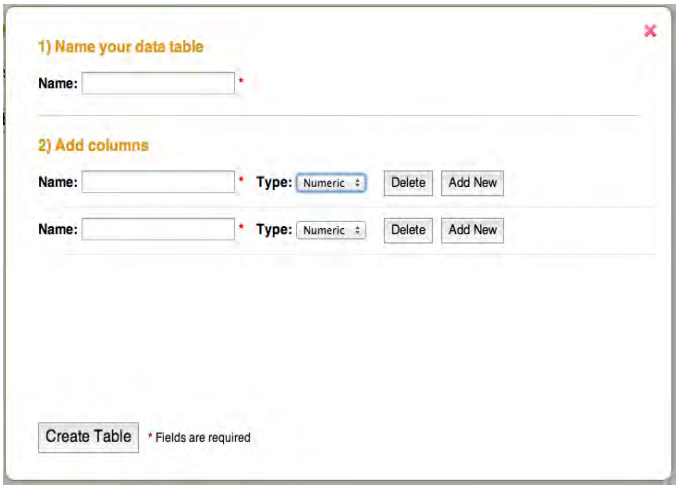
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



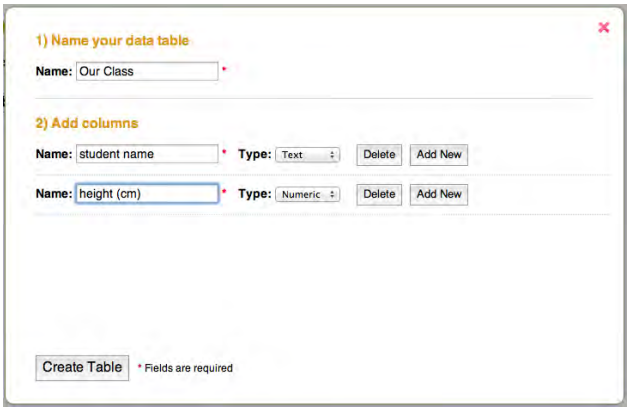
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

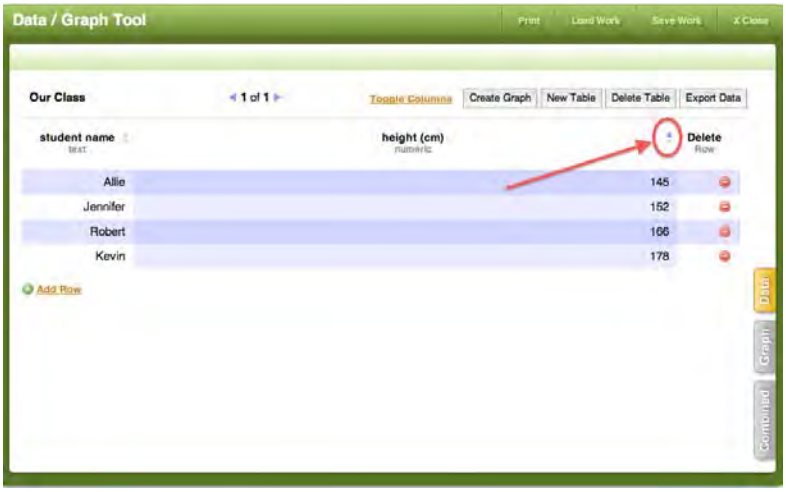
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

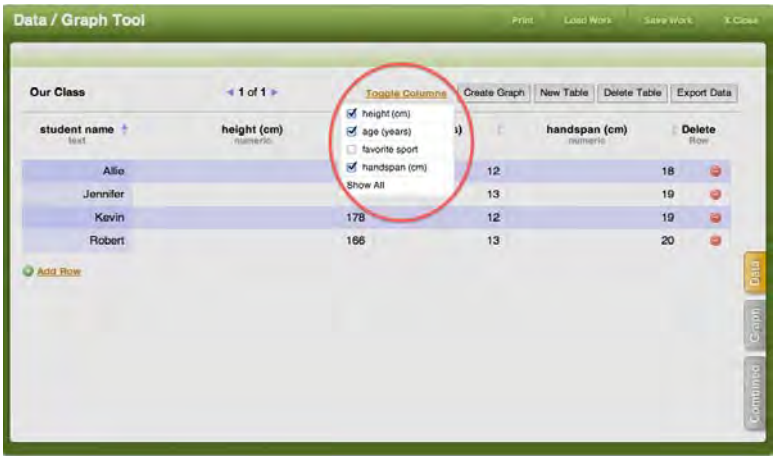


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

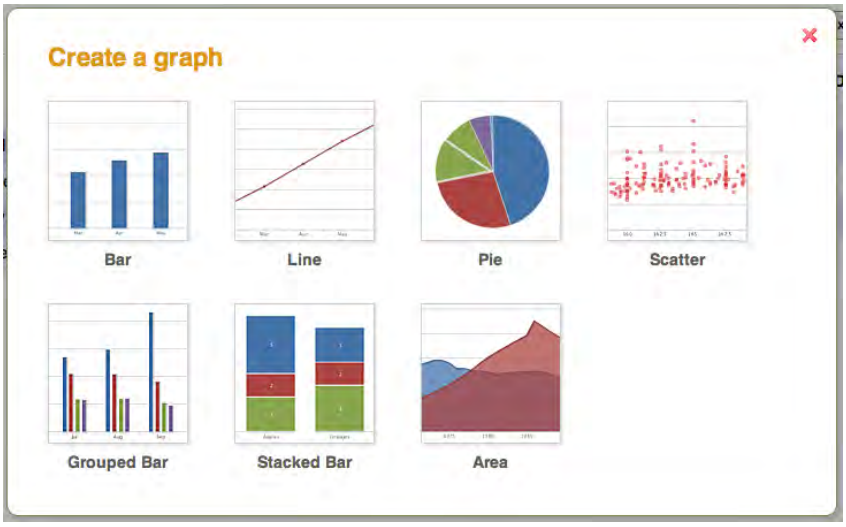
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

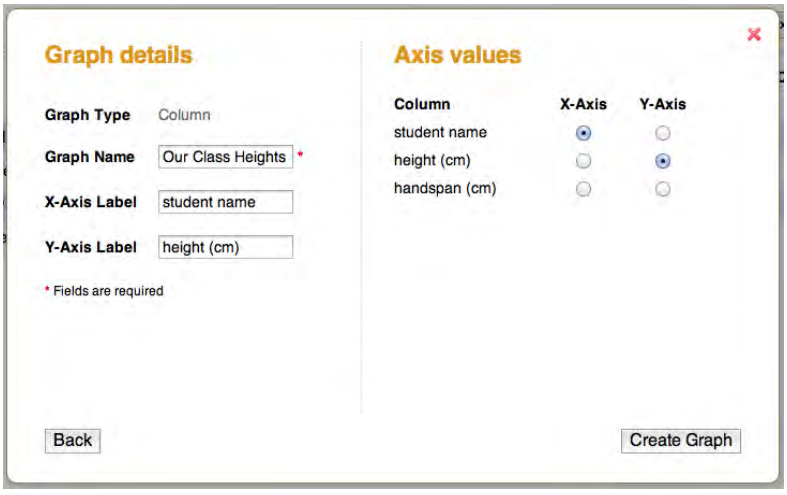
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

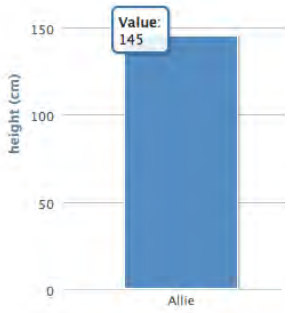


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

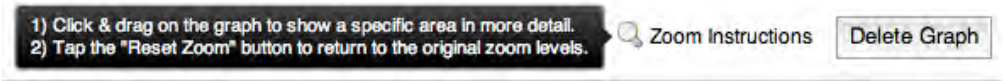
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Activity Sheet

Name _____

Date _____

Genetic Disorders and Technology

Work with a partner. Read the concept “Genetic Disorders and Technology.” Write difficult words in the chart below. Use the pictures, videos and words in Techbook to help understand the meanings of the words. Use the chart to create flashcards to help you learn the words.

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish? _____

Word or Sentence	Meaning	Example or Picture

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Exploration Teacher Guide: Genetic Disorders and Technology

Overview

Genetic disorders are the basis of many human diseases. Technology has the potential to study, cure, or prevent them. In this Exploration, students complete karyotypes of patients and determine their gender and the chromosomal abnormalities. While completing the karyotype, students observe how chromosomes pair with each other and how they are positioned in the karyotype. To complete the karyotype, students identify the differences in size, banding pattern, and position of the centromere of different chromosomes. Students then examine the genetic disorder caused because of the chromosomal abnormality.

Student Learning Objectives

- Determine how different chromosomes pair with each other.
- Complete the karyotype by placing homologous chromosomes in pairs.
- Compare the banding pattern, length, and the position of the centromere of chromosomes.
- Examine the completed karyotype to identify the gender and the chromosomal abnormality.
- Study the genetic disorder caused because of the identified chromosomal abnormality.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students complete the karyotype of patients. A patient is selected from the *Select Patient* dropdown list. The selected patient's karyotype with five incomplete chromosome pairs is visible in the activity area. The students complete the karyotype by dragging and dropping chromosomes from the *Chromosomes Available* section into the vacant slots of five incomplete chromosome pairs.

When the karyotype is complete, students examine it to identify the gender of the patient. When the gender is correctly identified, students indicate the abnormality of the karyotype. When the abnormality is correctly indicated, the feedback box describes the syndrome that this abnormality would indicate in the patient. After identifying both correctly, students use the *View Symptoms* button to learn about the genetic disorder caused by that abnormality.

The students may use the *Reset* button to undo what they have done.

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In the *Tracker* tab, students review the karyotypes that they have completed successfully and note the number of chromosomes, the gender, and the abnormality. The *View Symptoms* button and a thumbnail linking to a popup of the completed karyotype are also available.

Answers to Questions in the Student Worksheet

1. Explain what a karyotype is.

   Answer: A karyotype represents the number of chromosomes present in an individual. It also indicates the appearance of the chromosomes under a microscope. It is used to study genetic abnormalities.

2. In addition to indicating chromosomal abnormalities, what information will a karyotype reveal?

   Answer: In addition to indicating chromosomal abnormalities, a karyotype will reveal the gender of an individual.

3. Why does hemophilia occur more often in males?

   Answer: Hemophilia is caused by abnormalities due to a recessive allele present on the X chromosome. As males have only one X chromosome, hemophilia occurs more often in males.

4. A pregnant woman has learned that her fetus will have Down syndrome. How might this have been determined?

   Answer: This might have been determined by karyotyping the cells from amniotic fluid of the fetus.

5. Analyze and describe diagnosis of genetic disorders early in pregnancy.

   Answer: Genetic disorders can be diagnosed early by karyotyping amniotic fluid obtained from fetuses.

6. Identify two genetic disorders and state how their karyotypes differ from a normal karyotype due to a chromosomal abnormality.

   Answer: Two genetic disorders caused due to chromosomal abnormalities are Turner syndrome and Down syndrome. The karyotype of a patient with Turner syndrome will show a missing X chromosome. On the other hand, the karyotype of a patient with Down syndrome will show a trisomy of chromosome 21. Other examples include Edwards syndrome (Trisomy 18) and Klinefelter syndrome (extra X chromosome).

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7. Explain trisomy of chromosomes. Name two genetic disorders caused due to trisomy of chromosomes.

   Answer: A trisomy of chromosomes refers to the presence of three chromosomes are present, instead of two in a diploid individual. Down syndrome is caused by trisomy of chromosome 21 and Edwards syndrome is caused by trisomy of chromosome 18.

8. Complete the karyotype of patient 4. Determine the number of chromosomes present. Explain how this number is different from that of a healthy individual. Identify the chromosomal disorder of the patient.

   Answer: Patient 4 has 47 chromosomes in his karyotype. A healthy individual has 46 chromosomes. This patient is indicated for a chromosomal abnormality due to an extra X chromosome. This abnormality is Klinefelter syndrome.

9. The karyotype of a patient shows an extra chromosome 21. Which genetic abnormality is indicated in this patient? How do some individuals get the incorrect number of chromosomes?

   Answer: Down syndrome is indicated for this patient. Chromosome abnormalities are caused by faulty division of chromosomes during meiosis.

10. An individual only has one X chromosome and no Y chromosome. How is the genotype written for their sex chromosomes? Which genetic disorder is indicated in this patient? Can you determine the gender of the individual?

    Answer: The genotype of an individual who has only one X chromosome is written as XO. This genotype indicates a patient with Turner syndrome. The gender of this individual is female.

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Hands-On Lab

Human Karyotypes

Timing: one 90-minute class session

Objective(s):
In this lab, students will use their knowledge of genetic disorders and technology to learn about karyotypes. They will use mismatched sample karyotypes to understand how scientists diagnose chromosomal disorders. They will learn why and how a karyotype is performed and will practice determining which genetic disorder is represented by which karyotype.

Safety Precautions:
Remind students to be careful with scissors and not to eat or drink anything in the lab.

Materials:

Per student pair:

- scissors
- ruler
- paper
- tape
- sample unmatched karyotypes: one normal male, one normal female, and 2-3 disease types

Normal Female:

Normal Male:

Down syndrome:

Turner syndrome:

Teacher Preparation:
Students will perform a karyotype analysis for a normal male and a normal female, and then they will analyze two or three abnormal karyotypes to determine the disease associated with each one. Scrambled karyotypes for a normal female, a normal male, Down syndrome and Turner syndrome are provided. Make copies of the sample karyotypes for each student pair before class. Make one copy of the Student Investigation Sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory

techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Begin class by asking students to name a few genetic disorders caused by chromosomal aberrations. Briefly discuss the chromosomal abnormalities for each disease that students may encounter in the karyotypes you pass out and some of the symptoms. You may also wish to have students re-familiarize themselves with these disorders by conducting an Internet search for 5–10 minutes at the beginning of the lab.

Remind students that a normal karyotype consists of 23 pairs of homologous chromosomes, which includes 22 pair of autosomes (non sex chromosomes) and 1 pair of sex chromosomes (XX or XY). The analysis of human karyotypes has allowed scientists to determine the cause of many genetic disorders. Discuss with students that karyotypes are still commonly performed today to determine whether or not an individual has chromosomal abnormalities. Most commonly, amniotic fluid is removed from a fetus in a process called amniocentesis, and the chromosomal structure of the unborn child is determined. Ask students to describe the circumstances when parents or doctors are likely to call for amniocentesis. *Sample response: When there is a known family history of a genetic disorder that can be seen from a karyotype*.

Explain to students that in a traditional karyotype lab, scientists take pictures of the full complement of chromosomes (singles or homologous pairs frozen during the metaphase stage of dividing cells). The pictures are magnified many times and scientists cut out chromosomes and match them with their identical partners. Tell students that they will be cutting out and matching up chromosomes with their identical pairs as well. Scientists match and label each chromosome (1 through 22) based on the length, position of centromere, and banding pattern of the chromosome.

Hold up a sample karyotype as you review the steps with the class:

1. From the unmatched karyotype samples, cut out one chromosome at a time.
2. After cutting out one chromosome, match the chromosome with its pair and cut out the pair.

3. Tape the matching pair of chromosomes side-by-side on a sheet of paper. Templates can also be found or made onto which students can paste their pairs of chromosomes to make it more orderly.
4. Continue cutting out individual chromosomes and matching them with the appropriate pair, *one at a time,* not cutting out a second chromosome until the first is matched and taped together with its partner.
5. When the fully matched karyotype is complete, find the chromosomal abnormality within the karyotype, if any. Make a diagnosis based on the completed karyotype.

Students should record their findings for each karyotype by answering the following questions in their notebooks:

1. Is the individual in this karyotype male or female? *Answers will vary.*
2. How many chromosomes does the individual have? *Answers will vary.*
3. Is the individual normal or mutated? If mutated, what is the nature of the mutation? *Answers will vary.*
4. If mutated, what disorder does the individual have? *Answers will vary.*

Guided Inquiry

Students can work more independently with less discussion and direction from the teacher. You can hand out the unmatched karyotype samples and let students use computers to further their research of various genetic disorders. Ask the students some guiding questions to help them focus their inquiry:

- What is a karyotype and why would someone want to complete a karyotype? *A karyotype is a map of chromosome pairs. They are used to diagnose genetic diseases or find genetic abnormalities.*
- How do scientists perform karyotypes? *Scientists take pictures of chromosomes and enlarge them. They match individual chromosomes with an identical pair.*
- How do scientists determine the health or disease of an individual based on his or her karyotype? *Scientists look for the normal number of chromosomes, 23 pairs, including one pair of sex chromosomes. Any difference in these numbers indicates an abnormality, which they can compare to samples of specific disease karyotypes.*

Encourage students to compare their karyotypes and diagnoses with other groups. As a class, discuss the challenges that might be faced by scientists when matching chromosomes that are not labeled.

Analysis and Conclusions:

In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework.

1. Compare your results with those of another group. Discuss any differences in your karyotypes. *Answers will vary, but differences could be the result of errors in matching pairs correctly, or misdiagnosis.*

2. What can scientists learn from karyotypes? What are they unable to learn from them? *Scientists can learn about specific genetic abnormalities in an individual, or the chances that a child will inherit a disease from his or her parents if karyotypes are done on both parents. They can't learn what caused the abnormality without further study.*

3. Compare the diseases studied in this karyotyping exercise with some other diseases such as sickle-cell anemia, Tay-Sachs disease, Alzheimer's disease, and different forms of cancer. Would a karyotype be sufficient or help in the diagnosis of these diseases? Why or why not? *These diseases could not be diagnosed using karyotypes because they are either single-gene disorders or multifactorial disorders, without gross chromosomal abnormalities*.

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - Asks a question about a specific science concept or process
  - Develop predictions/hypotheses that:
    - State what may happen in an investigation based on prior knowledge or experience (prediction)
    - State the expected cause and effect (if-then statement) in an investigation based on prior knowledge and experience (hypothesis)
- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated.
    - Have as many details as possible replicated from the real thing.
    - Function exactly like or similarly to the real thing.
    - Are based on logic and evidence.
- Gather Data
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
  - Use the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
    - Sketch
- Interpret Data
  - Sort and classify using scientific reasoning by:
    - Sorting objects, substances and organisms by characteristic
    - Applying a classification scheme to objects, substances or organisms
    - Developing a classification scheme for objects, substances or organisms
  - Identify and interpret patterns using:
    - Analysis of data collected during an investigation
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Formulating scientific explanations/arguments
- Communication in Science
  - Report results using:
    - Peer presentation
    - Scientific illustration with proper labeling
    - Scientific explanations/arguments
- Analyze Scientific Results

    - Participate in critiquing/peer review by:
        - Evaluating data for accuracy
        - Evaluating a conclusion
- Scientific Investigation
    - Scientific Investigation:
        - Scientific investigations lead to the development of scientific explanations.
    - Scientific Data and Outcomes:
        - People are more likely to believe ideas if good reasons are given for them.
        - Scientific claims are based on data and reliable scientific sources.
- Scientific Endeavor
    - Characteristics of Science:
        - Science is based on factual knowledge.
        - Scientific claims can be substantiated using data and observation.
        - Scientific theories are based on accumulated evidence.
- Engineering and Technology
    - Societal Issues:
        - Scientific discoveries have benefitted people in many ways.
    - Uses of technology:
        - Technology extends the ability of people to make positive and/or negative changes in the world.
        - Human beings have made tools and machines, such as x-rays, microscopes, and computers, to sense and do things that they could not otherwise sense or do at all, or as quickly, or as well.

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116

Genetically Inherited Disease Detection

See Page 3 for storage instructions.

EXPERIMENT OBJECTIVE:

In this experiment, students will gain an understanding of the effect of mutations in health and disease, specifically as it relates to sickle cell anemia.

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All components are intended for educational research only. They are not to be used for diagnostic or drug purposes, nor administered to or consumed by humans or animals.

THIS EXPERIMENT DOES NOT CONTAIN HUMAN DNA. None of the experiment components are derived from human sources.

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Experiment Components

DNA samples are stable at room temperature. However, if the experiment will not be conducted within one month of receipt, it is recommended that the DNA samples be stored in the refrigerator.

DNA samples do not require heating prior to gel loading.

READY-TO-LOAD™ DNA SAMPLES FOR ELECTROPHORESIS

A Sickle cell gene sample
B Sickle cell trait (carrier) sample
C Normal gene sample
D Mother's DNA sample
E Child's DNA sample
F Father's DNA sample

REAGENTS & SUPPLIES

- UltraSpec-Agarose™ powder
- Concentrated electrophoresis buffer
- FlashBlue™ DNA Stain
- InstaStain® Blue cards
- Practice Gel Loading Solution
- 1 ml pipet
- Microtipped Transfer Pipets

Note: If you ordered Experiment #116-Q, the experiment components include InstaStain® Ethidium bromide instead of FlashBlue™ and InstaStain® Blue DNA stains.

Requirements

- Horizontal gel electrophoresis apparatus
- D.C. power supply
- Automatic micropipets with tips
- Balance
- Microwave, hot plate or burner
- Pipet pump
- 250 ml flasks or beakers
- Hot gloves
- Safety goggles and disposable laboratory gloves
- Small plastic trays or large weigh boats (for gel destaining)
- DNA visualization system (white light)
- Distilled or deionized water

Background Information

IN SEARCH OF THE SICKLE CELL GENE

A single nucleotide change in the DNA sequence of an important gene can affect health and disease. A large number of genetic diseases are identified where such changes have been correlated to the changes in a single nucleotide. More recently, mutations in oncogenes and tumor suppressor genes such as p53, have been associated with lung, colon and breast cancer. Other mutations in genes such as the BRCA 1 and II genes have been identified as specific markers with good potential as diagnostic tools for breast cancer.

Human genetics follows the basic findings of the Augustine monk, Gregor Mendel, who studied plant genetics in the mid-1800's. Mendelian genetics, which predicts traits inherited by offspring, is based on the inheritance of two alleles, or forms of the gene. These two alleles are inherited one from each parent. Alleles, and corresponding traits, can be either dominant or recessive. When a dominant allele is inherited, the trait coded by that allele will be apparent in the offspring. The presence of a dominant allele will, in effect, mask the trait coded by the recessive allele. To observe a recessive trait, it is required that both parental alleles be the recessive type. If both alleles are the same type, either both recessive or both dominant, the individual is said to be homozygous with respect to that trait. If an individual has one dominant and one recessive, the individual is said to be heterozygous for that trait.

	T	t
T	T T	T t
t	T t	t t

Genotype:

1/4	TT
1/2	Tt
1/4	tt

Phenotype:

3/4	dominant
1/4	recessive

Figure 1

Mendelian inheritance can be demonstrated with a 2 x 2 matrix, as shown in Figure 1. Parental alleles are placed on the sides of the matrix, and the genotype (what is genetically inherited) and phenotype (the way we look) of the offspring can be predicted. By convention, the dominant allele is denoted by an uppercase letter and the recessive allele by a lowercase letter. For example, assuming both parents each carry one dominant allele and one recessive allele, we can predict that 3/4 of their children will have the dominant phenotype and 1/4 of their children will have the recessive phenotype. Genotypically, 1/4 of the children will carry two dominant alleles; 1/2 of the children will carry one dominant and one recessive allele, and 1/4 will carry two recessive alleles. These estimates would be observed if there are a large number of offspring from two parents, as in the case of insects or plants.

Hemoglobin, which is present in red blood cells, is the carrier of oxygen to cells in the body. In capillaries carbon dioxide, which is a by product of metabolism, enters red cells and is converted to carbonic acid. The acidic pH reduces the affinity of oxygen binding to hemoglobin resulting in the release of oxygen in cells. Likewise when the bound carbon dioxide is released from red cells in the lungs there is an increase in pH which favors the binding of oxygen to hemoglobin. In individuals who suffer from certain blood diseases such as sickle cell anemia, the binding and subsequent transport of oxygen is compromised due to a single nucleotide mutation. This results in a deficiency of oxygen and carbon dioxide exchange in the patient. In sickle cell anemia patients, the substitution of the polar side chain (Glu) with a nonpolar hydro-

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Background Information

phobic side chain (Val) results in the polymerization of the unoxygenated form and subsequent precipitation of such polymers in red blood cells. The precipitation gives red blood cells a sickle shape due to the lack of diffusion through capillaries.

Blood disease such as sickle cell anemia and b-thalassemias are attributed to various point mutations or other translational product aberrations. Almost 400 different hemoglobin (Hb) variants of known structure have been identified. The early recognized variants were historically assigned alphabetical initials based sequence of discovery or hematologic features.

In the United States, sickle cell anemia is of special interest since it is estimated that 8% of African Americans are carriers of the sickle trait. Therefore, pregnancies at risk of an offspring suffering from sickle cell anemia is 8% x 8%, which equals 0.64 or 3.75%. It is of interest to note that heterozygous individuals for Hb S have a high resistance to the malaria parasite, part of whose life cycle is spent in red blood cells. Historically, sickle cell anemia has provided a selective advantage in some regions of the world such as parts of Africa. This can also explain the reason for the high frequency of this homozygous gene amongst African Americans.

Hemoglobin is made up of two a chains and two b chains. The gene where the a is located is on the short arm of chromosome 16, while the b-globin gene cluster is on the short arm of chromosome 11. In addition to the adult form of Hb encoded within the b Hb cluster are the Hb forms that substitute for the adult b Hb during the various stages of development. Hemoglobin S (Hb S) is the variant form of the normal adult hemoglobin A (Hb A) in which an amino acid substitution occurs in the B polypeptide. The amino acid substitution is that of Valine (Val) in Hb S for the glutamic acid (Glu) normal Hb A hemoglobin (Figure 2). This significant finding was reported in 1957 by Vernon Ingram who was able to determine this structural change using peptide mapping analysis. These procedures are tedious and difficult. It should be noted that this predates recombinant DNA technology.

The single base mutation is an A to T in the triplet codon of the amino acid residue number 6 from the amino acid end in the beta chain. This change introduces an amino acid with a polar (neutral) side chain valine instead of the acidic (negative) residue and changes the property of the hemoglobin molecule. This substitution changes the electrophoretic mobility of Hb S compared to Hb A. At slightly basic pH, such as 8.4, Hb S will be relatively more positive than Hb A and therefore will travel slower towards the positive (anode) electrode. This change in mobility is used as a diagnostic test of the presence of Hb S.

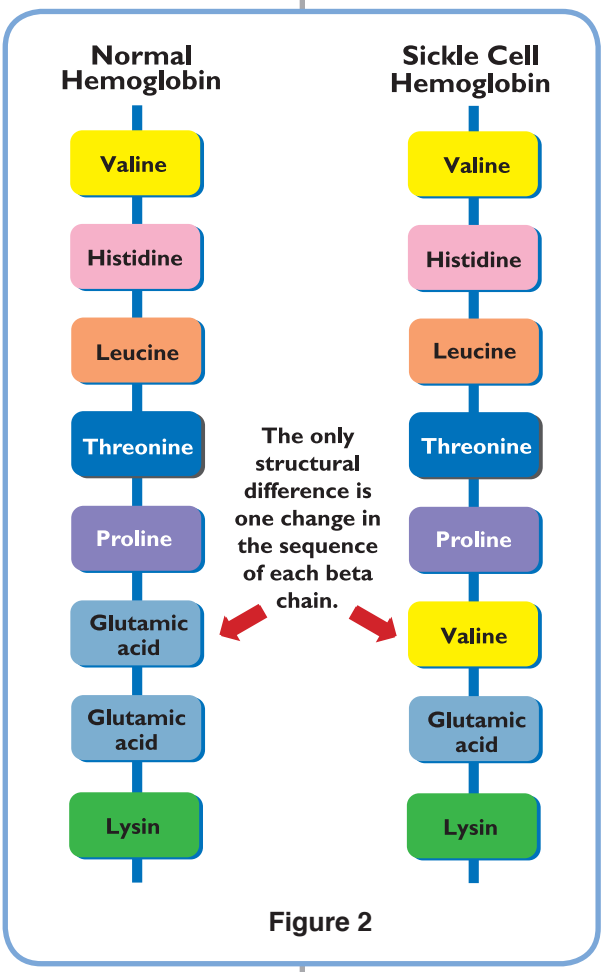

Figure 2

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Background Information

With the advent of biotechnology, parental or fetal DNA from cells obtained from amniocentesis can now be analyzed with a high degree of accuracy. DNA from a few cells can provide sufficient DNA to amplify using Polymerase Chain Reaction (PCR). Alternative methods can include growing cells in culture to yield sufficient DNA for analysis. The basis of the test is the recognition by restriction enzymes of specific palindromic sequences in DNA. In the normal b globin gene, the sequence of nucleotides that specifies amino acids 5, 6 and 7 (Pro-Glu-Glu) are CCT- GAG-GAG. The point mutation in codon 6 converting the A to T changing the sequence CCT-GTG-GAG. The palindrome recognition site of the restriction enzyme *Mst* II is CCTNAGG, where N can be any of the four nucleotides. Close examination of the sequence shows that *Mst* II will recognize the normal b globin CCT-GAG-G where N is a G, but not the mutated form.

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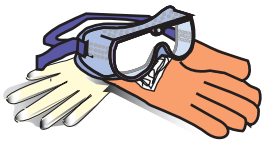
Experiment Overview and General Instructions

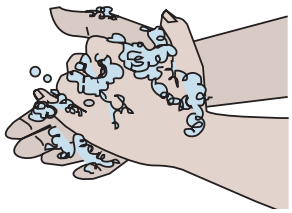
EXPERIMENT OBJECTIVE:

In this experiment, students will gain an understanding of the effect of mutations in health and disease, specifically as it relates to sickle cell anemia.

LABORATORY SAFETY



1. Gloves and goggles should be worn routinely as good laboratory practice.
2. Exercise extreme caution when working with equipment that is used in conjunction with the heating and/or melting of reagents.
3. DO NOT MOUTH PIPET REAGENTS - USE PIPET PUMPS.
4. Exercise caution when using any electrical equipment in the laboratory.
5. Always wash hands thoroughly with soap and water after handling reagents or biological materials in the laboratory.



LABORATORY NOTEBOOK RECORDINGS:

Address and record the following in your laboratory notebook or on a separate worksheet.

Before starting the Experiment:

- Write a hypothesis that reflects the experiment.
- Predict experimental outcomes.

During the Experiment:

- Record (draw) your observations, or photograph the results.

Following the Experiment:

- Formulate an explanation from the results.
- Determine what could be changed in the experiment if the experiment were repeated.
- Write a hypothesis that would reflect this change.

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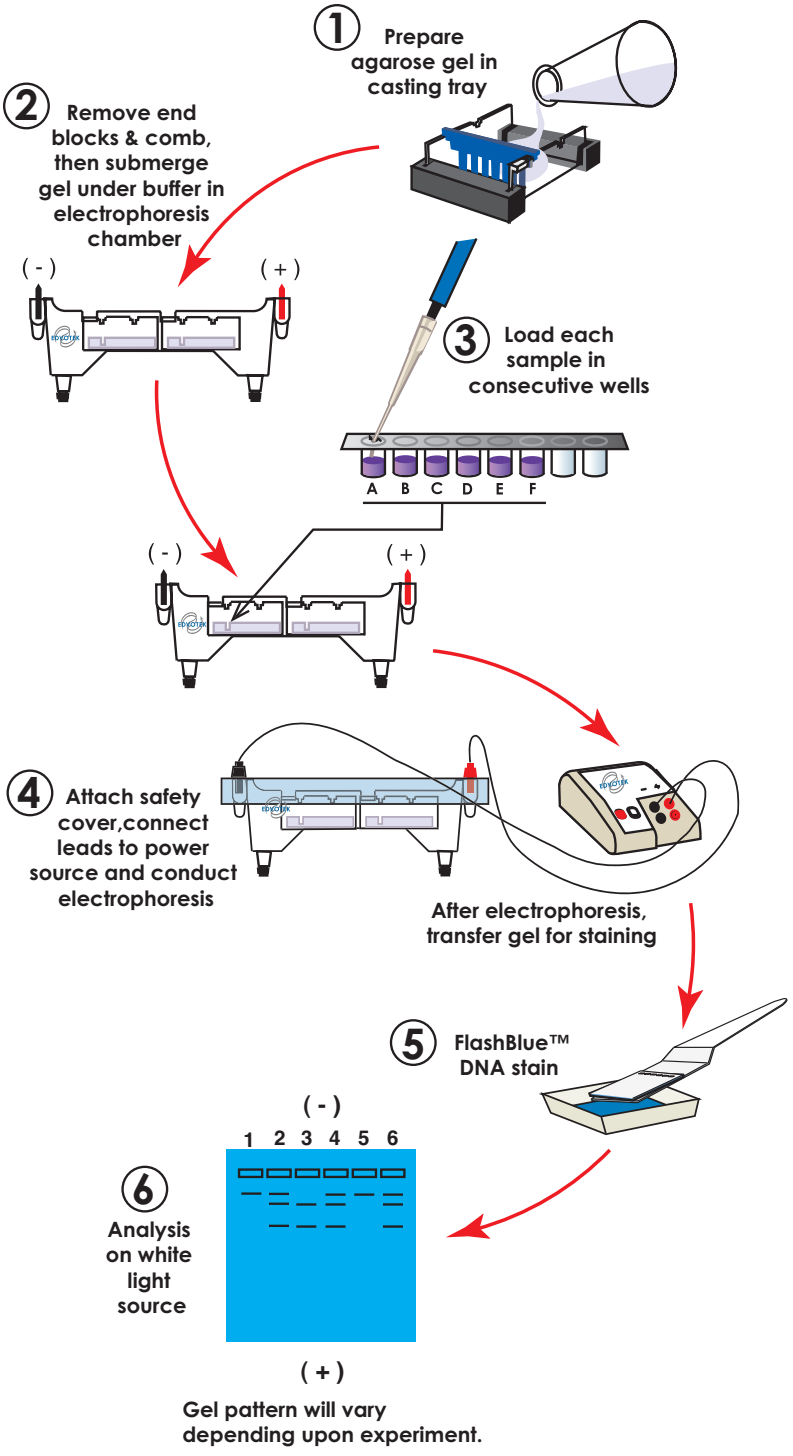
Experiment Overview: Flow Chart

Experiment Procedure



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Agarose Gel Electrophoresis

Prepare the Gel

1. Prepare an agarose gel with specifications summarized below. Your instructor will specify which DNA stain you will be using.

   - Agarose gel concentration required: 0.8%
   - Recommended gel size: 7 x 7 cm or 7 x 14 cm (two gels)
   - Number of sample wells required: 6
   - Placement of well-former template: first set of notches (7 x 7 cm)
     first & third set of notches (7 x 14 cm)

For gels to be stained with FlashBlue™ or InstaStain® Blue, prepare gels according to Appendix A.

For gels to be stained with InstaStain® Ethidium bromide, prepare gels according to Appendix B.

Step-by-step guidelines for agarose gel preparation are summarized in Appendix D.

Load the Samples

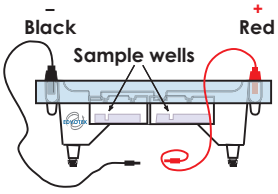
2. Load the DNA samples in tubes A - F into the wells in consecutive order.

   - For gels to be stained with FlashBlue™ or InstaStain® Blue, fill wells with 35 - 38 µl.
   - For gels to be stained with InstaStain® Ethidium Bromide, fill wells with 18 - 20 µl.

Lane	Tube	
1	A	Sickle cell gene sample
2	B	Sickle cell trait (carrier) sample
3	C	Normal gene sample
4	D	Mother's DNA sample
5	E	Child's DNA sample
6	F	Father's DNA sample

Reminders:

During electrophoresis, the DNA samples migrate through the agarose gel towards the positive electrode. Before loading the samples, make sure the gel is properly oriented in the apparatus chamber.



Run the Gel

3. After DNA samples are loaded, connect the apparatus to the D.C. power source and set the power source at the required voltage.

4. Check that current is flowing properly - you should see bubbles forming on the two platinum electrodes. Conduct electrophoresis for the length of time specified by your instructor.

5. After electrophoresis is completed, proceed to DNA staining and visualization. Refer to Appendix E, F, G, or H for the appropriate staining instructions.

6. Document the results of the gel by photodocumentation.

   Alternatively, place transparency film on the gel and trace it with a permanent marking pen. Remember to include the outline of the gel and the sample wells in addition to the migration pattern of the DNA bands.

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Material Safety Data Sheets

Full-size (8.5 x 11") pdf copy of MSDS is available at www. edvotek.com or by request.

EDVOTEK®

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): **Practice Gel Loading Solution**

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: 10/05/06

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)

This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard.

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_2O = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	No data
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Soluble

Appearance and Odor: Blue liquid, no odor

Section IV - Physical/Chemical Characteristics

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		No data	No data

Extinguishing Media: Dry chemical, carbon dioxide, water spray or foam

Special Fire Fighting Procedures: Use agents suitable for type of surrounding fire. Keep upwind, avoid breathing hazardous sulfur oxides and bromides. Wear SCBA.

Unusual Fire and Explosion Hazards: Unknown

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	None

Incompatibility: None

Hazardous Decomposition or Byproducts: Sulfur oxides, and bromides

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	None

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Acute eye contact: May cause irritation. No data available for other routes.

Carcinogenicity: No data available NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: May cause skin or eye irritation

Medical Conditions Generally Aggravated by Exposure: None reported

Emergency First Aid Procedures: Treat symptomatically and supportively. Rinse contacted area with copious amounts of water.

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Wear eye and skin protection and mop spill area. Rinse with water.

Waste Disposal Method: Observe all federal, state, and local regulations.

Precautions to be Taken in Handling and Storing: Avoid eye and skin contact.

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type):

Ventilation	Local Exhaust	Yes	Special	None	
	Mechanical (General)	Yes	Other	None	
Protective Gloves	Yes		Eye Protection	Splash proof goggles	

Other Protective Clothing or Equipment: None required

Work/Hygienic Practices: Avoid eye and skin contact

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Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): **50x Electrophoresis Buffer**

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: 10/05/06

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)

This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard.

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_2O = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	No data
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Appreciable, (greater than 10%)

Appearance and Odor: Clear, liquid, slight vinegar odor

Section IV - Physical/Chemical Characteristics

N.D. = No data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		N.D.	N.D.

Extinguishing Media: Use extinguishing media appropriate for surrounding fire.

Special Fire Fighting Procedures: Wear protective equipment and SCBA with full facepiece operated in positive pressure mode.

Unusual Fire and Explosion Hazards: None identified

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	None

Incompatibility: Strong oxidizing agents

Hazardous Decomposition or Byproducts: Carbon monoxide, Carbon dioxide

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	None

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): None

Carcinogenicity: None identified NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: Irritation to upper respiratory tract, skin, eyes

Medical Conditions Generally Aggravated by Exposure: None

Emergency First Aid Procedures: Ingestion: If conscious, give large amounts of water

Eyes: Flush with water Inhalation: Move to fresh air Skin: Wash with soap and water

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Wear suitable protective clothing. Mop up spill and rinse with water, or collect in absorptive material and dispose of the absorptive material.

Waste Disposal Method: Dispose in accordance with all applicable federal, state, and local enviromental regulations.

Precautions to be Taken in Handling and Storing: Avoid eye and skin contact.

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type):

Ventilation	Local Exhaust	Yes	Special	None	
	Mechanical (General)	Yes	Other	None	
Protective Gloves	Yes		Eye Protection	_Safety goggles	

Other Protective Clothing or Equipment: None

Work/Hygienic Practices: None

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Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List): Agarose

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name: **EDVOTEK, Inc.**

Address (Number, Street, City, State, Zip Code): **14676 Rothgeb Drive Rockville, MD 20850**

Emergency Telephone Number: **(301) 251-5990**

Telephone Number for information: **(301) 251-5990**

Date Prepared: 10/05/06

Signature of Preparer (optional):

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)

This product contains no hazardous materials as defined by the OSHA Hazard Communication Standard.

CAS #9012-36-6

Section III - Physical/Chemical Characteristics

Boiling Point For 1% solution 194 F		Specific Gravity (H 0 = 1) 2	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	No data
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data

Solubility in Water: Insoluble - cold

Appearance and Odor: White powder, no odor

Section IV - Physical/Chemical Characteristics

N.D. = No data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		N.D	N.D.

Extinguishing Media: Water spray, dry chemical, carbon dioxide, halon or standard foam

Special Fire Fighting Procedures: Possible fire hazard when exposed to heat or flame

Unusual Fire and Explosion Hazards: None

Section V - Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable	X	None

Incompatibility: No data available

Hazardous Decomposition or Byproducts:

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur	X	None

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Inhalation: No data available Ingestion: Large amounts may cause diarrhea

Carcinogenicity: NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: No data available

Medical Conditions Generally Aggravated by Exposure: No data available

Emergency First Aid Procedures: Treat symptomatically and supportively

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Sweep up and place in suitable container for disposal

Waste Disposal Method: Normal solid waste disposal

Precautions to be Taken in Handling and Storing: None

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type): Chemical cartridge respirator with full facepiece.

Ventilation	Local Exhaust		Special		
	Mechanical	Gen. dilution ventilation	Other		
Protective Gloves	Yes		Eye Protection	Splash proof goggles	

Other Protective Clothing or Equipment: Impervious clothing to prevent skin contact

Work/Hygienic Practices: None

EDVOTEK®

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List)	Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.
InstaStain® Blue, FlashBlue™	

Section I

Manufacturer's Name	Emergency Telephone Number
EDVOTEK, Inc.	(301) 251-5990
Address (Number, Street, City, State, Zip Code)	Telephone Number for information
14676 Rothgeb Drive Rockville, MD 20850	(301) 251-5990
	Date Prepared 03-26-09
	Signature of Preparer (optional)

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
Methylene Blue				
3.7 Bis (Dimethylamino) Phenothiazin 5 IUM Chloride	No data available			
CAS # 61-73-4				

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_2O = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	No data
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data
Solubility in Water	Soluble - cold		
Appearance and Odor	Chemical bound to paper, no odor		

Section IV - Physical/Chemical Characteristics

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data available	No data		No data

Extinguishing Media: Water spray, carbon dioxide, dry chemical powder, alcohol or polymer foam

Special Fire Fighting Procedures: Self contained breathing apparatus and protective clothing to prevent contact with skin and eyes

Unusual Fire and Explosion Hazards: Emits toxid fumes under fire conditions

Section V - Reactivity Data

Stability			Conditions to Avoid
	Unstable		None
	Stable	X	

Incompatibility: Strong oxidizing agents

Hazardous Decomposition or Byproducts: Toxic fumes of Carbon monoxide, Carbon dioxide, nitrogen oxides, sulfur oxides, hydrogen, chloride gas

Hazardous Polymerization			Conditions to Avoid
	May Occur		None
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Skin: May cause skin irritation Eyes: May cause eye irritation Inhalation: Cyanosis

Carcinogenicity: NTP? IARC Monographs? OSHA Regulation?
Meets criteria for proposed OSHA medical records rule PEREAC 47.30420.82

Signs and Symptoms of Exposure: No data available

Medical Conditions Generally Aggravated by Exposure: No data available

Emergency First Aid Procedures: Treat symptomatically

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Ventilate area and wash spill site

Waste Disposal Method: Mix material with a combustible solvent and burn in chemical incinerator equipped with afterburner and scrubber. Check local and state regulations.

Precautions to be Taken in Handling and Storing: Keep tightly closed. Store in cool, dry place

Other Precautions: None

Section VIII - Control Measures

Respiratory Protection (Specify Type): MIOSH/OSHA approved, SCBA

Ventilation			
	Local Exhaust	Special	
	Mechanical (General) Required	Other	

Protective Gloves	Rubber	Eye Protection	Chem. safety goggles

Other Protective Clothing or Equipment: Rubber boots

Work/Hygienic Practices:

EDVOTEK®

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard. 29 CFR 1910.1200 Standard must be consulted for specific requirements.

IDENTITY (As Used on Label and List)	Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.
InstaStain® Ethidium Bromide	

Section I

Manufacturer's Name	Emergency Telephone Number
InstaStain, Inc. **P.O. Box 1232** **West Bethesda, MD 20827**	**(301) 251-5990**
	Telephone Number for information **(301) 251-5990**
	Date Prepared 10/05/06
	Signature of Preparer (optional)

Section II - Hazardous Ingredients/Identify Information

Hazardous Components [Specific Chemical Identity; Common Name(s)]	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (Optional)
Ethidium Bromide		Data not available		
(2,7-Diamino-10-Ethyl-9-Phenylphenanthridinium Bromide)				
CAS# 139-33-3				

Section III - Physical/Chemical Characteristics

Boiling Point	No data	Specific Gravity (H_2O = 1)	No data
Vapor Pressure (mm Hg.)	No data	Melting Point	No data
Vapor Density (AIR = 1)	No data	Evaporation Rate (Butyl Acetate = 1)	No data
Solubility in Water	Soluble		
Appearance and Odor	Chemical bound to paper, no odor		

Section IV - Physical/Chemical Characteristics

N.D. = No data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
No data		N.D.	N.D.

Extinguishing Media: Water spray, carbon dioxide, dry chemical powder, alcohol or polymer foam

Special Fire Fighting Procedures: Wear protective clothing and SCBA to prevent contact with skin & eyes

Unusual Fire and Explosion Hazards: Emits toxic fumes

Section V - Reactivity Data

Stability			Conditions to Avoid
	Unstable		None
	Stable	X	

Incompatibility: Strong oxidizing agents

Hazardous Decomposition or Byproducts: Carbon monoxide, Carbon dioxide, nitrogen oxides, hydrogen bromide gas

Hazardous Polymerization			Conditions to Avoid
	May Occur		None
	Will Not Occur	X	

Section VI - Health Hazard Data

Route(s) of Entry: Inhalation? Yes Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic): Chronic: May alter genetic material
Acute: Material irritating to mucous membranes, upper respiratory tract, eyes, skin

Carcinogenicity: No data available NTP? IARC Monographs? OSHA Regulation?

Signs and Symptoms of Exposure: Irritation to mucous membranes and upper respiratory tract

Medical Conditions Generally Aggravated by Exposure: No data

Emergency First Aid Procedures: Treat symptomatically and supportively

Section VII - Precautions for Safe Handling and Use

Steps to be Taken in case Material is Released for Spilled: Wear SCBA, rubber boots, rubber gloves

Waste Disposal Method: Mix material with combustible solvent and burn in a chemical incinerator equipped afterburner and scrubber

Precautions to be Taken in Handling and Storing: Use in chemical fume hood with proper protective lab gear.

Other Precautions: Mutagen

Section VIII - Control Measures

Respiratory Protection (Specify Type): SCBA

Ventilation				
	Local Exhaust	Yes	Special	Chem. fume hood
	Mechanical (General)	No	Other	None

Protective Gloves	Rubber	Eye Protection	Chem. safety goggles

Other Protective Clothing or Equipment: Rubber boots

Work/Hygienic Practices: Use in chemical fume hood with proper protective lab gear.

EDVOTEK Series 100 Electrophoresis Experiments:

Cat. #	Title
101	Principles and Practice of Agarose Gel Electrophoresis
102	Restriction Enzyme Cleavage Patterns of DNA
103	PCR - Polymerase Chain Reaction
104	Size Determination of DNA Restriction Fragments
105	Mapping of Restriction Sites on Plasmid DNA
116	DNA Fingerprinting - Identification of DNA by Restriction Fragmentation Patterns
112	Analysis of *Eco* RI Cleavage Patterns of Lambda DNA
116	Genetically Inherited Disease Detection
115	Cancer Gene Detection
116	Sickle Cell Gene Detection (DNA-based)
117	Detection of Mad Cow Disease
118	Cholesterol Diagnostiics
124	DNA-based Screening for Smallpox
130	DNA Fingerprinting - Amplification of DNA for Fingerprinting

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

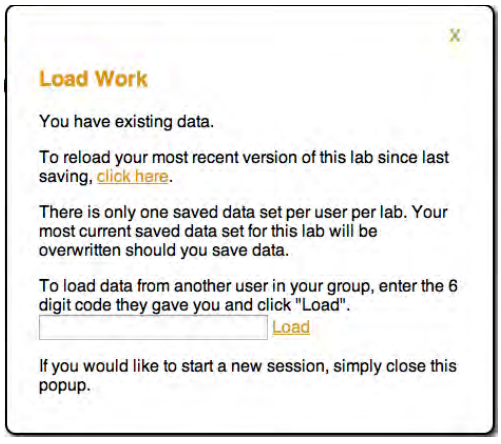
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

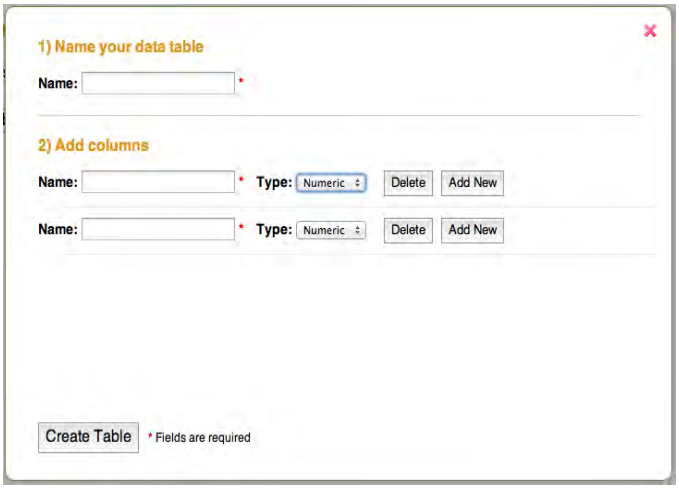
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



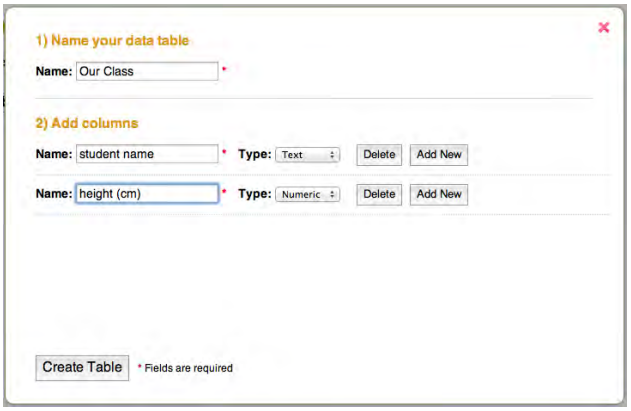
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

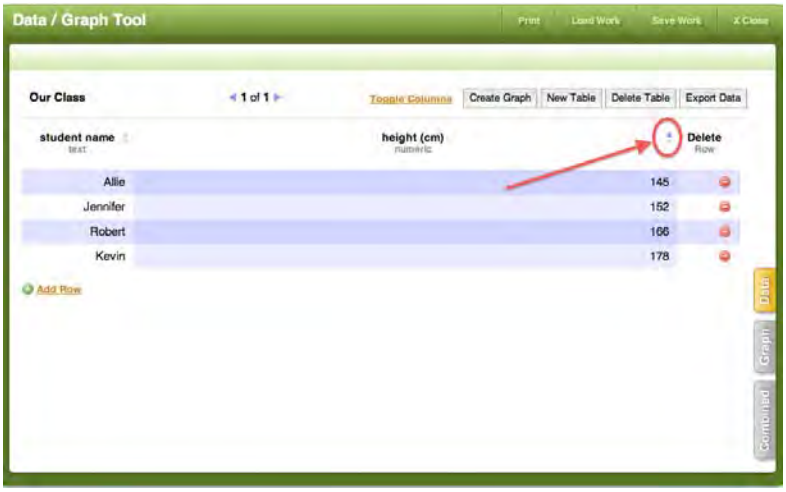
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

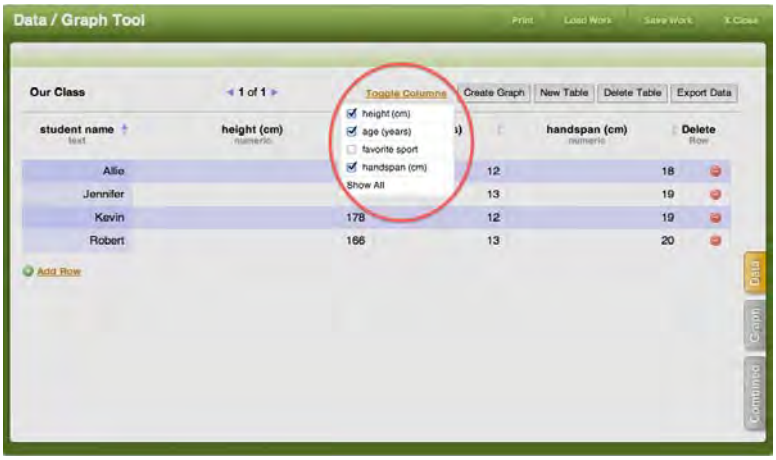


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

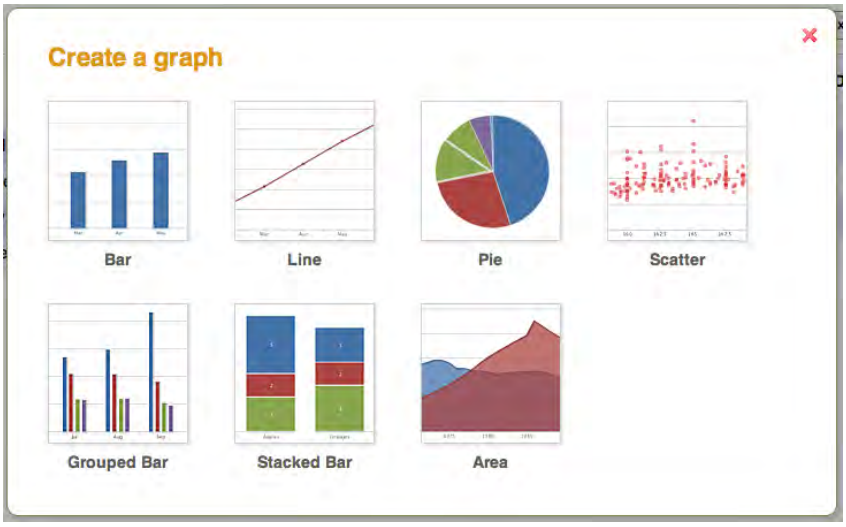
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

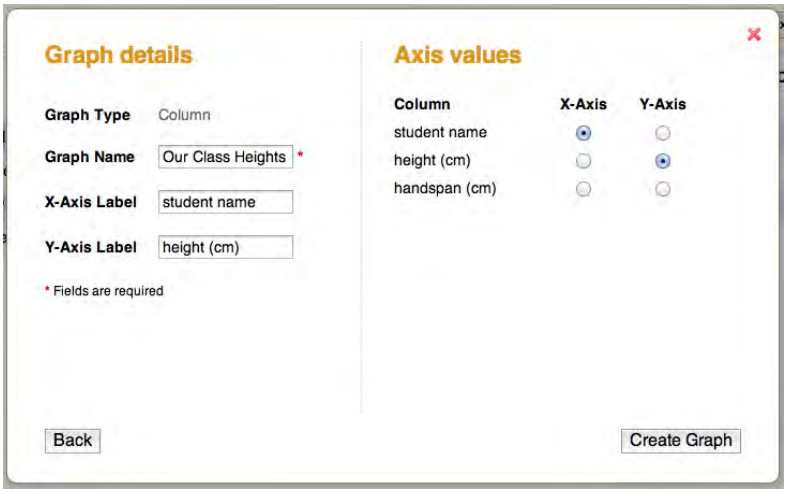
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

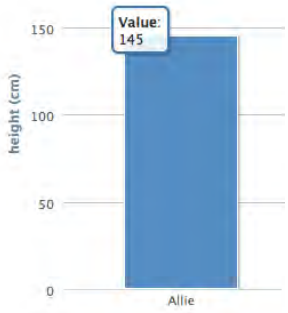


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

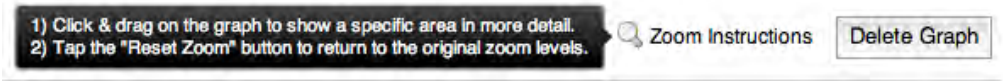
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Effect of Temperature and pH on Enzymes

Timing: One 60-minute class session

Objectives:
Students will design and carry out an investigation to learn how changing the temperature or the pH affects the activity of an enzyme.

Safety Precautions:
Remind students to follow all lab safety guidelines, especially those associated with chemical experiments. Students should report any broken glass immediately and not try to clean it up by themselves. Students must follow proper cleanup and disposal of chemicals, including wiping down their lab tables and washing their hands with soap and water. Make sure students wear proper safety attire including closed-toe shoes, safety goggles, lab coats or aprons, and gloves. For all chemicals, always refer to the material safety data sheets (MSDS) for specific safety information.

Materials:
Per pair:

- 11 test tubes
- test tube marker
- test tube rack
- test tube tongs
- disposable pipettes
- 4 glass beakers (100 mL)
- distilled water
- 3% hydrogen peroxide
- lemon juice
- ammonia
- ice
- 2 straws
- water
- hot plate
- thermometer
- small pieces of raw liver
- raw potato
- plastic spoon
- wide range pH paper or pH probe
- safety gloves, one pair per student
- lab apron, one per student
- safety goggles, one pair per student

Teacher Preparation:

- Purchase hydrogen peroxide, chicken or beef liver, and raw potato at a grocery store. Pure ammonia (without phosphates) can be purchased at hardware stores.
- Arrange a method of preparing and maintaining the four water baths: 20°C, 37°C, 45°C, and 100°C. Students will need a secure way to place the test tubes with which they are working in the water baths.
- Cut the liver and potato into pieces about a half of a centimeter (cm) wide. Each group will need about eight pieces of the material they select.

- Ammonia can cause severe respiratory, eye, and skin irritation. Provide a well-ventilated environment for its use. Review safety guidelines at your school and material safety data sheets. Consider dispensing it for each group rather than having students handle it themselves.
- Place the distilled water and the hydrogen peroxide into beakers for easy access for students.
- Make a copy of the Student Investigation Sheet for each student.
- Read all Student Instructions (for Part 1 and Part 2) to assist with the lab setup.

Background

Enzymes are catalysts for biological reactions. They speed up reactions but remain unchanged by them. Since enzymes are proteins, they are sensitive to both heat and acidity. Each enzyme has a narrow range of temperatures and pH at which it is most effective as a catalyst. Any temperature or pH that is above or below these optimum values causes the enzyme to be ineffective. Lower temperatures deactivate an enzyme because there are too few collisions between the substrate and the active site of the enzyme. Higher temperatures or pH values above or below the optimum range deactivate an enzyme by denaturing it. Denaturing is the unfolding of a protein caused by the breaking of hydrogen bonds. Denaturing alters the shape of the enzyme so that the substrate no longer fits in the active site.

In this investigation, students will be working with a common enzyme in living organisms called *catalase*. Hydrogen peroxide is released as a by-product of reactions in the body, but a buildup of this chemical can be toxic. Catalase prevents this buildup by acting as a catalyst in the decomposition of hydrogen peroxide to produce water and oxygen gas:

$$2H_2O_2 \xrightarrow{\text{catalase}} 2H_2O + O_2$$

Students will observe this oxygen gas in the lab as an indication that the enzyme is working. The optimum temperature for catalase activity is about 37°C, and its optimum pH is about 7.

Procedure

Prior to the experiment, lead students in a discussion of enzymes and their importance to biological systems. Explain that they will be working with either liver or potato as a source of an enzyme called catalase. Tell students that they will be able to see that the enzyme is working by observing the oxygen bubbles that are generated. Explain denaturing and ask students to predict what can cause this to happen. Divide the class into pairs to perform the experiment. Students should read the student sheet before proceeding with the lab. The student instructions for Part 1 and Part 2 are included below for your reference.

Prior to completing Part 1, be sure to have four water baths pre-prepared for your students. Inform them that they may mix the temperatures of the water baths to come up with their own temperatures, or they can use the pre-prepared water baths. Prior to completing Part 2, be sure to have the necessary supplies (ammonia, lemon juice, pH paper) ready for your students to use.

Part 1 – Effect of Temperature on Catalase Activity (Student Instructions)

1. Plan your investigation. Decide which source of catalase, either liver or potato, you will use for your investigation. Then choose four temperatures at which you will test the catalase. Water baths are available at temperatures of 20°C, 37°C, 45°C, and 100°C, but you can mix the water to obtain water temperatures between these if you wish. You will need to place test tubes into water at each of these temperatures to heat or cool the contents of the test tubes. Decide how you will do this and how you will keep the water at the temperatures you choose during the investigation.
2. Read through the remaining procedures to be sure you understand the investigation. Then make a data table to record your observations.
3. Label eight test tubes from 1 to 8 and place them in a test tube rack.
4. Add 3 mL of distilled water to test tubes 1 through 4. Since catalase does not act as a catalyst for water, these will be your controls at different temperatures.
5. Add 3 mL of hydrogen peroxide to test tubes 5 through 8. The hydrogen peroxide is the substrate. When it binds with the enzyme, it will decompose to produce the oxygen bubbles you will observe.
6. Prepare the four water baths for the four temperatures at which you will test the enzyme.
7. Place test tubes 1 and 5 in the water at the lowest temperature you are testing. Place test tubes 2 and 6 in the water at one of the mid-range temperatures you are testing. Place test tubes 3 and 7 in the water at the other mid-range temperature you are testing. Place test tubes 4 and 8 in the water at the highest temperature you are testing.
8. After the test tubes have been in the water for a few minutes, use a plastic spoon to add a piece of liver or potato into each of the test tubes. Use a straw to push the liver or potato down into the liquid.
9. For the next few minutes, observe the contents of each of the test tubes. Record your observations.
10. Clean your work station and dispose of the materials according to your teacher's instructions. Empty and dry the beakers to use for the next part of the investigation.

Sample Data Table Part 1: Effect of Temperature on Catalase Activity

Test Tube	Contents of Test Tube	Temperature	Observation
1	Distilled water, liver	20°C	No bubbles
2	Distilled water, liver	37°C	No bubbles
3	Distilled water, liver	45°C	No bubbles
4	Distilled water, liver	100°C	No bubbles
5	Hydrogen peroxide, liver	20°C	Small number of bubbles
6	Hydrogen peroxide, liver	37°C	Many bubbles
7	Hydrogen peroxide, liver	45°C	Some bubbles
8	Hydrogen peroxide, liver	100°C	Very few bubbles

Part 1: Analysis and Conclusions

To help students analyze and interpret their results, consider discussing some or all of the following questions after they finish Part 1 or assigning them as homework:

1. What did you observe in the three control test tubes? Why do you think you observed this? *Sample answer: No bubbles formed in the control test tubes. These test tubes contained only distilled water and liver at various temperatures. Catalase does not act as a catalyst for any reaction involving the distilled water.*
2. What reaction were you looking for in your investigation? How did you know whether catalase was catalyzing this reaction? *Sample answer: The reaction was the decomposition of hydrogen peroxide into water and oxygen gas. The formation of oxygen bubbles showed that the catalase was catalyzing the reaction.*
3. Describe what your observations showed about the action of catalase at different temperatures. What was the optimum temperature of those you tested? *Sample answer: The catalase only seemed to be acting at temperatures of 20°C, 37°C, and 45°C because we only saw more than a few bubbles at these temperatures. At 100°C, the very few bubbles that formed likely were due to the slow, uncatalyzed decomposition of the hydrogen peroxide. The optimum temperature that we tested was 37°C.*
4. Explain why the catalase does not seem to work at some temperatures. *Sample answer: The catalase does not work well at low temperatures because the lower energy means fewer collisions between the catalase and the hydrogen peroxide molecules. The catalase does not work well at high temperatures because the shape of protein molecules is altered at high temperatures.*
5. Based on your results, what do you think would happen to the rate of catalase activity in a person who has a high temperature? *Sample answer: The catalase activity would decrease.*
6. Based on your results, infer why it was necessary to use raw, instead of cooked, liver and potato for this investigation. *Sample answer: Cooking would produce temperatures high enough to denature the catalase.*

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Part 2 – Effect of pH on Catalase Activity (Student Instructions)

1. Plan an investigation for testing the effect of pH on catalase activity. As in Part 1, decide which source of catalase, either liver or potato, you will use for your investigation. It can be the same source that you used in Part 1, or it can be different. Then choose three pH values at which you will test the catalase. At least one of your pH values should be acidic, and at least one should be basic.
2. Read through the remaining procedures to be sure you understand what you will be doing in this part of the investigation. Then make a data table to record your observations.
3. Label three test tubes from 7 to 9 and place them in a test tube rack.
4. Add 2 mL of hydrogen peroxide to each of the test tubes.
5. Add lemon juice (pH 2) and ammonia (pH 11) to the three test tubes, either alone or together, about five drops at a time, until you have solutions with pH values that are approximately equal to the ones you have chosen. Try to have approximately the same volume of liquid in each test tube. Use pH paper or a pH probe to test each solution after gently swirling it. Record the final pH values.
6. Use a plastic spoon to add a piece of liver or potato to each test tube. Use a straw to push the liver or potato down into the liquid.
7. For the next few minutes, observe the contents of each of the test tubes and record your observations.
8. Clean your work station and dispose of the materials according to your teacher's instructions.

Sample Data Table Part 2: Effect of pH on Catalase Activity

Test Tube	Contents of Test Tube	pH	Observation
9	Hydrogen peroxide, lemon juice, ammonia, liver	3	Very few bubbles
10	Hydrogen peroxide, lemon juice, ammonia, liver	8	Many bubbles
11	Hydrogen peroxide, ammonia, liver	10	Small number of bubbles

Part 2: Analysis and Conclusions

1. Describe what your observations showed about the action of catalase at different pH values. What was the optimum pH that you tested? *Sample answer: The catalase seemed to be working for pH 8 and pH 10 because bubbles were generated. The catalase did not seem to be working at pH 3 because very few bubbles were generated at this pH. The bubbles that formed at this pH likely were due to the slow, uncatalyzed decomposition of the hydrogen peroxide. The optimum pH in this investigation was 8.*
2. Explain why the catalase does not seem to work at some pH values. *Sample answer: The catalase does not work well at very low or very high pH values because the acidity or basicity alters the shape of the catalase, disabling its ability to function as a catalyst.*
3. If you could perform another investigation about factors that affect the activity of catalase, what factors would you test? *Sample answer: Other pH or temperature values; amount of liver used; other sources of starch, such as pieces of fruit or other vegetables; concentration of the hydrogen peroxide; salinity levels of solutions.*

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Design and conduct investigations using:
    - Fair test – changing only one variable at a time makes comparisons valid
    - Dependent variables – what changes as a result of, or in response to, the change in the independent variable
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing
  - Practice lab safety by:
    - Following lab safety procedures

- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Answering the testable question
    - Using data to determine the cause–effect relationship observed in the investigation
    - Extrapolating results beyond the investigation
- Patterns and Systems
  - Systems
    - A system, such as the human body, is composed of subsystems

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Activity Sheet

Name _____

Date _____

The Chemistry of Life

Work with a partner. Read the explore section of "The Chemistry of Life." Use the table below to take notes about information in the text. Use your notes to help you understand "The Chemistry of Life."

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish? _____

Word or Idea	Meaning	Picture or Example
carbon		
molecule		
organic		
inorganic		

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Hands-On Lab

Forming Carbohydrates

Timing: one 30-minute class session

Objective(s):
Students will investigate how carbon, hydrogen, and oxygen form carbohydrates (sugars) and explain the role these elements play in the formation of amino acids. Students will also describe changes in matter and energy.

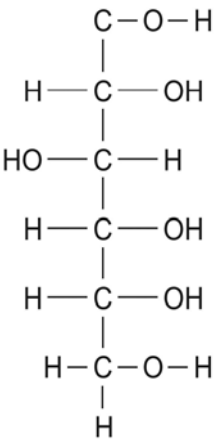
Safety Precautions:
Remind students to follow all general lab safety rules, and not to eat or drink anything in the lab. Specifically, instruct students not to eat the gumdrops being used in this activity. All materials should be thrown away when the activity is finished.

Materials:
Per pair or small group:

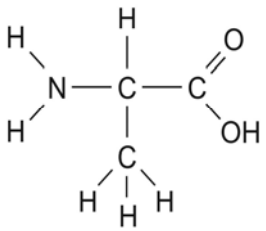
- gumdrops, green (6) (representing carbon or oxygen)
- gumdrops, red (6) (representing oxygen or carbon)
- gumdrops, yellow (12) (representing hydrogen)
- gumdrops, blue (2) (representing nitrogen)
- toothpicks, wooden (15-20)
- plate, disposable

Teacher Preparation:

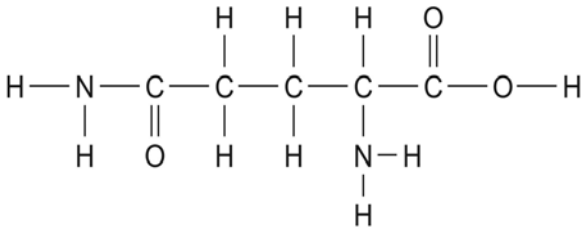
- Gather materials in advance of students performing the lab.
- Draw and label the simplified structures of glucose, alanine, and glutamine on the board or on an overhead projector. Identify glucose as a sugar and alanine and glutamine as amino acids. Alternatively, you can copy the image and hand them out to students.
-



glucose



alanine



glutamine

- Place each pair's or group's gumdrops and toothpicks on a disposable plate.

Procedure:

1. Provide students with their set of gumdrops and toothpicks. Explain that they will be using these materials along with structural diagram to build a simplified model of the carbohydrate glucose, with each color of gumdrop representing a different element.
2. After students have completed the glucose models, direct students' attention to the alanine and glutamine structures. Students should then build models of these amino acids using only the remaining materials on their plate or in their glucose models.

Analysis and Conclusions

1. What element did the green gumdrops represent? What elements did each of the other gumdrops represent?
   Green gumdrops represented either carbon or oxygen (this answer may vary, but one of these two elements should be named). Yellow gumdrops represented hydrogen, blue gumdrops represented nitrogen, and red gumdrops represented either oxygen or carbon (this answer may vary, but students should name whichever element is not already accounted for).

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2. What did you observe after modeling glucose?
None of the blue gumdrops were used.

3. What did you observe when modeling the amino acids?
It was necessary to rearrange the gumdrops in the glucose model to create the model of glutamine. Blue gumdrops, which were not used in the sugar model, were used in the amino acid models. In addition, the plate did not contain enough materials to model both of the amino acids at the same time.

4. Compare and contrast the three models you created.
All three molecules contained a "carbon backbone," hydrogen, and oxygen. The amino acids contained nitrogen, but the sugar did not. The molecules' shapes were different, and they contained different numbers of the variously colored gumdrops.

5. In this activity, you modeled the combination of a sugar with other elements to form amino acids. How were changes in matter represented in this model?
Changing the configuration of the gumdrops represented how matter changed.

6. How were changes in energy represented in this model?
Taking gumdrops off of toothpicks and rearranging their connections represented how energy (in the chemical bonds) changed.

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.
- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)
- Interpret Data
  - Identifies and interprets patterns
    - Trends in data
    - Repeating physical or data pattern
    - Graphed data points
    - Tables and graphs
    - Analyzes data collected during an investigation

- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause effect relationship observed in the investigation
    - reporting out trends and patterns in the data.
  - Assessing the conclusion by:
    - Answer the testable question
    - Extrapolating results beyond the investigation
  - Communication in Science
    - Peer presentation

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Hands-On Lab

Identifying Organic Nutrients

Timing: one 90-minute class session

Objective(s):
Students will use chemical indicators to test unknown substances for the presence of certain organic molecules (glucose, starches, proteins, and lipids). They will make predictions about known/control substances and compare their results from the unknown substances with those from their control substances.

Safety Precautions: Students should wear closed-toe shoes, gloves, a lab apron, and safety goggles. Remind students not to eat or drink anything in the lab, including the experiment materials. Students should report any broken glass or chemical spills immediately and should not try to clean these up by themselves. Familiarize yourself with the hazards posed by all the reagents used in this lesson by reading the appropriate MSDS sheets. Be sure to communicate any hazards to your students.

Materials:
Per group of 3–4 students:

- dropper bottle of of Benedict's solution
- dropper bottle of IKI (Iodine Potassium Iodine solution)
- dropper bottle of Biuret's reagent
- dropper bottle of Sudan IV
- ethanol
- eye dropper
- test tubes, approximately 24
- test tube racks, 4
- hot water bath
- distilled water
- 25 mL graduate cylinder
- marker for labeling test tubes
- stopwatch or timer
- four unknown nutrient samples, one of each: glucose (labeled A), starch (labeled B), protein (labeled C), lipid (labeled D)
- clearly labeled positive and negative nutrient samples, one of each liquefied nutrient samples containing: glucose, starch, lipid, and protein
- disposable gloves, one pair per student
- lab apron, one per student
- safety goggles, one pair per student

Teacher Preparation:
Once the nutrient indicator chemicals are obtained, materials can be prepared in a day prior to the lab. Make sure to obtain positive and negative control samples for each test. These controls can overlap. For instance, the lipid control can serve as a positive control for the lipid test and a negative control for the protein, starch, and sugar tests. Also make sure to obtain known and unknown samples that are as pure as possible. You may choose food samples from home (such as flour, pasta, oil, corn syrup, and meat; just make sure they've been sufficiently mashed or liquefied. Alternatively, you might choose to use laboratory-grade chemicals such as glucose, cellulose, laboratory grade amino acids, etc.) Prepare a copy of the student investigation sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>
Engage students in a discussion about the different nutrient macromolecules (make sure to mention that the class of macromolecules that will not be addressed in this lab are the nucleic acids). Students should be able to name and classify the major organic nutrients according to their basic chemical composition and characteristics, as well as their functional roles in living cells. Review this material by providing students with specific characteristics and/or functions of the different macromolecules and asking students to identify and hold up for display the corresponding macromolecule on an individual white board or sticky note. It may be helpful to also have the information on the board so that students are able to use it as a reference throughout the lab. Remind students about the difference between organic and inorganic molecules.

In this lab, students will work in groups of three or four to test unknown nutrient samples for the presence of simple sugars (monosaccharides; some disaccharides), starches, lipids, or proteins. For each test, students should make a prediction about what colors they will observe after testing their

positive and negative control food samples. They will compare the results of their test samples with the positive and negative control nutrient samples. Make sure that students use a marker to label *every* test tube that they use, denoting the contents of the tube. Hand out or copy onto the board the following table, noting that each test will take approximately three to five minutes for colors to develop:

Indicator Results: Negative and Positive

Indicator	Nutrient Molecule	Negative Test	Positive Test
Benedict's Solution	Simple carbohydrate	Blue	Yellow/Green/ Red/Orange
IKI Solution	Complex carbohydrate	Dark Red	Purple/Blue/ Violet/Black
Biuret Solution	Protein	Blue	Pink/Purple/ Violet/Black
Sudan IV	Lipid	Dark Red	Red/Orange

Read the steps aloud for each test, using one lab group's materials to model each step.

Simple sugars test using Benedict's solution:

1. Label four test tubes A1, B1, C1, D1.
2. Add 5 mL of distilled water to the test tubes.
3. To each test tube, add 1 mL of a different unknown nutrient sample, making sure the test tube labels coordinate with the nutrient sample labels.

4. Add 20 drops of Benedict's solution to each test tube.
5. Label two more test tubes, one with “positive” and one with “negative.” Add 20 drops of Benedict's solution to each of the test tubes: one containing a positive and one containing a negative glucose control nutrient sample.
6. Place the test tubes in a hot water bath for 10 minutes.
7. Record the observations/results in a data chart.

Complex carbohydrate test using IKI (iodine potassium iodine) solution:

1. Label four test tubes A2, B2, C2, D2.
2. Add 5 mL of distilled water to the test tubes.
3. To each test tube, add 1 mL of a different unknown nutrient sample, making sure the test tube labels coordinate with the nutrient sample labels.
4. Add 20 drops of IKI solution to each test tube.
5. Label two more test tubes, one with “positive” and one with “negative.” Add 20 drops of IKI solution to each of the test tubes: one containing a positive and one containing a negative starch control nutrient sample.
6. Record the observations/results in a data chart.

Protein (amino acid) test using Biuret solution:

1. Label four test tubes A3, B3, C3, D3.
2. Add 5 mL of distilled water to the test tubes.
3. To each test tube, add 1 mL of a different unknown nutrient sample, making sure the test tube labels coordinate with the nutrient sample labels.
4. Add 20 drops of Biuret solution to each test tube.
5. Label two more test tubes, one with “positive” and one with “negative”. Add 20 drops of Biuret solution to each of the test tubes: one containing a positive and one containing a negative protein control nutrient sample.
6. Record the observations/results in a data chart.

Lipid test using Sudan IV solution:

1. Label four test tubes A4, B4, C4, D4.
2. Add 5 mL of distilled water to the test tubes.
3. To each test tube, add 1 mL of a different unknown nutrient sample, making sure the test tube labels coordinate with the nutrient sample labels.
4. Add 20 drops of Sudan IV solution to each test tube.
5. Label two more test tubes, one with “positive” and one with “negative”. Add 20 drops of Sudan IV solution to each of the test tubes: one containing a positive and one containing a negative lipid control nutrient sample.
6. Record the observations/results in a data chart.

*Note: students may need to add a few drops of ethanol to their water + nutrient sample solutions if the Sudan IV test did not work. The same number of drops should be added to each test tube.

Allow lab group to review their results and determine the identities of the four unknown nutrient samples. Have a student from each group record their results on the board. For example, they might write, “Nutrient A was a protein, Nutrient B was a carbohydrate, etc.”

Reveal the identities of the four unknown nutrient samples. Students will analyze any discrepancies in results as they answer the Conclusion/Analysis questions.

Guided Inquiry

For a guided inquiry, explain to students that they will be investigating the contents of different unknown solutions that contain nutrient molecules, either simple sugars, complex carbohydrates, proteins, or lipids. They may design their experiments based on their knowledge of the procedures and materials used in this lab. Depending on available time and resources, you may wish to provide students with a chart of indicator results like the one from the Directed Inquiry, or you may instruct students to research the use and results of the indicators. Provide students with some guiding questions to help them focus their inquiry:

1. What are the four main types of organic nutrient macromolecules?
2. What chemical indicator is used to determine the presence of each of the following molecules: simple sugars, starches, proteins, and lipids?
3. What, specifically, does each indicator react with?
4. What color results do you predict each indicator to yield from each of the positive and negative control tests?
5. What will be your independent variable, dependent variable, constants, and control for each test?

Have students work in their lab groups to develop a procedure and method for recording data. Students should seek your approval prior to starting on the experiments. Help them test their questions and predictions by making sure they use a logical progression of experiments. For instance, make sure that they make use of the negative and positive control samples whenever using an indicator solution to test an unknown sample.

Analysis and Conclusions:

In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. How did your predictions for each of the known positive and negative control samples compare with the test results from those samples? *Answers will vary.*

2. Why was it important to have both a positive and negative control sample? *It was important to use both positive and negative controls so that one can be confident that the indicator does successfully indicate the presence of the desired molecule and does not accidently indicate the presence of the desired molecule when it is not actually present. This avoids both false positive and false negative results.*

3. What sources of error might have been present in your lab group's experiments or your classmate's experiments? *The food solutions that were used may not have been concentrated or pure enough or sufficiently broken down and liquefied.*

4. If you were given a sample of an unknown food, how would you go about analyzing it to determine what it is composed of? *Sample answer: I would make several test solutions using the food and test each with one of the reagents used in this experiment. In that way, I could determine what the food does and does not contain.*

5. What results would you expect to get if you tested whole milk, and why? *Sample answer: Whole milk contains lipids, protein, and sugar, so I would expect positive result when I tested it with the appropriate reagents.*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop a question that:
    - Asks a question about a specific science concept or process
  - Recognize and develop testable questions that
    - Require the changing of one variable at a time
    - Can be answered with a science investigation or observational study.
  - Develop predictions/hypotheses that:
    - State what may happen in an investigation based on prior knowledge or experience (prediction)
- Design Investigations
  - Practice Lab Safety By:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
    - Incorporating laboratory safety practices into the investigation design
  - Design and conduct investigations using:
    - Fair test - changing only one variable at a time makes comparisons valid
    - Independent variable - the one variable the investigator chooses to change
    - Dependent variables - what changes as a result of, or in response to, the change in the independent variable
    - Control (control group) - used for comparison in which the independent variable is not changed
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Volume
    - Temperature
  - Chooses appropriate tools to conduct an investigation
    - Glassware
    - Pipette
    - Test tube
    - Hot plate
    - Other laboratory equipment
  - Uses senses to observe
    - Seeing (color)
  - Uses the appropriate format to record data
    - Writing (journal, worksheet, electronic text)
- Interpret Data
  - Sorts and classifies using scientific reasoning
    - Objects, substances and organisms by characteristic

        - Apply a classification scheme to objects, substances or organisms
    - Identifies and interprets patterns
        - Repeating physical or data pattern
        - Based on an analysis of data collected during an investigation
- Evaluate Evidence
    - Drawing and supporting a conclusion by
        - Comparing results to hypothesis
        - Answer the testable question
- Communication in science:
    - Participating in critiquing/peer review by:
        - Evaluating data for accuracy
- Patterns and Systems
    - Systems
        - Physical and biological systems tend to change until they reach equilibrium and remain that way unless their surroundings change.
        - A system usually has some properties that are different from those of its parts but appear because of the interaction of those parts.
    - Patterns and Change
        - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.
        - Some small changes can be detected by taking measurements.
        - Some changes are very slow and some are very fast and that some of these changes may be hard to see and/or record.
        - Certain things change in some ways and stay the same in others, such as in their color, size, and weight.
- Scientific Investigation
    - Scientific Investigation:
        - Scientific investigation begins with a testable question
        - Scientific investigation results in things we know and things we don't know.
        - Hypotheses are valuable, even if they turn out not to be true, because they lead to further investigation.
        - Scientific investigations lead to the development of scientific explanations.
    - Scientific Data and Outcomes
        - It is important in science to keep honest, clear, and accurate records.
        - Arguments and conclusions are invalid if based on very small samples of data, biased samples, or samples for which there was no control sample.

Exploration Teacher Guide: Cell Structure and Function

Overview

Students will learn about the structure and function of various organelles found in prokaryotic, plant, and animal cells. They will explore these cells by adding organelles to the cytoplasm.

Student Learning Objectives

- Observe the differences in the structure of prokaryotic, plant and animal cells.
- Identify the specialized functions that these cells perform.
- Investigate the structure of various cellular organelles.
- Understand the individual role of each organelle in the cell.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

Students can use the *Prokaryotic Cell*, *Plant Cell*, and *Animal Cell* radio buttons to select the type of cell they wish to build. A specialized function for the selected cell must then be selected from the options provided in the dropdown list. Students can add any organelle to the selected cell by clicking on the button provided for it. Clicking on the organelle button again will remove it from the cell. The *Check* button remains inactive until a function and at least one organelle are selected for the cell. On clicking the *Check* button, the student is provided with feedback for the cell structure created. If the structure and/or function are incorrect, the student can make changes to the selections made previously. If the cell structure and function have been correctly identified, the student can click on the *View Cell* button, which opens a popup with an image of a completely filled cell. The *Reset* button can be used at any point in the Exploration to repeat the procedure of building a cell.

Students can use the *Tracker* tab to view and compare the functions of all the organelles added to the cells. Clicking on the *Image* button for the respective organelles opens a popup with the image of the selected organelle.

Answers to the Questions in the Student Worksheet

1. Differentiate between a plant cell and an animal cell.

   Answer: The plant cell is characterized by a cell wall which is absent in animal cells. Plant cells also have chloroplasts since they are capable of synthesizing their own food. These chloroplasts are absent in animal cells. Plant cells usually have one, large vacuole which occupies 90% of the cell, whereas animal cells have multiple smaller vacuoles. In addition, plant cells are usually rectangular in shape, while animal cells are more or less irregular.

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2. Describe the structure and function of the nucleus.

   Answer: The nucleus, which is known as the control center of the cell, is the most important cellular organelle. It is spherical in shape and contains all the genetic material of the cell comprising the DNA and chromosomes.

3. Explain how prokaryotic cells are different from eukaryotic cells.

   Answer: The major difference between prokaryotic and eukaryotic cells is that eukaryotic cells have a nucleus and prokaryotic cells do not. Moreover, prokaryotic cells reproduce through binary fission, whereas eukaryotic cells divide through mitosis and meiosis.

4. Explain the role of cellular organelles in protein synthesis.

   Answer: The process of protein synthesis consists of two main steps, transcription and translation. Transcription is carried out by the DNA which is a part of the chromosomes in the nucleus of the cell. Ribosomes are the site of translation and are present in the cellular cytoplasm.

5. Describe the role of cytoplasm in the cell.

   Answer: Cytoplasm is the jellylike substance of the cell in which all the organelles are embedded. Most of the cellular activities occur within the cytoplasm. These include glycolysis and cell division.

6. Give an example of functional differences between cells belonging to two different parts of the human body.

   Answer: Cells belonging to the female reproductive tract are ciliated to aid the movement of the female gamete through the fallopian tubes. On the other hand, muscular cells are made of contractile filaments that can bring about an increase or decrease in cell size.

7. Endoplasmic reticulum is of two types. Name these two types and state the differences between them.

   Answer: Eukaryotic cells contain smooth endoplasmic reticulum and rough endoplasmic reticulum. Smooth endoplasmic reticulum does not contain ribosomes. Its main function is the manufacture of lipids that help in maintenance of the cell membrane. Rough endoplasmic reticulum is studded with ribosomes which aid in protein synthesis.

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8. Chloroplasts are present only in plant cells. Describe the structure and function of these specialized organelles.

   Answer: Chloroplasts appear like flat discs under the microscope. These chloroplasts are filled with a fluid called stroma, which is the site of the Calvin Cycle. Suspended in the stroma are disc shaped structures called thylakoids, containing empty spaces called thylakoid spaces. The boundary of these thylakoid spaces is known as the thylakoid membrane, which is the site of the light-dependent reactions of photosynthesis.

9. Explain why mitochondria are called power houses of the cell.

   Answer: Mitochondria are the sites of cellular respiration. ATP is produced in the mitochondria which is the major source of source of energy. This is the reason they are referred to as power houses of the cell.

10. Mesosomes are no longer considered a part of the cell. Give reasons for this exclusion.

    Answer: Mesosomes were earlier thought to be folded invaginations in the plasma membrane of bacteria. However, it was later concluded that these were only artifacts and were not associated with any particular cellular function.

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Hands-On Lab

Classifying Prokaryotic and Eukaryotic Cells

Timing: one 90-minute class session

Objective(s):
In this activity, students will prepare slides of Elodea and bacteria and observe them under a microscope. They will then use their knowledge of cell structures to compare and classify cells as prokaryotic or eukaryotic.

Safety Precautions:
Remind students to wear a lab apron, gloves, goggles, and closed-toe shoes. Students should wear heat-resistant gloves when heat fixing the slide and rubber gloves at all other times. Remind students not to eat or drink anything in the lab (including the experimental materials). Tell students to report any broken glass and not to try and clean it up by themselves. Remind students to be extremely cautious when working with the Bunsen burner. Instruct students to keep hair and sleeves away from the Bunsen burner flame. Remind students where the fire extinguishers are and how to use them.

Materials:
Per pair or group:

- Bunsen burner
- clean slides, 2
- cover slip
- distilled water, about 10 mL
- Elodea leaf
- forceps
- heat-resistant gloves
- light microscope
- matches, 2
- methylene blue, about 2 mL
- pipette
- plain yogurt with active cultures
- toothpick
- heat-resistant rubber gloves, one pair per student
- safety goggles, one pair per student
- lab apron, one per student

Teacher Preparation:
Make sure all microscope slides are clean, and check that all microscopes are functioning properly. Obtain images of lactobacillus bulgaricus, lactococcus thermophilus, and/or other bacteria commonly found in yogurt. These may be found in scientific books, journals, or on the Internet. Prepare copies of the Student Investigation Sheet.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry
Tell students that they will observe two different cellular samples, and they will classify the cells from each sample as prokaryotic or eukaryotic. Have students work in pairs or small groups to come up with the criteria they will use to classify the samples.

Review with students how to prepare a wet mount slide with an Elodea sample.
1. Add a drop of water on the center of a clean microscope slide.
2. Use forceps to break off a leaf from the tip of the Elodea plant and place it in the drop of water on the slide.
3. Add a cover slip on top of the sample.

Demonstrate for students how to prepare a bacterial smear.
1. Get a clean microscope slide. Place one drop of water on the center of the slide.
2. Using a toothpick, transfer a dab of yogurt to the drop of water on the slide. Gently spread the cells around in a circle about the size of a dime. Allow the slide to air dry.
3. Put on heat-resistant gloves. Hold the slide with forceps and pass it over a Bunsen burner flame about three times to heat fix the sample.
4. Add 1–2 drops of methylene blue to the smear. Let it sit for about 2 minutes. Then rinse off the excess stain with a weak stream of water. Allow the slide to air dry.

Have students prepare their own slides for each sample, following the steps from the demonstration. Then instruct students to observe both the Elodea and the bacterial samples with a microscope under low, medium, and high power. Students should sketch their observations for each level of magnification. Ask students to identify and label visible subcellular structures in their sketches.

After students have observed both samples, show them images of lactobacillus bulgaricus, lactococcus thermophilus and/or other bacteria commonly found in yogurt. Explain that these bacteria can only been

seen in detail with very powerful microscopes. Allow students to examine the images and identify cell parts such as the capsule and cytoplasm.

Finally, have students classify each sample as prokaryotic or eukaryotic based on the images and based on their own observations. Have students compare their findings with the information from the **Core Interactive Text**. Then ask students to discuss their observations with other groups, evaluating each other's conclusions.

Guided Inquiry

Students can develop their own protocols for classifying the samples based on their knowledge of cell types and microscope use. Ask the students some guiding questions to help them focus their inquiry:

- How will you prepare and observe the cellular samples?
- What do you expect to observe?
- What characteristics will you use to classify each sample?
- What will you do if one of the samples is not clear enough to classify?

Have students present their protocols to you for approval before proceeding with the investigation. Make sure students accurately describe the steps necessary to prepare microscope slides. If students have never before prepared a bacterial smear, demonstrate for the class how to do so following the steps from Directed Inquiry. In addition to the bacterial cells, you may provide a variety of other samples to observe and classify. For example, allow students to choose from onion skin, Elodea, and potato cells.

Students will discover that the microscopes in this investigation do not provide a very detailed view of the bacterial cells. Have students identify reliable resources that provide supplementary images of the bacterial cells found in yogurt. For example, students may consult government or academic websites for SEM or TEM images of the bacteria.

Finally, have students classify each sample as prokaryotic or eukaryotic based on the images and based on their own observations. Have students compare their findings with the information from the **Core Interactive Text**. Then ask students to discuss their observations with other groups, evaluating each other's conclusions.

Analysis and Conclusions

In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. Compare and contrast the samples of *Elodea* and yogurt cells. What were some differences between the samples? What were some similarities?

Students refer to the size of the cells (both are small, requiring the use of the microscope however the yogurt bacterial cells are much smaller than those of Elodea). Both appear to have a fixed shape. Because of their small size it is usually impossible to observe any internal structure of bacterial cell

using a light microscope. The bacterial cells are usually separate (unicellular) and appear to be colorless. The larger Elodea cells have easily observable structures including cell walls and green chloroplasts. They are joined to other cells (in a multicellular organism).

2. Which of the samples was prokaryotic? Which was eukaryotic? What specialized parts of prokaryotic and eukaryotic cells did you use to classify each sample? *The Elodea cells have internal structures (nucleus, chloroplasts and vacuoles) that are quite separate (bounded by membranes). No structures are observed in the bacterial cells. The Elodea is therefore eukaryotic. The bacterial cells are prokaryotic*

3. What was the purpose of the methylene blue?
It helped make the bacterial cells more visible.

4. What would you expect to see if you observed a human cheek cell under the microscope? Why? *I would expect to see a nucleus because animal cells are eukaryotic, and eukaryotic cells have nuclei. If the magnification were strong enough, I would also expect to see membrane-bound organelles because eukaryotic cells have organelles.*

5. Given the difference in sizes between prokaryotic and eukaryotic cells, how does your selection of equipment affect your ability to compare and contrast their structure?
Students should mention that they need a very powerful microscope to observe any internal cell structure in prokaryotes. The use of a light microscope severely impairs their ability to see inside the prokaryotic cell and reduced their ability to comprehensively compare and contrast the two types of cells. Access to an electron micrograph of both cells would provide an additional, useful source for comparison.

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
- Gather Data
  - Choose appropriate tools to conduct an investigation:
    - Bunsen burner
    - Microscope
    - Slides and cover slips
    - Pipette
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
  - Use the appropriate format to record data:
    - Sketch
- Interpret Data
  - Sort and classify using scientific reasoning by:
    - Sorting objects, substances and organisms by characteristic
    - Developing a classification scheme for objects, substances or organisms
- Communication in Science
  - Report results using:
    - Peer presentation
- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating data for accuracy
    - Evaluating a conclusion
- Patterns and Systems
  - Systems:
    - A system, such as the human body, is composed of subsystems.
- Scientific Endeavor
  - Characteristics of Science:
    - Scientific claims can be substantiated using data and observation.

Hands-On Lab

Creating and Evaluating Scientific Models of the Cell

Timing: two 90-minute class sessions

Objective(s):
Students will create a model of the cell and then evaluate their model to determine its limitations.

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should be careful using sharp objects such as scissors and other modeling equipment. Remind students to wear proper safety attire including lab coats or aprons, and gloves if necessary. Students should follow proper disposal and cleaning procedures after the lab.

Materials:
Per group:

- variety of modeling materials, such as:
  - modeling clay
  - extruded polystyrene foam
  - colored paper
  - colored pens
- glue
- box cutter and/or scissors
- notebook
- lab apron, one per student
- paper towels

Teacher Preparation:

- Gather materials in advance of students performing the lab.

Procedure

1. Have students research the structure and function of the cell, in particular reviewing images and processes that are of interest.
2. Instruct students to create a simple plan, including the goals of the model as well as proposed techniques.
3. Students may choose to build 3D models, but also encourage students to think of models that are not simple 3D representations, including more abstract models such as flowcharts and mathematical representations. Also encourage students to consider models of detailed cell structure such as organelles or the cell membrane as well as models of the whole cell.
4. When students have completed their models, encourage them to explore the benefits and limitations of their models. For example, you can guide students with questions such as:
    a. What does your model show that cannot be seen directly?
    b. Can your model be used to make predictions?
    c. How does your model help communicate the structure and function of the cell?
    d. Does your model omit details or processes that scientists know about?
    e. Is your model an exact representation of the cell or its processes?

Analysis and Conclusions

1. What new information did you learn about the cell by creating a model?

Answers may vary. Some examples of student answers may be: I learned the different organelles that exist within cells and what they look like. I learned the function of different organelles within a cell. I learned how various cell structures relate to their function. I learned the similarities and differences that exist between different types of cells. I learned the relative sizes and locations of various organelles within cells.

2. What predictions did you make about using your model to understand the cell's structure and function?

Answers may vary. Some examples of student answers may be: I predicted making the model would provide me a better understanding of different cellular organelles and their appearances. I predicted I would learn how the different organelles in cells function. I predicted I would learn how various cell structures relate to their functions. I predicted studying my model would help me understand similarities and differences between different types of cells.

3. How does creating a model of the cell, rather than reading about it or looking at pictures about it, provide you with a better idea about its structure and function?

It is more engaging process that helps you better visualize and understand the cell and its organelles. When you just read about cells and organelles or just see pictures, you may forget about them more easily than if you take the time needed to incorporate all the details you do when making an actual model of the cell and all its components. Learning kinesthetically helps to better retain what you have learned. By building a model, it helps me understand how the how all of the parts of the cell work and interact with each other.

4. Models are always an imperfect representation of reality. Think about the model you created. What aspects of the cell could your model not show? Evaluate the limitations of your model, and how they could be overcome with an improved model or different approach.

Answers may vary. Some examples of student answers may be: The movement of organelles or materials within a cell could not be shown with the model I created. This could be overcome by creating multiple models to illustrate different stages of materials moving within cells or different movements by organelles. A computer model could also be used to help show these cellular movements. My model may not be to scale and may provide an inaccurate visual representation of different parts of the cell. Using rulers and doing various calculations could help ensure my model is more accurate in terms of scale. My model does not show how different cellular structures allow cells to interact with and communicate with each other. Making multiple models would help show how cells interact with and communicate with each other. A computer model could also be used to help show how cells interact with and communicate with each other.

Inquiry skills

In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

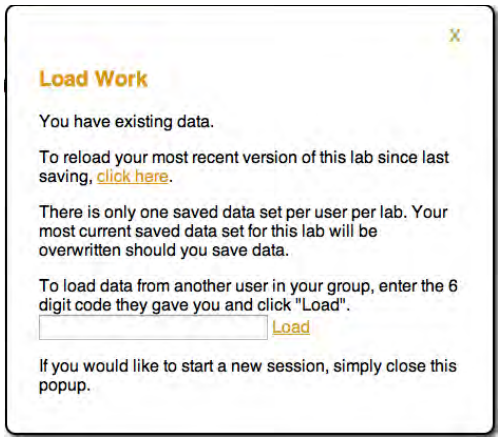
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

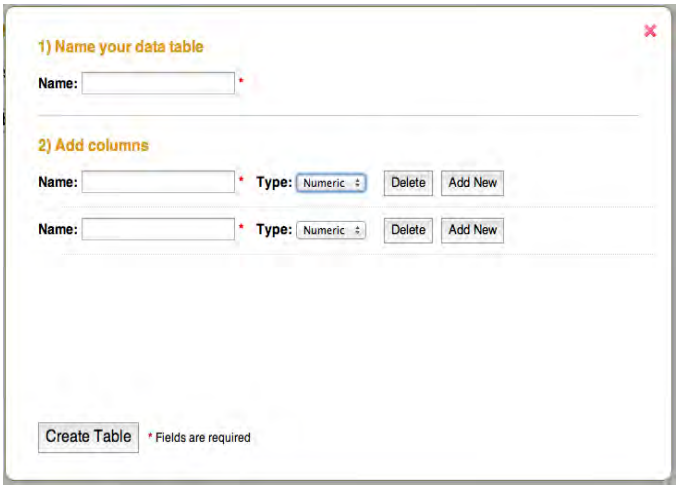
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



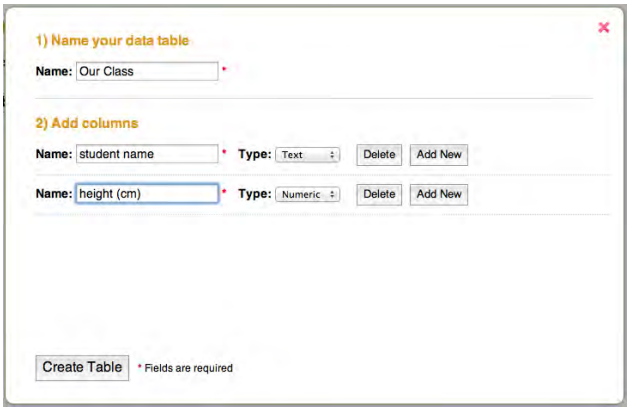
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

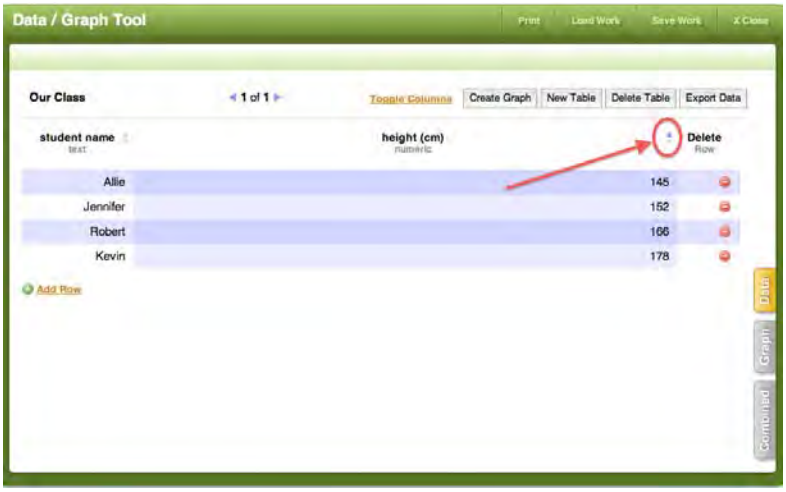
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

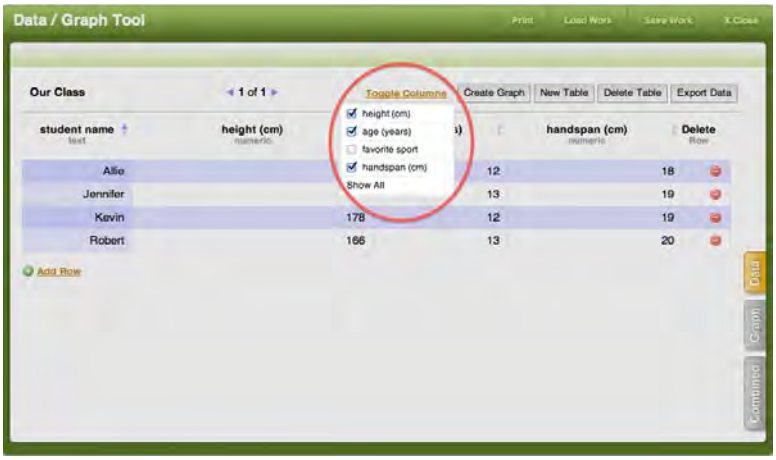


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

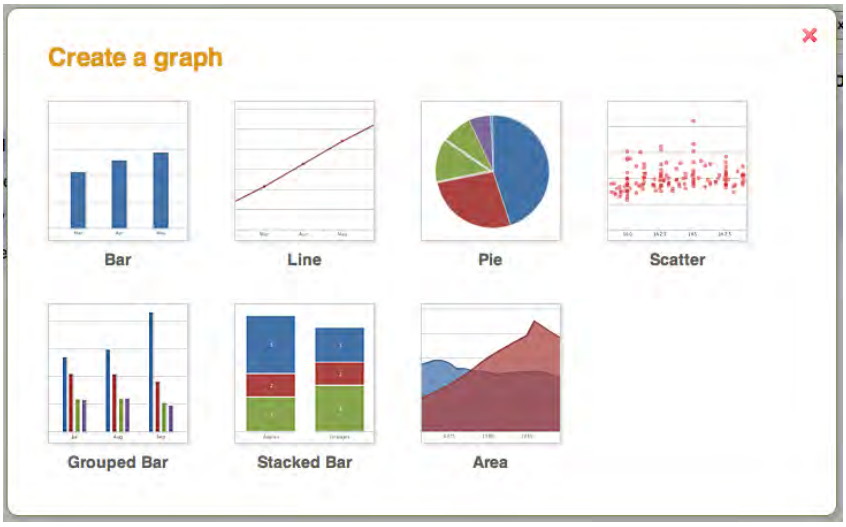
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

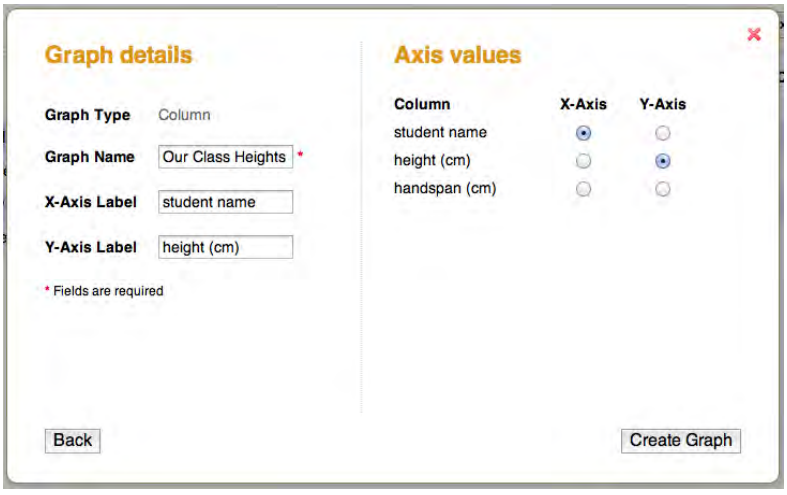
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

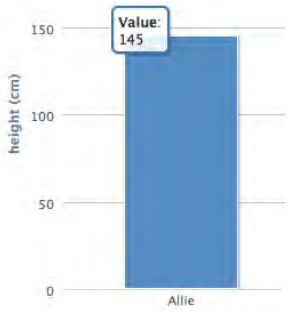


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

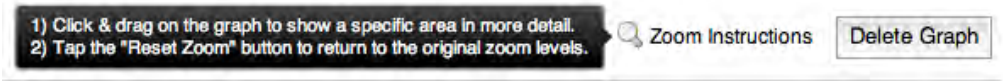
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Examining Cells and Tissues

Timing: one 90-minute class session

Objective(s)
In this activity, students will examine, draw, and label a variety of plant and animal tissues and the types of cells from which they are composed.

Safety Precautions
Remind students:

- To wear safety goggles.
- Not to eat or drink anything in the lab.
- To report any broken glass. They should not try to clean it up themselves.

Materials
For the class:

- Microprojector or microscope compatible video camera
- Document camera

Per individual or pair:

- Microscope with magnification up to 300x
- Prepared slides of plant and animal tissues
- Plain paper for drawing
- Labeled micrographs or books containing labeled micrographs (to help students with labeling)

Teacher Preparation

1. Obtain enough slides so each pair has two or three different tissues on hand. Excellent prepared, stained, and dry slides can be obtained from reputable suppliers. Alternatively, if these are not available, prepare slides for the students in advance.
2. If available, have a microprojector on hand to show students examples of tissues and cells.
3. Have selected drawings of tissues and cells to provide students with examples of the types of drawings they should produce.

Procedure
You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

1. Explain to the students that they will be examining a number of different plant and animal tissues, and that they are expected to make labeled drawings of each. Show students the examples of the types of drawings that they are expected to produce. Emphasize the importance of using label lines.
2. Review and demonstrate the correct use of the microscope.
3. Provide each individual or pair with a slide.
4. Students should observe and draw part of the tissue sample and label individual cells.
5. Walk around the lab, providing hints and tips on microscope use and drawing and labeling techniques.
6. Insist that each individual or pair draws at least two tissues; at least one animal and one plant should be included.
7. Spend ten minutes towards the end of the lesson reviewing student drawings. Project some onto a screen using a document camera. Use this as an opportunity to discuss differences in cell structure and how this relates to the functions of the tissues in which they are found.

Guided Inquiry

1. Explain that the objective of the lesson is to create a class library of pictures of different types of cells and tissues.
2. Have students collect and set up the microscopes, and select a slide of a type of tissue they wish to illustrate
3. Discuss protocols for illustration and labeling.
4. After about thirty minutes, have students exhibit their drawings.
5. Have students look at the exhibited drawings.
6. Facilitate a discussion of the differences between cells in different tissues and how their structures relate to their functions.

Analysis and Conclusions

In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework:

1. From your observations, list any fundamental differences between plant and animal cells. *Observation of commercially prepared slides usually shows one fundamental difference, the presence of cell walls in plant cells. Slides prepared by the teacher, if fresh, may show other differences, such as the presence of chloroplasts and large cell vacuoles in plant cells.*
2. What do you notice about cells that make up a particular tissue? *Cells making up a particular tissue are of similar structure.*
3. How were cells, in the tissue(s) you observed, adapted to meet the function of the tissue(s)? *Answers will depend upon the type of tissue observed. For example, xylem tissue in plants consists of long hollow cells with thick cell walls. This enables them to conduct water much like pipes. The thick cell walls cope with pressure changes and make them less permeable to water. The end walls of the cells are perforated to allow the flow of water.*

4. Revisit the pictures of cells that you have drawn. What components (such as cell walls, vacuoles etc.) can you observe. Ensure you have labeled these components. For each cell component identify the primary organic or inorganic compound that makes it up. Complete the table listing the cell component and its primary organic or inorganic compound. *Some possible student answers are provided in the table.*

Cell Component	Primary compound that makes it up
cell wall	*cellulose*
nucleus	*nucleic acids*
plant vacuole	*water (contents)*
cell membrane	*phospholipids*

Inquiry and Nature of Science Skills in This Lab

- Identify Questions
  - Develop a question that:
    - Asks about a specific science concept or process
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
- Design Investigations
  - Design and conduct investigations using:
    - Fair test—changing only one variable at a time makes comparisons valid
    - Independent variable—the one variable the investigator chooses to change
    - Dependent variables—what changes as a result of, or in response to, the change in the independent variable
    - Control (control group)—used for comparison in which the independent variable is not changed
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Properly citing all equipment and materials
    - Describing it so that it can be easily repeated by a fellow scientist
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
- Gather Data
  - Choose appropriate tools to conduct an investigation:
    - Glassware
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Reporting trends and patterns in the data
    - Comparing results to hypothesis
- Communication in Science
  - Report results using:
    - Peer presentation
- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating an investigative design
    - Evaluating a conclusion
- Scientific Investigation
  - Scientific Data and Outcomes
    - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
    - It is important in science to keep honest, clear, and accurate records.

- Scientific Endeavor
    - Characteristics of Science
        - One way to make sense of something is to think of how it relates to something more familiar.

Student Investigation Sheet

DNA Extraction

Safety Precautions

- Wear gloves, goggles, and closed-toe shoes; do not eat or drink anything in the lab (including the experimental materials).
- Report any broken glass. Do not try to clean it up yourself.
- Be cautious when working around electrical outlets. If working with a blender or food processor, do not touch the blades.

Objective(s)

In this activity, you will use your understanding of the properties of cells and DNA to extract DNA from peas. You will then alter a step in the investigation protocol, predicting and testing how this change will affect your results.

Materials

Per pair or group:

- Blender, food processor, or large resealable plastic bag
- Frozen peas, 50 ml
- Isopropyl alcohol (90% or higher), 100 ml
- Plastic tub
- Ice, about 10 cm deep in the plastic tub
- Water, 50 ml
- beaker, 250 ml; or large clear plastic cup
- beaker, 50 ml; or graduated cylinder
- Cheesecloth
- Liquid dish detergent, 15 ml
- Salt, 1 tsp or less
- Glass stirring rod
- Goggles
- Rubber gloves

Key Question

What is the question you want to answer?	
	Directions: Write the question for the investigation. The question should be specific and investigable.
	Key Components • Question is specific (one general thought, does not combine two or more questions). • Question is able to be investigated.

Hypothesis

What do you predict will be the result of the investigation?	
	Directions: Develop a claim about what you think is going to happen.
	Key Components • Claim expresses a cause-and-effect relationship. • Claim is testable. • Claim incorporates prior knowledge.

Plan

How will you investigate the question?	
	Directions: Describe the plan that you will use to study your question and analyze your hypothesis.
	Key Components • Plan is easily repeatable by others. • Plan describes the use of materials. • Plan is in a logical order.

Data

What evidence was gathered during the investigation?	
	Directions: Record all of the evidence that has been collected. Use graphic organizers, tables, and graphs when appropriate.
	Key Components • Data (from an investigation and/or other sources, such as observations, reading material, archived date, etc.) • Appropriate (data applies directly to the question) • Sufficient (uses enough data to completely answer the question and determine a finding on the hypothesis)

Conclusion

What did you learn from this investigation?	
	Directions: Develop a conclusion for your investigation. The conclusion should contain clear thoughts and proper vocabulary. This section focuses on the answer to your question. It should prove or refute the hypothesis by using logical reasoning to link the hypothesis to the data.
	Key Components • Use precise and accurate language. • Use scientific vocabulary. • Provide clear logical thoughts. • Use evidence and reasoning to support or refute the hypothesis.

Analysis and Conclusions

1. What property of DNA did we manipulate in order to isolate it from cells and from solution?

2. Do you think that this procedure would have worked on some other fruit or vegetable? Would it have worked with meat? Why or why not?

3. Meat tenderizer contains proteases, which are enzymes that degrade proteins. What would have happened to our isolated DNA if we had added meat tenderizer to the solution?

4. Can you think of some reasons that a scientist might want to isolate DNA from a tissue sample?

Hands-On Activity

Modeling Plant and Animal Cells

Objective:

Students will work in small groups to construct models of plant and animal cells.

Estimated time to complete: 30 minutes

Materials:

For each small group of 4-6 students:

- clear tape
- modeling clay of various colors
- permanent marker
- plastic wrap, 3 feet
- ping pong balls, 2
- ribbon, 2 feet
- scissors
- small beads, 30
- small cardboard box
- toothpicks, 20
- white paper
- yarn, 2 feet

Procedure:

Divide students into small groups and distribute the necessary materials. Instruct each group to use their materials to create one model of an animal cell and one model of a plant cell. Each model should include the structures appropriate for that type of cell. For example, students may construct a plant cell by using the materials as follows:

- cell wall: small cardboard box
- cell membrane: plastic wrap
- cytoplasm: modeling clay
- nucleus: ping pong ball
- ribosomes: beads
- mitochondria: ovals of modeling clay
- endoplasmic reticulum: yarn
- chloroplasts: ovals of modeling clay
- Golgi apparatus: folded ribbon

Have students create labels by writing the names of the cell parts on strips of paper and taping the strips to toothpicks. Students can then insert the toothpick labels at the appropriate places on their models.

When students have finished constructing and labeling their models, have each group present their models to the class. Ask other students to determine whether or not the models correctly show the similarities and differences between plant and animal cells.

Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
- Gather Data
  - Choose appropriate tools to conduct an investigation:
    - Other Laboratory equipment
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
    - Touching (temperature, texture, shape, size, vibration, motion)
- Interpret Data
  - Sort and classify using scientific reasoning by:
    - Sorting objects, substances and organisms by characteristic
- Communication in Science
  - Report results using:
    - Peer presentation
- Patterns and Systems
  - Systems:
    - A system, such as the human body, is composed of subsystems.

Hands-On Lab

Cell Membranes and Diffusion

Timing: one 90-minute class session

Objective(s):
In this investigation, student will examine the cellular process of homeostasis. Students will observe the effects of a semi-permeable membrane to see how cells maintain homeostasis through passive transport (diffusion).

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should never leave the lab area unattended with chemicals sitting out. Remind students to wear safety equipment including goggles, gloves, and lab aprons. Students should follow all instructions for disposal and cleaning of the chemicals and their containers. Students should report any chemical spills or broken glass immediately and should not try to clean up any spills or glass by themselves.

Materials:
Per group:

- dialysis tubing or other semi-permeable membrane
- beaker, large
- water
- starch solution
- iodine
- safety goggles, one pair per student
- lab apron, one per student
- disposable gloves, one pair per student

Teacher Preparation:

- Gather materials in advance of students performing the lab.
- Prepare the starch solution before the class, 10 mL potato or corn starch per 100 mL water. The water will need to be boiling when the starch goes in, and boil for a minute.

Procedure:

The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to estimate the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Watching Cell Diffusion

Directed Inquiry

1. Have students put the starch solution into the semi-permeable membrane. Knots can be tied at either end to achieve a sealed container.
2. Explain to the students that this represents a cell.
3. Put some iodine in the beaker and fill it 2/3 full with water.
4. Explain that iodine is a starch indicator. If iodine comes in contact with starch it will turn black.
5. Have the students put their cell into the iodine. Make sure that the cells do not have any of the starch solution on the outside of them.
6. Ask the students what they think will happen.
7. Have them observe and record their results.

Guided Inquiry

Students can develop their own experimental design and plans for collecting data, based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry:

- How can you use the materials provided to study cell homeostasis and the cell membrane?
- What will you hope to learn about passive transport?
- What do you hope to learn about cell membranes?
- What is the hypothesis you hope to prove or disprove?

Students should create a hypothesis in the "If, then" format before starting the experiment. They need to make sure that the iodine and starch solutions do not come in contact with each other before the "cell" is immersed in the iodine solution. This means that the cell surface must be clean before it is put in the beaker.

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Analysis and Conclusions

1. What did you observe?
We observed that the starch solution went black over time, but the iodine solution stayed brown.

2. What did you learn about the semi-permeable membrane?
We learned that some molecules can go through the semi-permeable membrane, but others cannot.

3. What did you notice about the color of the starch solution? What did you notice about the color of the iodine solution?
The starch solution went black, indicating the iodine had reached the starch. The iodine solution stayed brown, indicting it had not changed.

4. Why did one solution change color? Why did the other remain unchanged?
The starch solution went black as the iodine had crossed the semi-permeable membrane and entered the cell. The iodine solution remained unchanged as the starch was not able to cross the semi-permeable membrane.

5. How would this result change if the iodine was in the cell and the starch solution was in the beaker?
If the iodine was in the cell, the starch solution would go black and the solution inside the cell would remain unchanged, as the iodine would go out through the semi-permeable membrane.

Further Questions

6. Can membranes allow some molecules to cross them and not others? How does this help you understand the role of the cell membrane in cellular homeostasis?
This experiment shows that the membrane allowed water, but not starch to pass through it. This means that the membrane is selectively permeable to substances and can regulate the flow of some (like starch) but allow in others (like water) to pass freely. If the cell membrane has similar properties it can control what enters and leaves the cell. This means that the membrane could play be involved in controlling the internal content of the cell. It could therefore play an important role in homeostasis.

7. How does this help you understand osmosis?
This experiment helps us understand osmosis because it shows how water molecules will move from one side of a membrane to another—from dilute to concentrated solution—to attain a concentration balance.

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In this lab, students will demonstrate the following Inquiry Skills:

- Communication in Science
    - Report results using:
        - Scientific explanations/arguments

- Interpret Data

- Identify Questions
    - Develop predictions/hypotheses that:
        - State the expected cause and effect (if-then statement) in an investigation based on prior knowledge and experience (hypothesis)
- Evaluate Evidence
    - Draw and support a conclusion by:
        - Comparing results to a hypothesis
        - Answer the testable question
        - Formulating scientific explanations/arguments

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Exploration Teacher Guide: Cell Transport

Overview

Students will learn about the various mechanisms of cell transport. They will use these mechanisms to transport ions and molecules across the cell membrane.

Student Learning Objectives

- Observe the structure of the cell membrane and how it divides the inner and outer regions of the cell.
- Investigate the process of passive transport of water molecules across the cell membrane.
- Identify the specialized mechanisms required to carry out active transport.
- Analyze the process of facilitated diffusion of glucose molecules across the cell membrane.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

Students can use the *Water*, *Na^+* and *K^+*, and *Glucose* radio buttons to select the molecule or ion they wish to transport across the cell membrane. To carry out passive transport of water molecules, students must drag them across the cell membrane from one side to another. They can observe the equilibrium meter to decide the concentration gradient.

Ion pumps and gated channels can be added using the *Add Pump* and *Add Channel* buttons. To supply energy to the system, students may use the *Release ATP* button. To transport Na^+ and K^+ ions across the cell membrane, students must first use the *Add Pump* button. After the pumps appear across the cell membrane, they can use the *Release ATP* button to continue with the active transport of Na^+ and K^+ ions. To transport glucose molecules across the cell membrane, students must first use the *Add Channel* button. After the channels appear across the cell membrane, they can drag the molecules through the channels. Dragging molecules through any other part of the cell membrane will not be possible.

Students can use the *Reset* button to undo changes made to the cell and restart the same run with the initial number of ions or molecules inside and outside the cell. They can use the *Start Over* button to generate a random number of ions or molecules inside and outside the cell.

Students can use the *Tracker* tab to view and compare the number of ions and molecules present inside and outside the cell, initially and at equilibrium.

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Answers to Questions in the Student Worksheet

1. Differentiate between active and passive transport.

   Answer: Active transport is the type of cellular transport that requires the expenditure of energy. This energy is provided in the form of ATP molecules. On the other hand, passive transport can take place through the process of diffusion across the concentration gradient.

2. Explain the process of facilitated diffusion. Give an example of an ion or molecule which is transported across the cell membrane through this process.

   Answer: Facilitated diffusion in the intercellular passage of ions or molecules due to transmembrane proteins. Gated channels are used by cell membranes to carry out facilitated diffusion. Glucose molecules are transported across the cell membrane using this method.

3. Describe the structure of the cell membrane and its primary function.

   Answer: The cell membrane is made up of a phospholipid bilayer. This bilayer consists of hydrophilic heads and hydrophobic tails of the lipids. The arrangement of this layer is such that the two layers of tails are facing each other and the heads are in contact with the intracellular and extracellular environments. The primary function of the cell membrane is to control cellular transport.

4. Explain the difference between intracellular and extracellular transport.

   Answer: Intracellular transport occurs within the cytoplasmic fluid due to the transfer of nutrients through the network of tubular structures. On the other hand, extracellular transport is carried out across the cell membrane, with the passage of ions and molecules through the phospholipid bilayer.

5. Explain the difference between phagocytosis and pinocytosis.

   Answer: Phagocytosis and pinocytosis are both types of endocytosis, which means that they are mechanisms used by cells to engulf particles. The only difference between the two is that phagocytosis is the ingestion of solid particles, whereas pinocytosis is that of liquids.

6. Give an example of a nutrient that is transported actively in the human body.

   Answer: Metal ions like Na^+, K^+, Mg^{2+}, and Ca^{2+} are nutrients that are transported actively in the human body.

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7. Explain the difference between ion pumps and gated channels.

   Answer: Ion pumps are used by cells to actively transport ions across the cell membrane. Gated channels are a means of facilitated diffusion which are adaptive mechanisms used to transport molecules or ions that cannot be transported passively.

8. Passive transport, active transport, and facilitated diffusion are shown in the Exploration. List any other form of specialized cell transport and explain it in brief.

   Answer: Osmosis is a specialized type of passive transport in addition to the ones mentioned above. In this process, a solution can pass through a semipermeable membrane owing to the concentration gradient. Reverse osmosis is a similar transport of solutions across the membrane under pressure.

9. Explain the processes of exocytosis and endocytosis.

   Answer: Endocytosis is the process of absorption of nutrients into the cell. The cell creates invaginations to engulf these particles and a vesicle is created to accommodate them. Exocytosis, on the other hand, is the process of releasing the waste products of the cell outside, through similar vesicles.

10. List two factors that can affect the rate of cell transport.

    Answer: The size of the molecule undergoing transport, concentration gradient across the cell membrane, charges on either side of the membrane and lipid solubility are some of the factors that can affect the rate of cell transport.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

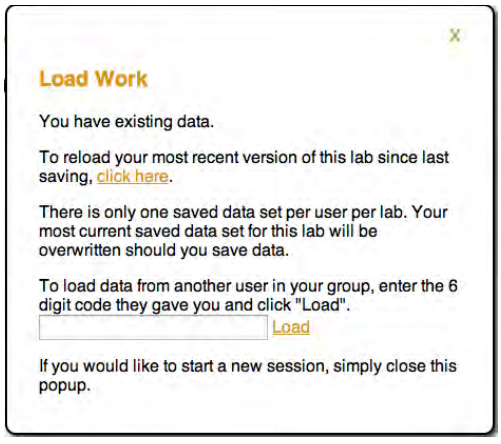
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

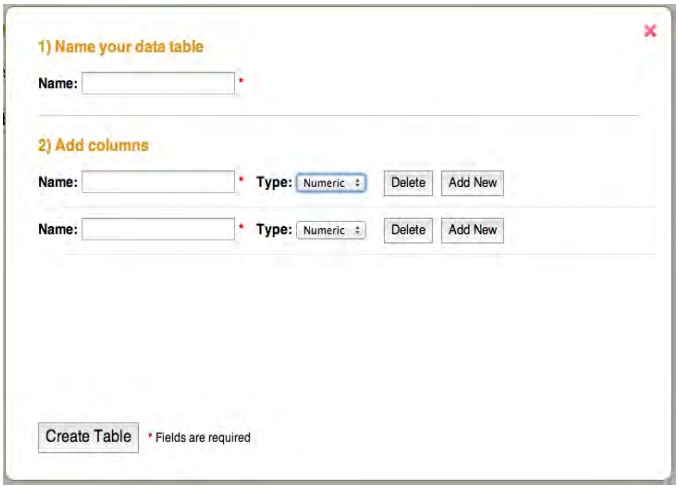
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



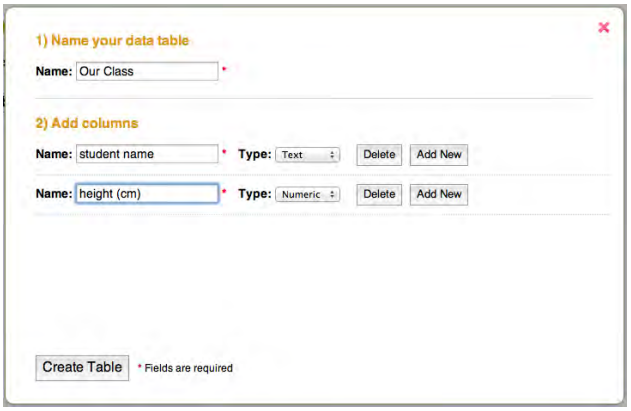
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

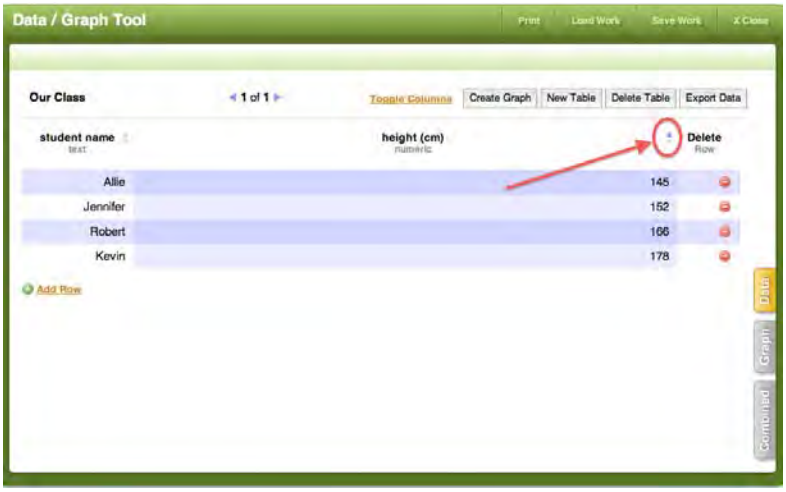
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

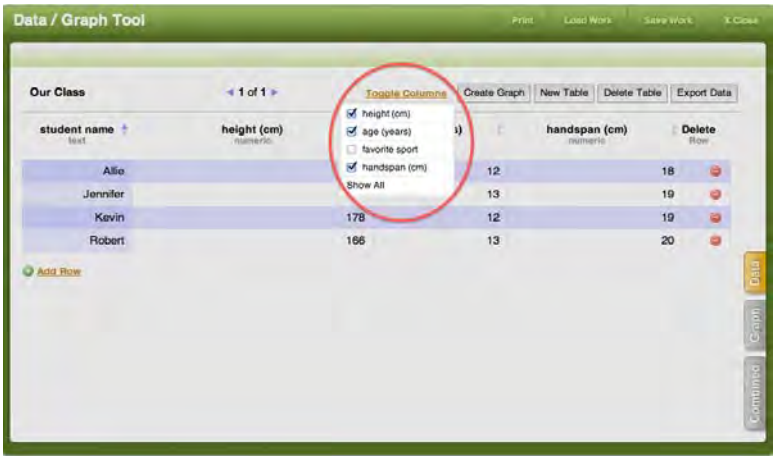


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

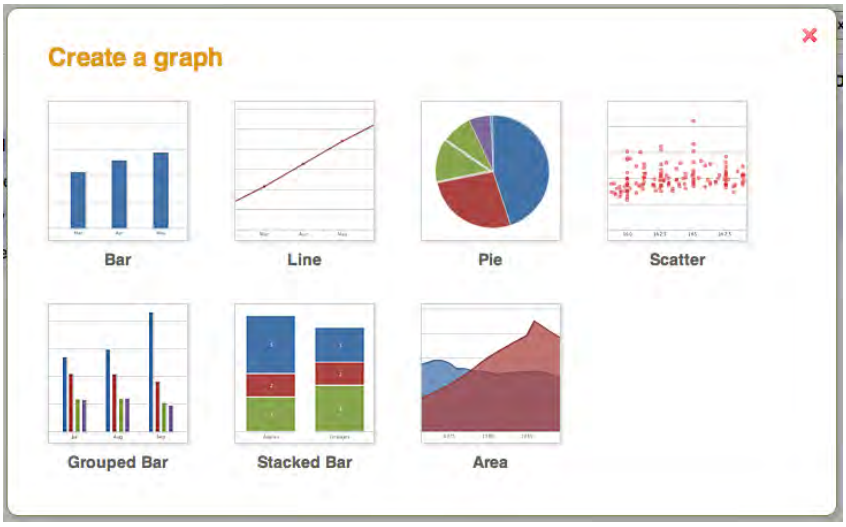
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

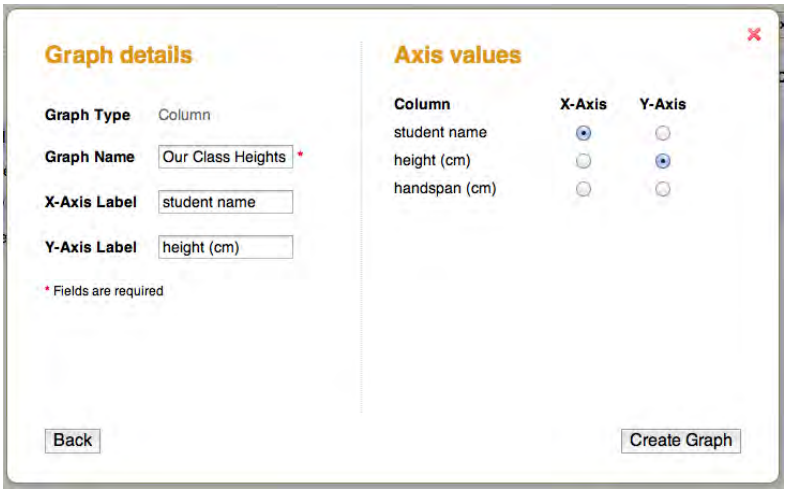
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

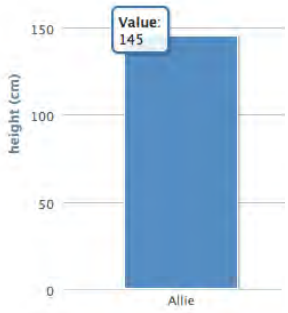


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

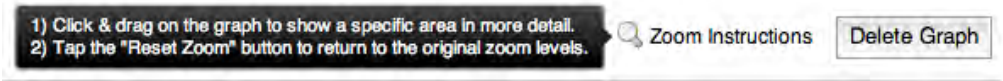
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Activity Sheet

Name _____

Date _____

Cell Transport

Work with a partner. Read the 'Explore' section of "Cell Transport." Use the Interactive Glossary to help understand the words. One student will read definitions and the other will writes notes in the chart. Take turns.
Compare your notes to what you read in the Interactive Glossary. Add any changes to the chart.

What parts of Techbook are you using? _____
Who are you working with? the whole class a group one other person nobody

What will you have when you finish?

Vocabulary word	What I heard	What I read
transport		
cell membrane		

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Hands-On Lab

Homeostasis at the Cellular Level

Timing: two 90-minute class sessions

Objective(s):
Students will investigate homeostasis at the cellular level by observing the stomata of plant leaves subject to varying moisture regimes.

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should be careful using sharp objects such as scissors and forceps. Remind students to wear proper safety attire including lab coats or aprons, and gloves if necessary. Students should follow proper disposal and cleaning procedures after the lab.

Materials:
Per pair:

- 2 plants (preferably a monocot such as spider plant)
  - wilted due to insufficient water
  - watered sufficiently
- forceps
- compound microscope
- dissecting microscope (optional)
- glass slides
- clear nail polish
- clear tape
- lab apron, one per student
- paper towels for clean up

Teacher Preparation:

- Gather materials in advance of students performing the lab.
- Be sure that the type of plant you use works with the nail polish procedure. Leaves of some plants are affected by the solvent and the stomata cannot be observed.

Procedure

1. Have students research the structure and function of the cell, in particular reviewing the principle of homeostasis at the cellular and how it applies to plants.
2. Instruct students to create a simple plan for their investigations, including the goals as well as proposed techniques.
3. Have students obtain a leaf from a plant that is not wilted (i.e., turgid).
4. Instruct the students in the following procedure to observe stomata:
    a. Apply a thin layer of clear nail polish to the underside of the leaf, and allow to dry
    b. When the nail polish is dry, use the forceps to peel away the nail polish. If this is difficult you can use the clear tape to peel away the nail polish. This will lift away the outer layer of cells (cuticle), exposing the lower epidermal cells. This procedure may be easier with a dissecting microscope.
    c. Use the scalpel to prepare a small square of the leaf and place on the slide, with the lower epidermis right side up.
    d. Use the compound microscope to observe the stomata and guard cells.
    e. Note observations using text and diagrams
    f. Repeat the procedure using a leaf from a wilted plant.
5. When students have completed observations, have them consider the role of the guard cells (hence stomata) in maintaining homeostasis within the plant. For example, you can guide students with questions such as:
    a. What is the difference in appearance between guard cells in turgid versus wilted leaves?
    b. How might the difference help the plant regulate the water concentration in the leaves?
    c. What do you think is the role of the guard cells and stomata in maintaining homeostasis at the cellular level?
    d. Can you think of other cellular processes in animals or plants that may be important in maintaining homeostasis? Examples include:
        i. Cellular respiration
        ii. Active transport
        iii. Osmosis
        iv. Diffusion
        v. Lactic acid fermentation

Analysis and Conclusions

1. What new information did you learn about homeostasis at the cellular level by observing stomata in leaves from plants subject to adequate and inadequate water levels?

Cells have the ability to regulate the amount of water that is inside the cells. In this lab, plants can open and close their stomata to help regulate how much water is lost through the process of transpiration. Plants that are turgid have sufficient water within them and are able to maintain homeostasis, while wilted plants do not have sufficient water. The regulation of water levels inside the cell is just one example of homeostasis.

2. What did you notice about stomata in plants subject to adequate and inadequate water levels? How does their form relate to watering regime of the plant?

When plants were given an adequate supply of water the stomata were closed. This is because the plant had reached the perfect amount of water on the inside of the cell and wanted to absorb no more. When the stomata are closed, the plant cell indicates it does not need more water.
When the plant cells were given an inadequate supply of what the stomata were in the open position. The stomata are open it indicates that the plant cell does not have enough water on the inside of the cell. With the stomata open the cell would be able to absorb more water. When plants have inadequate water levels, they lose too much water through the process of transpiration, fail to maintain homeostasis, and become wilted. If you observe plants becoming wilted, you should increase the volume of water or the frequency of when you water your plants.

3. How does observing homeostasis at the cellular level, rather than reading about it or looking at pictures about it, provide you with a better understanding of the process?

Looking at the actual plant and the stomata in leaves and seeing them up close and under a microscope really helps to visualize and internalize the mechanism that plants use to maintain homeostasis with how they conserve water. Reading about it or just looking at pictures doesn't completely depict the process in your mind as much as actually observing it and learning about it kinesthetically.

4. Cellular processes and tissue and organ functions help organisms maintain homeostasis. Describe an activity or experiment that would investigate what functions enable homeostasis when an organism is subject to high temperature.

Answers may vary. Some examples of student answers may be: Placing one plant in an environment with high temperature and one plant in an environment with a low temperature could help investigate what functions enable homeostasis by comparing stomata of these plants. Placing an animal in an environment with high with high temperature and another animal in an environment with a low temperature could help investigate what functions enable homeostasis by observing animal behavior, metabolic rate, body temperature, respiration rate, and physiological activity.

Inquiry skills

In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

Hands-On Lab

Observing Active Transport: Phagocytosis

Timing: One 45-minute class session

Objective(s)
In this activity, students will observe phagocytosis by an amoeba.

Safety Precautions
Remind students to:

- Wear a lab apron, gloves, goggles, and closed-toe shoes.
- Do not to eat or drink anything in the lab (including the experimental materials).
- Report any broken glass; students should not try to clean it up themselves.

Materials
Per pair or group:

- Compound microscope with a light source
- Glass microscope slide
- Glass coverslip
- Dropping pipette
- Sample from a starved amoeba culture
- Amoeba food (*Chilomonas*)

Teacher Preparation

Obtain a culture of amoebae and appropriate food from a reputable supplier. Some suppliers provide kits containing both items. Be sure to starve the amoeba for about twenty-four hours before conducting this lab with your students.

Procedure

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Demonstrate the procedure to the students. If it has been some time since they last used microscopes, go over the procedures for illuminating and focusing the microscope. Demonstrate how to place the drops in the slide and add the coverslip.

Guided Inquiry

Students can follow the instructions on the student investigation sheet or develop their own procedures based on their knowledge.

Analysis and Conclusions

In order to help students analyze and interpret their results, discuss some or all of the following questions or assign them as homework:

1. Using numbered steps, describe what you observed under the microscope. *Their steps will vary, but students should mention the movement of the amoeba, the development of "arms" (pseudopodia), the food being engulfed, and the food entering the cell.*
2. What evidence do you have that phagocytosis is active rather than passive transport? *The process involves directed movement of the whole organism and components of the cell, which indicates that energy is being consumed; therefore, the process is active.*

Further Questions

1. Use additional resources to locate an example of phagocytosis conducted by human cells. *A type of white blood cell called phagocyte cells protects the body by phagocytosing harmful particles, bacteria, foreign bodies, and dead or dying cells. Dead phagocytes form the puss around wounds and destroy invading pathogens.*

Inquiry and Nature of Science Skills in This Lab

- Identify Questions
  - Develop a question that:
    - Asks about a specific science concept or process
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
- Design Investigations
  - Design and conduct investigations using:
    - Fair test—changing only one variable at a time makes comparisons valid
    - Independent variable—the one variable the investigator chooses to change
    - Dependent variables—what changes as a result of, or in response to, the change in the independent variable
    - Control (control group)—used for comparison in which the independent variable is not changed
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Properly citing all equipment and materials
    - Describing it so that it can be easily repeated by a fellow scientist
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
- Gather Data
  - Choose appropriate tools to conduct an investigation:
    - Glassware
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Reporting trends and patterns in the data
    - Comparing results to hypothesis
- Communication in Science
  - Report results using:
    - Peer presentation
- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating an investigative design
    - Evaluating a conclusion
- Scientific Investigation
  - Scientific Data and Outcomes
    - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
    - It is important in science to keep honest, clear, and accurate records.

- Scientific Endeavor
    - Characteristics of Science
        - One way to make sense of something is to think of how it relates to something more familiar

Hands-On Lab

Osmosis

Timing: one 90-minute class session

Objective(s):
Students will investigate the cellular processes of osmosis and homeostasis. To do this, students will determine the internal solute concentration of a potato by placing potato pieces in various salt concentrations and determining the change in mass of each piece. Students will implement their own experimental design and plans for collecting data, including selecting the appropriate equipment based on the materials provided, and formulating their hypothesis and questions they will try to answer.

Safety Precautions:
Remind students to wear gloves, goggles, and closed-toe shoes, and not to eat or drink anything in the lab including the experimental materials. Tell students to report any broken glass and not to try and clean it up by themselves. If students are cutting the potato pieces, remind them to be careful when handling sharp instruments, to hold the tool by the handle, and to cut away from themselves.

Materials:
Per group:

- potato, 1
- knife or other cutting tool
- 50 mL beakers, 7
- balance (triple beam or electronic) for measuring mass
- salt, approximately 15 g
- water, approximately 160 mL
- paper towels for drying potatoes
- watch or timer
- safety goggles, one pair per student
- lab apron, one per student

Teacher Preparation:
Prepare the demonstration one day prior to class. Cut two pieces of potato about the same size. The exact size is not important, just that they are of similar size, and bigger is better than smaller. Oval, flat pieces are better than “chunks” (cutting a round potato slice is ideal). Record the mass of each piece. Place one piece of potato in water, and place the other piece in a 25% salt solution (25g salt per 100 ml water). Leave the pieces in these solutions until class time. Make copies of the Student Investigation Sheets (1 per student). Students can either cut their own potato pieces or the pieces can be provided. If the teacher is providing potato pieces, cut seven pieces (0.5 cm x 3 cm) per group.

Students can either make their own solutions, or solutions could be provided. If solutions are to be provided, prepare the following salt solutions so that each group has at least 20 mL: 0%, 0.5%, 1%, 2%, 5%, 10%, 20%, and 25%.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to estimate the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry
Discuss the demonstration with students. Explain that these potato pieces have been soaking overnight. One is in a 25% salt solution, and the other is in water (0% salt).

Take out both pieces of potato and allow the students to examine them. Label the potato pieces 'A' and 'B'. Potato piece A in the chart represents the one that was in salt. Potato piece B represents the one that was in water. Do not list which potato was in salt and which was in water. Place each potato individually on the balance to find the mass, and record the data on the board (see sample chart below). Discuss with students the level of accuracy appropriate to the limitations on determining the mass of the potato slices and the mass of the salt that will be used to make the test solutions for this lab.

Sample data:

	Potato Piece A	Potato Piece B
Before	*28 g*	*28 g*
After	*24 g* *Limp* *Brown*	*31 g* *Turgid*

After you have completed the demonstration, discuss the results with the entire class. Ask students to describe what they have observed in the demonstration. If necessary for your students, direct the discussion by asking leading questions such as:

- Which piece was in the salt solution? How do you know? *Potato piece A was in the salt solution because it was limp.*
- What happened to the potato in the salt solution? Why do you think this happened? *The piece that was in salt dehydrated. The water moved out of the potato due to osmosis because the external solute concentration is much higher than the internal solute concentration.*
- How would you use a similar study to estimate the approximate internal solute concentration of the potato? *If the solute concentration outside of the potato is isotonic (equal) to the solute concentration inside the potato then the weight of the potato should not change.*

Next, have each group design an experiment that estimates the internal solute concentration of the potato. Groups can determine which solute concentrations to choose, but the range should be inclusive of both 0% and 25%. Have them predict the concentration. Discuss with the group the importance of the controls. (*Since we already know the results of these concentrations, we can use them as controls for the study)*. Have students write a hypothesis in the "If, then" format prior to starting the experiment.

Students should be instructed to make approximately 20 mL of each solution; this should be enough to cover the potato piece. Before placing the potato into the solution, students should stir the solution well for a few minutes to help the salt dissolve.

Students should be instructed to cut potato pieces into 3 cm x 0.5 cm pieces. Students should use a paper towel to pat the pieces dry. Then they should measure the initial mass of each piece and make notations on the appearance (turgid, wilted, etc.) Students should place one piece into each of the solutions that they have prepared. After 15 minutes, remove each piece, dry it, and record the mass of each piece. Return each piece to its solution and repeat this procedure after soaking in the solution for 30 minutes, and (if time permits) 60 minutes. Students should also note the appearance of the pieces at each of these times, noting color and flexibility of the potato. If the student groups are guided to select the same concentrations, an average for the class can be determined. Students should record their data in a table similar to the one provided.

	0%	0.5%	1%	2%	5%	10%	20%	25%
0 min								
15 min								
30 min								
60 min								
Total change in mass								
Average change in mass for all groups								

Guided Inquiry

Students can develop their own experimental design and plans for collecting data, based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry:

- How can you use the materials provided to study osmosis?
- What is your hypothesis?
- What will be the control in the experiment?
- What will be the independent variable?
- What will be the dependent variable? What are you going to measure?
- ?

Have students discuss protocols with you and with other groups. You may need to assist them when choosing the highest level of salt concentration to use by showing them the demonstration from the Directed Inquiry. The potatoes were placed in 0% and 25% concentrations. They are trying to find the approximate internal solute concentration of the potato.

Students should create a hypothesis in the “If, then” format before starting the experiment. They should collect the initial masses of the pieces and make notations on the appearance (turgid, limp, etc.). Students should remove the piece, dry it, and take the mass after soaking in the solution at intervals of their choosing up to maximum of 60 minutes. Students should design a format for their own data table that includes both measurements and notes about the appearance of the pieces at each of the times, noting color and flexibility of the potato.

Sample data

	0%	0.5%	1%	2%	5%	10%	20%	25%
0 min	*2.6 g Turgid*	*2.1 g Turgid*	*2.7 g Turgid*	*2.5 g Turgid*	*2.1 g Turgid*	*2.3 g Turgid*	*2.6 g Turgid*	*2.4 g Turgid*
15 min	*2.7 g*	*2.1 g*	*2.6 g*	*2.1 g*	*1.7 g*	*2.0 g*	*2.2 g*	*2.0 g*
30 min	*2.8 g*	*2.1 g*	*2.4 g*	*2.1 g*	*1.7 g*	*1.9 g*	*2.2 g*	*1.9 g*
60 min	*2.8 g*	*2.1 g*	*2.4 g*	*1.9 g*	*1.6 g*	*1.8 g*	*2.1 g*	*1.8 g*
Total change in mass	*+0.2 g Turgid*	*0 g Turgid*	*-0.3 g Limp*	*-0.4 g Limp*	*-0.5 g Limp*	*-0.5 g Limp*	*-0.5 g Limp*	*-0.6 g Limp*

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. What is the approximate internal solute concentration of the potato? Did this support your hypothesis (and/or predictions)? *Answers will vary, but should be greater than 0% and less than 25%.*

2. Compare your results with other lab groups. Are the results consistent? What could cause inconsistencies between the groups? *Inconsistent results can be explained by experimental error (measurement errors, errors in data collection, errors inherent in the balance, the freshness of the potato etc.)*

3. In our experiment, is water demonstrated to be the only molecule that diffused in or out of the potato? Provide one alternative for a molecule that could have diffused in or out of the potato and how we might test for it. *This experiment does not prove that water is the only molecule that diffused. Starch or other molecules inside the potato could have diffused out into the water. We would need to test the solution for the presence of other molecules to test this hypothesis. We can test for the presence of starch by adding iodine to the external solution.*

4. If left for longer periods of time, what happens to the potato? Until what point would the potato continue to change in mass? *The longer the potato is left in solution, the greater the change in mass. The potato would continue to change in mass until equilibrium is reached.*

5. Foods that are highly salted or sugary (like jams) have a high solute concentration, preserving them and giving them a longer shelf life. Why might the high solute concentration of these foods make it difficult for bacteria and fungi to grow on them? *The high solute concentration of the foods dehydrates the bacterial and fungal cells and can kill them.*

6. Have students plot their results on a graph. Students will need to standardize their results for each piece of potato by calculating the percentage increase or percentage loss of mass. For guided inquiry set this task as an open ended exercise. On completion of the exercise, ask the students how they could use their graph to estimate the concentration of salt water in a saltwater lake. Students could place a piece of potato in the lake water and determine which of their salt solutions of known concentration produced an effect most similar to the lake water.

7. What did your investigation tell you about the abilty of potato cells to maintain homeostasis?*Homeostasis is the process by which a cell maintain its internal conditions when the external environment changes. The cell membrane is involved in homeostasis. It regulates the movement of some molecules into and out of the cell. However water is not one of these. The investigation demonstrated the movement of water molecules was not controlled by the cell.. In solutions below 1% the cells took on water, probably up to the point that the pressure of water inside the cell equaled the osmotic pressure of the solution. In the more concentrated solutions the potato pieces (and their cells) lost mass. However the result suggests that the solute, sodium chloride, does not easily cross the cell membrane which must therefore be semi-permeable and able to prevent unwanted salt entering the cell.*

- **Inquiry and Nature of Science Skills in this Lab:**

- Identify Questions
  - Develop a question that:
    - asks a question about a specific science concept or process
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
    - Require the changing of one variable at a time
    - Can be answered with a science investigation or observational study
  - Develop predictions/hypotheses that:
    - State what may happen in an investigation based on prior knowledge or experience (prediction)
    - State the expected cause and effect (if-then statement) in an investigation based on prior knowledge and experience (hypothesis)

- Design Investigations
  - Design and conduct field studies using:
    - Interventional Study - adjusts one or more elements and observes resulting changes over time
  - Design and conduct investigations using:
    - Fair test - changing only one variable at a time makes comparisons valid
    - Independent variable - the one variable the investigator chooses to change
    - Dependent variables - what changes as a result of, or in response to, the change in the independent variable
    - Control (control group) - used for comparison in which the independent variable is not changed
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Properly citing all equipment and materials
    - Describing it so that it can be easily repeated by a fellow scientist
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
    - Incorporating laboratory safety practices into the investigation design

- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Mass
    - Time

- Choose appropriate tools to conduct an investigation:
  - Balance
- Use senses to observe:
  - Seeing (color, shape, size, texture, motion)
- Use the appropriate format to record data:
  - Chart

- Interpret Data
  - Identify and interpret patterns using:
    - Trends in data
    - Analysis of data collected during an investigation

- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Reporting trends and patterns in the data
    - Comparing results to hypothesis
    - Answering the testable question
    - Extrapolating results beyond the investigation
    - Identifying alternative explanations
    - Formulating scientific explanations/arguments

- Communication in Science
  - Report results using:
    - Written report
    - Table/graph showing data

- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating an investigative design
    - Evaluating data for accuracy

- Patterns and Systems
  - Patterns and Change:
    - Some small changes can be detected by taking measurements.
  - Systems:
    - Physical and biological systems tend to change until they reach equilibrium and remain that way unless their surroundings change.

- Scientific Investigation
  - Scientific Investigation:
    - Science investigation begins with a testable question.
    - Hypotheses are valuable, even if they turn out not to be true, because they lead to further investigation.

        - Scientific investigations lead to the development of scientific explanations.

    - Scientific Data and Outcomes:
        - Scientific claims are based on data and reliable scientific sources.
        - Collecting and analyzing data is the best way to understand a changing pattern.
        - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
        - Comparisons of data are not accurate when some of the conditions are not kept the same.
        - It is important in science to keep honest, clear, and accurate records.
        - When similar investigations give different results, it often takes further studies to decide what is right.
        - Arguments and conclusions are invalid if based on very small samples of data, biased samples, or samples for which there was no control sample.

- Scientific Endeavor
    - Characteristics of Science:
        - Science is based on factual knowledge.
        - Scientific claims can be substantiated using data and observation.
        - Scientific theories are based on accumulated evidence.
        - An important part of science is the critical review and analysis of any idea or conclusion.

Hands-On Lab

Passive and Active Transport Maintain Homeostasis

Timing: two 90-minute class sessions

Objective(s):
Students will examine the process of osmosis in a chicken egg to observe how passive transport maintains homeostasis in the cell.

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should be careful using sharp objects such as scissors and forceps. Remind students to wear proper safety attire including lab coats or aprons, and gloves if necessary. Students should follow proper disposal and cleaning procedures after the lab.

Materials:
Per pair:

- gloves, one pair per student
- lab apron, one per student
- 2 raw eggs
- 250 ml corn syrup
- 250 ml vinegar
- 250 ml distilled water
- 2 large beakers
- 250 ml measuring cylinder
- balance
- plastic wrap
- paper towels

Teacher Preparation:

- Gather materials in advance of students performing the lab.

Procedure

1. Have students research the structure and function of the cell, in particular reviewing the principle of passive and active transport and how these maintain homeostasis at the cellular level.
2. Instruct students to create a simple plan for their investigations, including the goals as well as proposed techniques.
3. Instruct the students in the following procedure to examine osmosis in a chicken egg:
4. Weigh the eggs and note the weight.
5. Place the eggs in the beaker, and pour enough vinegar over the egg to cover it.
6. Leave the eggs in the vinegar for two days. The vinegar will start to foam, due to the acid-base reaction of the acetic acid in vinegar with the calcium carbonate in the shell.
7. Remove the eggs and rinse them carefully in tap water.
8. Weigh the eggs again. The vinegar will have dissolved the eggshell, so take care not to break the membrane, or you will need to start over.
9. Place one egg in corn syrup. Place the other egg in the distilled water.
10. Leave the eggs overnight. Then rinse the eggs in tap water and weigh again. Record any differences in appearance, by holding the egg up to the light and observing the egg yolk.
11. When students have completed observations, have them consider the role of osmosis (passive transport) in maintaining homeostasis within egg cell. For example, you can guide students with questions such as:
    a. What is the difference in appearance between the egg immersed in corn syrup versus distilled water? Which treatment is a hypertonic solution, and which is a hypotonic solution? (Water is hypotonic, causing the egg to increase in size, corn syrup is hypertonic, causing the yolk to become smaller.)
    b. How might the difference help the yolk regulate its water concentration?
    c. What do you think is the role of the membrane around the egg in maintaining homeostasis at the cellular level?
    d. Can you think of other cellular processes in animals or plants that may be important in maintaining homeostasis? Examples include:
        i. Cellular respiration
        ii. Active transport
        iii. Diffusion
        iv. Lactic acid fermentation

Analysis and Conclusions

1. What new information did you learn about passive transport as it relates to homeostasis of the cell from the different solvents the egg was treated with?

A cell is constantly trying to maintain a specific amount of water level on the inside of the cell. In order to accomplish this it uses a mechanism known as passive transport. In passive transport the cell will move water into or out of the cell depending on the concentration of water molecules. When the concentration of water molecules was greater outside the cell, passive transport allowed water molecules to flow into the cell. When the concentration of water molecules was higher inside the cell, passive transport moved water molecules out of the cell. The example that was used in this was that when eggs have their outer shell removed they can be used to model a cell. The eggs placed in corn syrup lose water through osmosis, as the corn syrup is hypertonic and causes water to move out of the egg. I learned that eggs placed in distilled water gain water though osmosis, as the water is hypotonic and causes water to move into the egg.

2. What did you notice about the appearance of the egg? How did the appearance relate to the different solvents? What did you observe about the amount of solvent measured? How did the measured amounts relate to the different solvents?

The egg placed in corn syrup shrank and began to shrivel up while the egg placed in distilled water grew and swelled up. This appearance related to the solvents as water was drawn out of the egg placed in the corn syrup, which caused it to shrink and shrivel up while the egg placed in distilled water absorbed water and grew in size. There was more solvent with the egg placed in corn syrup after a day, as water left the egg and went into the corn syrup while there was less solvent with the egg placed in distilled water, as water moved into the egg. The increase in volume of the corn syrup solvent related to the water that was drawn out of the egg while the decrease in volume of the distilled water related to the water that was absorbed by the egg.

3. How does investigating passive transport at the cellular level, rather than reading about it or looking at pictures, provide you with a better idea about the process?

Looking at the eggs and seeing the differences in the eggs after sitting in each solution helps to show that passive transport (osmosis) occurs, when the eggs are placed in different solutions. When the concentration of water is higher in the cell than the surroundings, water will leave the cell. When the concentration of water is lower in the cell than the surroundings, water will ener the cell Reading about it or just looking at pictures doesn't help you to see the process in your mind as much as actually observing it and learning about it kinesthetically.

4. Passive transport is an essential process to maintain homeostasis in the cell. Describe an activity that would investigate active transport as it relates to homeostasis in the cell.

Answers may vary. Some examples of student answers may be: Observing amoebas eating food under a microscope would help investigate how the process of phagocytosis (a type of active transport) occurs and how this process helps amoebas maintain homeostasis. Using the exploration on active

transport helps investigate how the sodium-potassium pump maintains sodium and potassium levels within cells through active transport to maintain homeostasis within cells. Placing a Congo Red dye solution onto live yeast cells and heat-killed yeast cells helps investigate exocytosis (a type of active transport) and how the process helps yeast cells maintain homeostasis by getting rid of this toxin.

Inquiry skills

In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

Exploration Teacher Guide: Cell Division

Overview

Students will learn about the various phases of cell division. They will identify these phases and the changes occurring in the cell, along with their significance in the cell cycle.

Student Learning Objectives

- Observe the morphology and structure of the cell in the different phases of cell division.
- Identify the phase of the cell cycle to which the cell belongs.
- Examine the effects of the action performed by the cell in a phase of cell division.
- Investigate whether the daughter cell is healthy or cancerous.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

Students can use the *Prokaryotes* and *Eukaryotes* radio buttons to select the type of cell for which they wish to observe cell division. They must select the phase of the cell cycle that the cell will proceed to, by clicking the corresponding region of the cell cycle clock. After identifying the phase correctly, students can identify the action that the cell must perform to proceed in the cell cycle by using the *Cell Growth*, *Chromosome Duplication*, and *Cell Division* buttons.

Students can use the *Check Cell Size* button to verify if the size of the cell is sufficient to proceed to the next phase. After correctly identifying all the phases of cell division, students can examine the new daughter cell formed to identify if it is *Healthy* or *Cancerous* using the buttons provided for the same.

Students can use the *Reset* button to undo changes made to the cell and restart the same run of the cell cycle. They can use the *Start Over* button to generate another cell in a random phase of the cell cycle.

Students can use the *Tracker* tab to examine the path in the cell cycle followed by the cell in each run. They can also keep a tab on the type of cell and the cell health.

Answers to Questions in the Student Worksheet

1. List the different phases of cell division along with their significance.

   Answer: The different phases of cell division are G1, S, G2 and M. Phases G1 and G2 are characterized by cell growth. In the S phase, DNA replicates to form two copies of each chromosome. The M phase, which is also known as the mitosis phase, is further subdivided

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into prophase, metaphase, anaphase, and telophase. These phases lead to the separation of the chromosomes and cytoplasm of the parent cell, producing a new daughter cell.

2. Describe the G0 phase that is exhibited by some special cells.

   Answer: Some cells, such as the cardiac cells of the heart, are usually in an inactive stage called quiescent stage (G0) of the cell cycle. Cells in this stage remain metabolically active but no longer divide unless called on to do so depending on the requirement of the organism.

3. List the different stages of the M phase.

   Answer: The different stages of M phase are prophase, metaphase, anaphase, and telophase. Chromosome separation and cytokinesis occur in this phase.

4. The G1, S, and G2 phases collectively belong to a single stage. Name this stage.

   Answer: G1, S, and G2 collectively belong to the interphase.

5. Cytokinesis is the term given to the division of the cytoplasm. Explain what karyokinesis is.

   Answer: Karyokinesis is defined as the division of the nuclear material during cell division.

6. Explain the difference between mitosis and meiosis.

   Answer: The product of mitosis is a daughter cell with the same number of chromosomes as the parent cell. On the other hand, meiosis gives rise to four daughter cells, each of which has half the number of chromosomes as compared to the parent cell.

7. Describe why mitosis is also known as equational division.

   Answer: Mitosis is known as equational division as the number of chromosomes in the parent cell and daughter cell is equal.

8. List one phase of the cell cycle that is different for plant and animal cells. Give reasons for your answer.

   Answer: Cytokinesis is different in plant and animal cells. This is because plant cells have a cell wall and animal cells do not. Due to this the process of cytokinesis in plant cells begins with formation of a cell plate which divides the cytoplasm in half. The cell plate further gives rise to the tubulovesicular network which aids the process of cytokinesis. On the other hand, cytokinesis in animal cells is characterized by the formation of a contractile ring.

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9. If the body cells of chickens have 78 chromosomes, calculate the number of chromosomes in the sperm cells.

   Answer: Since sperm cells are the gametes of male chicken, the number of chromosomes in them will be half of those in the parent. Hence, sperm cells of the chicken will have 39 chromosomes.

10. Explain the term ploidy and its significance in cell division.

    Answer: Ploidy is defined as the number of sets of chromosomes in a cell. Human cells are diploid since there are two sets of 23 chromosomes each. Their gametes are haploid.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

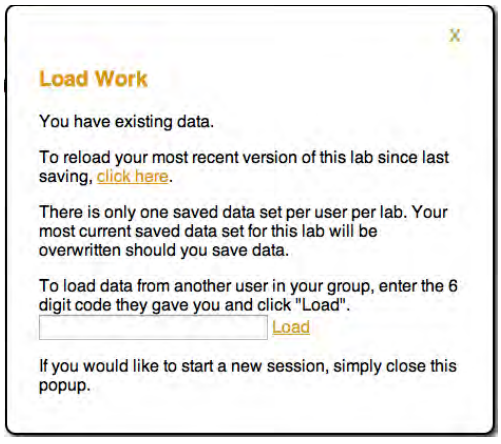
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

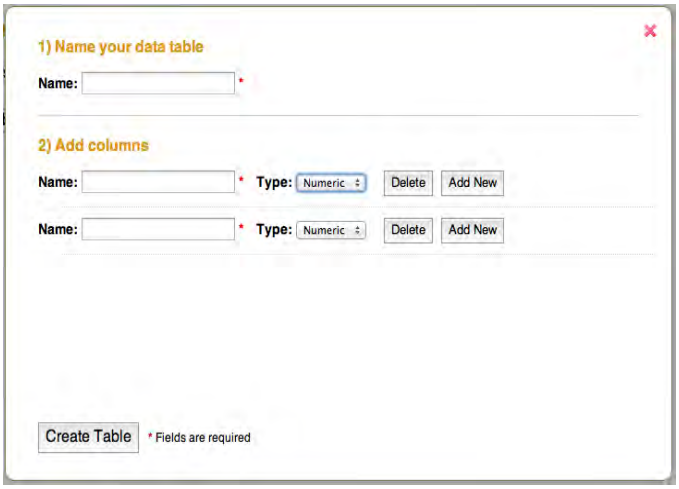
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



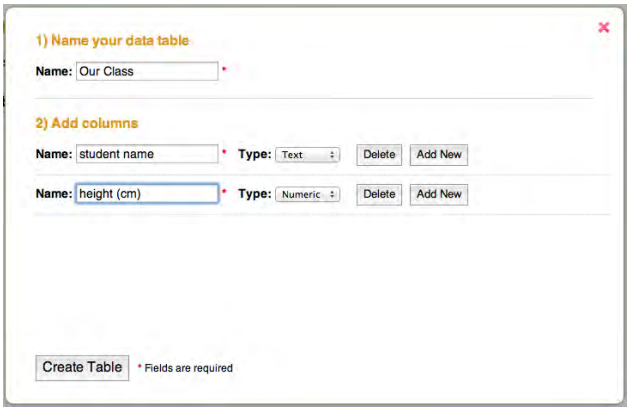
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

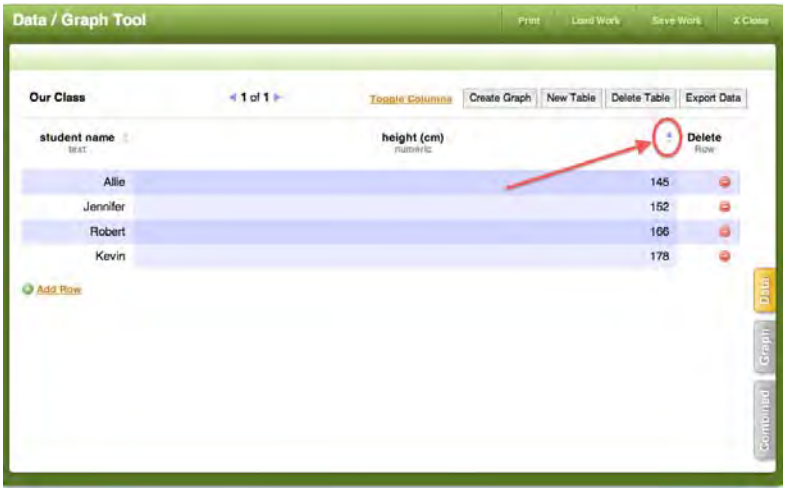
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

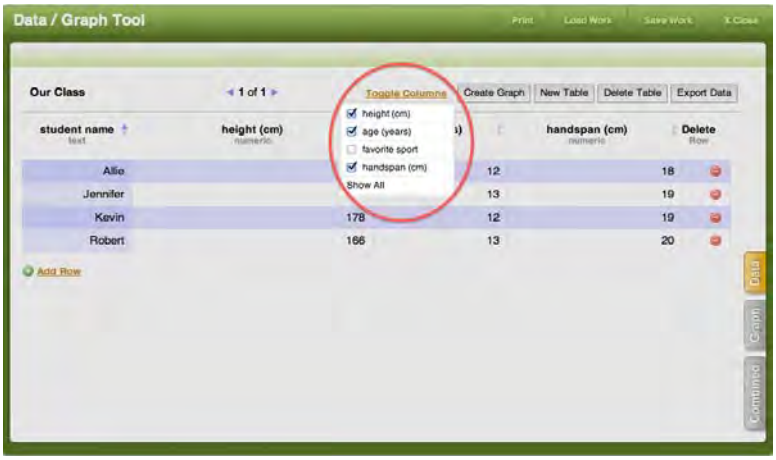


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

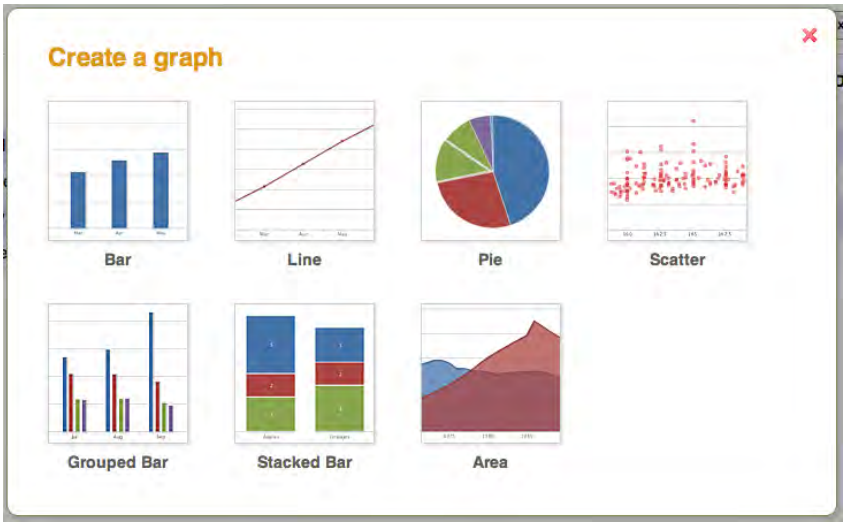
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

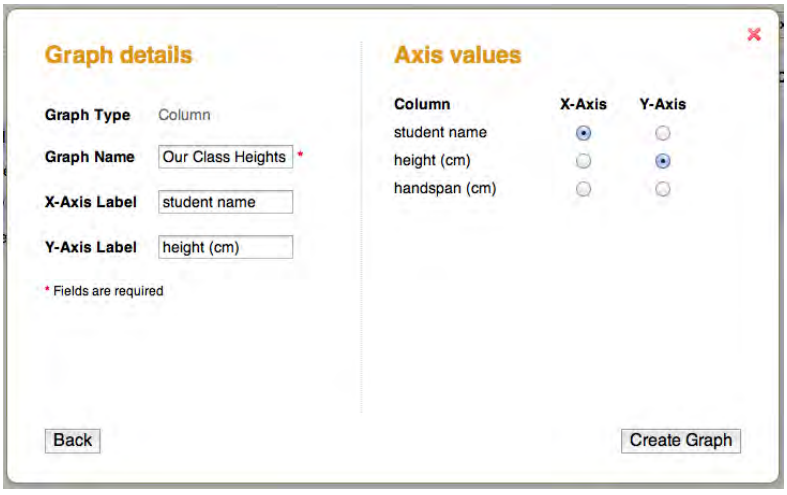
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

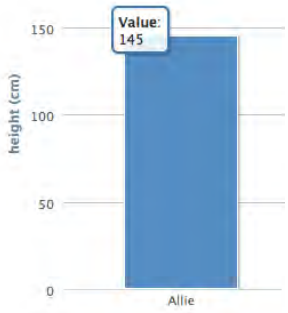


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

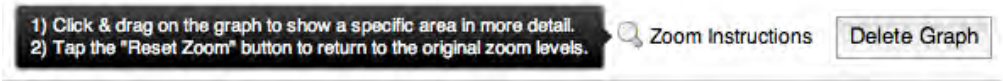
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Activity Sheet

Name _____

Date _____

Cell Division

Work with a group. Read the text and watch the videos in the Explore section of “Cell Division.” Write difficult words in the chart below. Work with your group to understand what they mean. Talk about the types of words in your list. Work with your group and your teacher. Sort the words into the “Parts of Speech” table below.

What parts of Techbook are you using? _____

Who are you working with?

the whole class a group one other person nobody

What will you have when you finish? _____

Word or Sentence	Meaning	Example or Picture

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Activity Sheet

Name _____

Date _____

Parts of Speech Table

Nouns (persons, places, things, ideas)	Verbs (actions or states of being)	Adjectives (describe persons, places, things, ideas)	Adverbs (describe actions or states of being)

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Hands-On Lab

Observing Mitosis

Timing: one 90-minute class session

Objective(s):
In this activity, students will prepare slides of onion root tip cells and observe them under a microscope. Students have the option to organize and present quantitative data using a computer spreadsheet program. Students will then use their understanding of cell division to identify the stages of mitosis.

Safety Precautions:
Remind students to wear gloves, aprons, goggles, and closed-toe shoes, and not to eat or drink anything in the lab (including the experimental materials). Tell students to report any broken glass and not to try and clean it up by themselves. Remind students to handle the toluidine blue carefully so as not to stain clothing. Students should also be cautious when handling the hydrochloric acid and the razor blade.

Materials:
Per class:

- onion
- glass jar (wide enough to fit the bottom of an onion)
- water
- toothpicks, 5

Per pair:

- cover slip
- distilled water, 2 mL
- forceps
- hydrochloric acid (1M), 2 mL
- compound microscope
- onion root tip
- pencil
- petri dish
- pipette
- razor blade
- scissors
- slide
- disposable gloves, one pair per student
- tissue or paper towel
- toluidine blue, 2 mL
- goggles, one pair per student
- lab apron, one per student
- clock with minute hand or stopwatch
- computer with spreadsheet software

Teacher Preparation:
Prepare the onion for this investigation by cutting off any old roots that appear brown or wilted. Then place the onion so that only its root portion is underwater. This can be done by putting toothpicks into the onion and using them to suspend the onion from the rim of a water-filled jar. Allow the onion to remain in the water for 2–3 days. Remove the onion from the water before the investigation. To save time, you may prepare the onion root tip slides for students by following the procedure described in the Directed Inquiry. If the class is larger than 20 students, more than one onion may be needed for this investigation. Prepare a copy of the Student Investigation Sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>
Have lab groups prepare slides of onion root tips using the following procedure. Demonstrate each step for students before they attempt the procedure on their own. Remind students about safety precautions, particularly when using the hydrochloric acid and razor blades.

1. Take a prepared onion. Cut off about 5 mm of the bottom of an onion root.
2. Place the root tip in a petri dish and use a pipette to add 1M HCl to the dish, covering the root tip. Let the root tip sit for four minutes.
3. Use forceps to transfer the root tip to a clean microscope slide. Set the slide on a firm surface such as the lab table and then use a razor blade to cut the root tip to about 1–2 mm. Throw away the remaining section of root tip.
4. Add two drops of toluidine blue stain to the root tip and let it sit for two minutes.
5. Absorb the excess stain by using a piece of tissue to blot around the root tip. Do not touch the root tip itself.
6. Add a drop of water to the slide and place a cover slip on top of the root tip. Use the eraser of a pencil to gently press straight down on the cover slip. Do not press hard

enough to break the coverslip. This will spread the cells into a single layer on the slide.
7. Observe the slide under a microscope to ensure that mitotic stages are visible. If the cells are too close together to distinguish individual cells, remove the slide from the microscope and gently press down on the cover slip again in order to spread the cells more thinly.
8. Create a data table for each stage of mitosis. As a technology option use a spreadsheet. Count the number of cells you observe at different stages of mitosis. Record the data in a spreadsheet. Use the spreadsheet to calculate the percentage of cells that are at each stage. Use the software to create a histogram of your data.

Once their slides have been prepared, instruct students to observe the chromosomes of the cells closely under the microscope. Have students try to identify a cell in each stage of mitosis. Guide them with the following questions:

- In what ways will the chromosomes appear different in each stage? For example, how will the chromosomes appear in interphase versus prophase? *Sample response: The chromosomes in interphase will be difficult to observe and may look like one large dark area in the nucleus. In prophase, they will be easier to see as chromatin begins to condense.*

Students should sketch their observations of each stage that they are able to identify, labeling the structures that are visible. Also, have them create a data table like the one below to record the average cell count for each stage. This will help them determine the relative length of time cells spend in each stage.

Cell Count per Stage of Mitosis

Stage	Number of cells
Interphase	
Prophase	
Metaphase	
Anaphase	
Telophase	

Have students compare their sketches and data tables with other pairs. Discuss their data table results as a class and find the class averages for the number of cells counted in each stage.

Ask the following question:

- In which stage do cells spend the most time? *Interphase*

Guided Inquiry

After students have observed the stages of mitosis in the onion root tip cells, have them investigate the relative length of time that cells spend in each stage on their own. Students can develop their own plans for collecting data based on their knowledge of the procedure and materials used. Ask the students some guiding questions to help them focus their inquiry:

- How can you calculate the relative length of time cells spend in each stage?
- How will you identify cells in interphase?

For example, students may choose a field of view to observe and count the number of cells in each stage within this view. Students may record their data in a table similar to the one below. Students could also choose to observe several fields and compute the average cell count for each stage.

Sample Data Table

Cell Count per Stage of Mitosis

Stage	Number of cells
Interphase	
Prophase	
Metaphase	
Anaphase	
Telophase	

Analysis and Conclusions:

Have students draw conclusions from their data about which stage is the longest and display their data in an appropriate graph, such as a pie chart. Then have pairs discuss their procedure and conclusions with other pairs. Were their findings and conclusions the same? What might account for differences in the findings? Encourage students to constructively evaluate and critique each other's procedures.

1. In which phase were the greatest number of cells in? In which phase were the smallest number of cells in? Use data to support your answer. *Answers will vary according to student data. Interphase is the longest phase of the cell cycle. Metaphase is the longest phase of mitosis. Anaphase is the shortest phase.*

2. What criteria did you use to identify the stages of mitosis? *Sample answer: We used the shape and position of the chromosomes to identify the stages of mitosis.*

3. Assume the cell cycles of neighboring cells are not dependent on each other. How could you estimate how much time cells spend in each phase of mitosis with only a single view of cells at one point in time? *Sample answer: In a large group of cells, the number of cells in each phase represents the portion of time any random cell spends in each phase. Thus if more cells were in a specific phase at any point in time, then that phase must last longer than other phases.*

4. How do your observations in this investigation support the cell theory? *Sample answer: We observed cells that were undergoing cell division to create daughter cells. This observation demonstrates that cells arise from pre-existing cells.*

Further Questions

5. Why was an onion root tip used to observe mitosis, rather than a different part of the onion? *Since the onion roots are growing the cells in the tip are dividing quickly. This means there are many opportunities to view mitosis in this tissue.*

6. Based on your data from the spreadsheet, in which stage do you think cells spend the greatest percentage of time?

   Because more were in interphase than any other stage it seems likely that cells spend the greatest percentage of their time in interphase.

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
  - Design and conduct investigations using:
    - Sample (if needed) - a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
- Gather Data
  - Choose appropriate tools to conduct an investigation:
    - Microscope
    - Slides and cover slips
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
  - Use the appropriate format to record data:
    - Graph
    - Chart
    - Sketch
- Interpret Data
  - Sort and classify using scientific reasoning by:
    - Sorting objects, substances and organisms by characteristic
  - Identify and interpret patterns using:
    - Trends in data
    - Tables and graphs
    - Analysis of data collected during an investigation
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Reporting trends and patterns in the data
- Communication in Science
  - Report results using:
    - Peer presentation
    - Table/graph showing data
- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating an investigative design
    - Evaluating data for accuracy
    - Evaluating a conclusion

- Patterns and Systems
    - Patterns and Change:
        - Many patterns in nature occur in cycles.
        - Cycles may be short, such as the second hand of a clock, or long such as the cycle of a year.
- Scientific Investigation
        - Scientific Investigation:
        - When a scientific investigation is repeated, a similar result is expected
    - Scientific Data and Outcomes:
        - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
- Scientific Endeavor
    - Characteristics of Science:
        - Scientific claims can be substantiated using data and observation.

Hands-On Lab

The Role of Mitosis

Timing: one 30-minute class session

Objective(s):
Students will investigate the role of mitosis in forming and maintaining organisms by making models with classroom manipulatives.

Safety Precautions:
Remind students to follow all general lab safety rules and not to eat or drink anything in the lab.

Materials:
Per group:

- string, 20-inch sections, 25
- blue pipe-cleaner chromosomes, 3-inch, 25
- red pipe-cleaner chromosomes, 5-inch, 25

Teacher Preparation:

- Gather materials in advance of students performing the lab. Create "pipe-cleaner chromosomes" by taking two pipe-cleaner segments of the same length (3 inches of blue or 5 inches of red) and twisting them together into an "X" shape. Make enough for each group of students to have 25 chromosomes of each length. You may wish to have students make these for you on the day before this activity takes place.
- Each group should have a fairly large desk or table area on which to create their models.
- Students will be given more materials than they need to complete the task.

Procedure:

1. Tell students to create a model of a cell that has two (different) chromosomes using the materials they have been given.
2. Next, tell students that the cell has undergone mitosis. They should model the results of this mitotic division. (There should be two new cells, identical to the first cell.)
3. Then tell students that mitosis occurs twice more. Students should model the results of these mitotic divisions. (Underneath each of the cells formed in step 2, there should be two more cells, for a total of four cells. Underneath each of those four cells, there should be two more cells, for a total of 8 cells. Students should end up with four rows of cells: row 1: one cell; row 2: two cells; row 3: four cells; row 4: eight cells.)
4. Now, walk around the room and remove one of the cells from each group's model. Vary which cell you remove from each student group. Tell students, "That cell just died." Have students create a new model of what, if anything, will replace that cell. (Students should replace it with a cell that is identical to the one that was there previously. Some students may incorrectly leave the spot empty.)

Analysis and Conclusions

1. What happens during mitosis?
   During mitosis, a cell divides to produce two identical cells.

2. Mitosis plays an important role in the formation of complex organisms. Explain how your model illustrates this role.
   Answers should indicate that the number of cells increased with each mitotic division. It is through this increase of cells through repeated division that an organism grows and structures and tissues are formed.

3. What other role of mitosis was demonstrated in this activity?
   Mitosis plays a role in maintaining complex organisms by producing new cells when old cells are damaged or die.

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4. Mutations can occur during mitosis. How do mutations further contribute to the production of complex organisms?
   Mutations result in genetic variation. This can lead to varied genetic expression within a population and further contributes to the production of complex organisms.

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In this lab, students will demonstrate the following:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

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Hands-On Lab

A Cycle Through Reproduction

Timing: one 90-minute class session

Objective(s):
Students will observe, model, and interact with concepts related to reproduction including asexual reproduction, the stages of meiosis, and a non-disjunction mutation in a series of stations throughout the classroom.

Safety Precautions:
Students should wear safety goggles and lab aprons when appropriate, and should not eat, drink, or taste any substances in a laboratory. Also, students should be cautious when using microscopes and glassware including microscope. They should report any broken glass and not try to clean it up themselves.

Materials:
Per student group:

- yeast, 2 mL
- cane sugar, 1 mL
- graduated cylinder, 10 mL
- warm water, 4 mL
- petri dish with cover
- lamp
- toothpicks
- blank microscope slides
- coverslips
- compound microscopes, at least two
- safety goggles, one pair per student
- disposable gloves
- lab apron, one per student
- prepared microscope slides showing stages of meiosis including a slide showing several cells in meiosis; labeled with nonconsecutive numbers or letters
- colored pencils
- paper plates
- pipe cleaners, two colors
- scissors

Teacher Preparation:

- Gather materials and set up stations around the classroom prior to class. Refer to the Procedure section of the Hands-On Lab to determine which materials are needed for each station.
- Depending on class size, you may need to set up more than one of each station.
- Prepared slides of meiosis stages can be purchased from a science supply company.

Cross-sections of lily anthers are commonly used to make these types of slides.

- Each station should take student groups approximately 20 minutes to complete. This allows for time to make notes, change stations, and clean up.

- Prepare a copy of the Student Investigation Sheet found at the end of this lab for each student.

Procedure:

Directed Inquiry

Students will rotate through four different stations that are related to concepts of reproduction. Review the procedure for each station, using one lab group's materials to model the steps when applicable.

Station 1: Asexual Reproduction: In this activity, students will observe asexual reproduction (budding) in yeast.

1. Label one petri dish and one microscope slide with an *S* for sugar. Label the other petri dish and a second microscope slide *C* for control.
2. Place 2 mL of yeast grains in each of the two petri dishes.
3. Add 1 mL of cane sugar to the petri dish labeled S.
4. Add 4 mL of warm water to each of the dishes, and cover them.
5. Place the dishes under the lamp and wait approximately 10 minutes.
6. While waiting, write a prediction about the yeast. What will you observe in the different petri dishes? Why?
7. Uncover one of the petri dishes and use a toothpick to place a sample of the yeast on an appropriately-labeled slide, and cover it with a coverslip. Repeat with the second petri dish.
8. Look at each sample under the microscope at 40×.
9. Record your observations.

Station 2: Meiosis: In this activity, students will observe prepared slides of meiosis and determine which phase they are observing.

1. Create a data table to record your observations. Include three columns with the titles Slide Name, Sketch of Observations, and Description of Meiosis Stage.
2. Place a slide under the microscope.
3. Determine which phase of meiosis is shown on the slide.
4. Record your observations in the data table including a sketch and a brief description of meiosis stage shown on the slide.
5. Repeat with remaining slides.
6. Make sure that you observe the slide showing several cells in mitosis at the same time.

Sample data table:

Slide Name	Sketch of Observations	Description of Meiosis Stage

Station 3: Modeling Non-Disjunction: In this activity, students will use materials to model non-disjunction.

1. Use two different colors of pipe cleaners to represent two chromosomes. The paper plate models the cell. Feel free to draw spindle fibers or other structures of cell division on the plate.
2. Model the stages of meiosis I using the pipe cleaners and a new plate for each stage. You will need two plates for the final stage. You may cut the pipe cleaners into smaller pieces as needed.
3. At the appropriate point, introduce the mutation of non-disjunction into your model.
4. Show how the chromosomes are affected by this mutation and how the daughter cells end up with aneuploidy.
5. Sketch a picture of the model in your data sheet.

Guided Inquiry

Students can develop their own plans for collecting data, based on their knowledge of the procedure and materials used. Allow them to walk around the room to observe the available materials for each station, but do not show them the step-by-step procedures. Ask the students some guiding questions to help them focus their inquiry:

- Have you ever used yeast in cooking? If so, what do you have to do to make the yeast active?
- How can you use the materials in Station 1 to observe asexual reproduction?
- What data can you collect about meiosis in Station 2?
- How can you model the stages of meiosis I in Station 3 to show what happens in non-disjunction?

Divide students into small groups and instruct them to develop a procedure for each station. Have them make a list of the available materials, design a step-by-step procedure, and develop a method for data collection. Once you have approved the station procedures for each group, allow the group to begin one station and rotate through all three.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. What did you observe in your *S* group of yeast and your *C* group of yeast? Sample answer: *I observed individual yeast cells from the C sample, and I observed many budding cells in the S sample.*

2. What accounted for the difference in the two groups of yeast? *Because the only difference in the two samples is the presence of sugar, I can infer than sugar starts or increases budding in yeast.*

3. If you were able to observe a prepared slide of meiosis with several cells going through meiosis, which meiotic phase did you observe most? *Student answers will vary. The longest (and thus most common) phase of meiosis is prophase I.*

4. What can you conclude about the relative length of the phase that you observed most, and why? *Sample answer: I can conclude that prophase I is the longest meiotic phase because in a random sample, more cells were in prophase I than in any other phase.*

5. How did you model crossing over in Station 3? *To model crossing over, we twisted the two pipe cleaners around each other. Then we used scissors to cut the pieces and switch them.*

6. How would a model of monosomy be different than a model of trisomy? *We would model monosomy by giving one of the daughter cells only one copy of a chromosome. We would model trisomy by giving a daughter cell three copies of a chromosome.*

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing.
    - Applies mathematical operations and principles to replicate the real thing.
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
- Gather Data
  - Chooses appropriate tools to conduct an investigation:
    - Clock/stopwatch
    - Microscope
    - Petri dish
    - Graduated cylinder
    - Slides and cover slips
  - Uses senses to observe:
    - Seeing (color, shape, size, texture, motion)
  - Uses the appropriate format to record data:
    - Table
    - Writing (journal, worksheet, electronic text)
    - Sketch
    - Photograph/image
- Interpret Data
  - Identifies and interprets patterns:
    - Repeating physical or data pattern
- Patterns and Systems
  - Patterns and Change
    - Patterns in nature may be simple repeating patterns or complex growing or changing patterns.
    - Many patterns in nature occur in cycles.
    - Cycles may be short, such as the second hand of a clock, or long such as the cycle of a year.
    - Mathematical patterns help to predict future events and describe change in systems.

    - Systems
        - A system, such as the human body, is composed of subsystems.

- Scientific Endeavor
    - Characteristics of Science
        - Scientists are curious about wanting to know how things work.

One way to make sense of something is to think of how it relates to something more familiar.

Exploration Teacher Guide: Asexual and Sexual Reproduction

Overview

Students will observe the processes of asexual and sexual reproduction. They will explore the various stages of mitosis and meiosis and examine the difference between the two. Students will also analyze and identify the position of chromosomes and chromatids during various phases of mitosis and meiosis.

Student Learning Objectives

- investigate how cells undergo the processes of mitosis and meiosis
- identify the position of chromosomes and chromatids during different phases of mitosis and meiosis
- examine the types of reproduction in various organisms

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Divide* tab, students will start the activity by selecting mitosis or meiosis using the *Mitosis* and *Meiosis* radio buttons provided. An empty cell in the first phase of the selected process will appear on the screen. Students will drag chromosomes or chromatids from the *Chromosomes Available* section and *Chromatids Available* section and drop them in the cell. Students will identify the correct position of chromosomes or chromatids based on the phase of the cell. The *Complete Phase* button is used when all the chromosomes and chromatids are dropped. Any incorrectly dropped chromosomes or chromatids will fade away and students will be asked to try again. When all chromosomes and chromatids are dropped successfully, students will use the *Proceed* button to proceed to the next phase of the cell division process.

As a phase of the cell is completed, a smaller image of the cell is available in the interactivity area as a hint. Students can click on this image of the cell to view the arrangement of chromosomes in the completed phase.

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Students may use the *Reset* button to remove the chromosomes and chromatids that they have added to the cell. They may use the *Start Over* button to start again from the beginning.

In the *Reproduce* tab, students will select an organism using options in the *Organism* dropdown list. They will select a type of reproduction from the *Type of Reproduction* dropdown list. Students then will select the type of cells required for the reproduction of the selected organism. If the selected organism is human or rat, students must select two cells for reproducing the selected organism. Students can use the *Reproduce* button to view an animation describing the reproduction process of the selected organism.

Students may use the *Reset* button to undo what they have done and start again.

Answers to Questions in Student Worksheet

1. Explain the importance of reproduction.
   Answer: Reproduction leads to the production of the next generation of individuals of the same species. It is important as it is necessary for the continuation of the species. The species will become extinct if there is no reproduction.

2. Differentiate between asexual and sexual reproduction.
   Answer: Asexual reproduction describes a type of reproduction where only one parent offers genes to the offspring whereas sexual reproduction involves the fusion of two special cells called gametes. Gametes can come from two different parents or from the same parent.

3. Describe the advantages and disadvantages of sexual and asexual reproduction.
   Answer: The advantage of asexual reproduction is that only one parent can produce a large number of offspring. However, this leads to the production of clones with no genetic variability.
   Sexual reproduction gives rise to genetic variability due to the combination of two different gametes. However, this process is more tedious and produces a smaller number of offspring.

4. Comment on the implications of mitosis and meiosis for genetic variation.
   Answer: Mitosis duplicates the DNA of the parent cell, with no genetic variation between generations. Meiosis produces genetic variation through crossover events during meiosis. Genetic variation also occurs by the production of haploid cells that combine their DNA with other haploid cells, usually originating from different parents.

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5. List five different types of asexual reproduction.
   Answer: binary fission, budding, vegetative propagation, fragmentation, and spore formation.

6. List the correct order of the phases of mitosis.
   Answer: The correct order of the phases of mitosis is prophase, prometaphase, metaphase, anaphase, and telophase.

7. Compare and contrast at least four different characteristics of mitosis and meiosis
   Answer:

Characteristics	**Mitosis**	**Meiosis**
Site	Somatic Cells	Gametes
Number of Divisions	One	Two
Number of cells produced	Two	Four
Crossing Over	No	Yes
Parent Cell	Haploid or Diploid	Diploid
Daughter Cells	Diploid	Haploid

8. Explain the term *crossing over*.
   Answer: Crossing over involves the exchange of genetic material by non-sister chromatids in the prophase stage of meiosis. It is important as it results in a new combination of alleles.

9. Comment on the importance of centrioles.
   Answer: Centrioles are important because they form spindle fibers. Spindle fibers attach to the chromatids and help in the movement of chromatids.

10. List the phase of mitosis during which
    a. the nuclear membrane is broken into fragments
    b. the equatorial plate of the mitotic spindle is formed
    c. the centrioles divide and start moving toward the opposite poles

    Answer:

    a. prometaphase
    b. metaphase
    c. prophase

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11. Differentiate between anaphase I and anaphase II.
    Answer: During anaphase I the homologous chromosomes separate and move to opposite poles of the cell. During anaphase II, the centromeres split, and the sister chromatids are pulled apart to opposite poles of the cell.

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Exploration Teacher Guide: Asexual and Sexual Reproduction

Overview

Students will observe the processes of asexual and sexual reproduction. They will explore the various stages of mitosis and meiosis and examine the difference between the two. Students will also analyze and identify the position of chromosomes and chromatids during various phases of mitosis and meiosis.

Student Learning Objectives

- Investigate how cells undergo the processes of mitosis and meiosis.
- Identify the position of chromosomes and chromatids during different phases of mitosis and meiosis.
- Examine the types of reproduction in various organisms.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Divide* tab, students start the activity by selecting mitosis or meiosis using the *Mitosis* and *Meiosis* radio buttons provided. An empty cell in the first phase of the selected process appears on the screen. Students drag chromosomes and/or chromatids from the *Chromosomes Available* section and *Chromatids Available* section and drop them in the cell. Students identify the correct position of chromosomes/chromatids based on the phase of the cell. The *Complete Phase* button is used when all the chromosomes and/or chromatids are dropped. Any incorrectly dropped chromosomes and/or chromatids fade away and students are asked to try again. When all chromosomes and/or chromatids are dropped successfully, students use the *Proceed* button to proceed to the next phase of the cell division process.

As a phase of the cell is completed, a smaller image of the cell is available in the interactivity area as a hint. Students click on this image of the cell to view the arrangement of chromosomes in the completed phase.

Students may use the *Reset* button to remove the chromosomes and/or chromatids that they have added to the cell. They may use the *Start Over* button to start again from the beginning.

In the *Reproduce* tab, students select an organism using options in the *Organism* dropdown list. They select a type of reproduction from the *Type of Reproduction* dropdown list. Students then select the type of cells required for the reproduction of the selected organism. If the selected organism is human or rat, students must select two cells for reproducing the selected organism. Students use the *Reproduce* button to view an animation describing the reproduction process of the selected organism.

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Students may use the *Reset* button to undo what they have done and start again.

Answers to Questions in Student Worksheet

1. Explain the importance of reproduction.

   Answer: Reproduction leads to the production of the next generation of individuals of the same species. It is important as it is necessary for the continuation of the species. The species will become extinct if there is no reproduction.

2. Differentiate between asexual and sexual reproduction.

   Answer: Asexual reproduction describes a type of reproduction where only one parent offers genes to the offspring whereas sexual reproduction involves the fusion of two special cells called gametes. Gametes can come from two different parents or from the same parent.

3. Describe the advantages and disadvantages of sexual and asexual reproduction.

   Answer: The advantage of asexual reproduction is that only one parent can produce a large number of offspring. However, this leads to the production of clones with no genetic variability.
   Sexual reproduction, on the other hand gives rise to genetic variability due to the combination of two different gametes. However, this process is more tedious and produces a smaller number of offspring.

4. List five different types of asexual reproduction.

   Answer: Binary fission, budding, vegetative propagation, fragmentation, and spore formation.

5. List the correct order of the phases of mitosis.

   Answer: The correct order of the phases of mitosis is prophase, prometaphase, metaphase, anaphase, and telophase.

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6. Compare and contrast at least four different characteristics of mitosis and meiosis

   Answer:

Table 1: Comparison of Mitosis with Meiosis

Characteristics	Mitosis	Meiosis
Site	Somatic Cells	Gametes
Number of Divisions	One	Two
Number of cells produced	Two	Four
Crossing Over	No	Yes
Parent Cell	Haploid or Diploid	Diploid
Daughter Cells	Diploid	Haploid

7. Explain the term crossing over.

   Answer: Crossing over involves the exchange of genetic material by non sister chromatids in the prophase I stage of meiosis I. It is important as it results in a new combination of alleles.

8. Comment on the importance of centrioles.

   Answer:Centrioles are important as they form spindle fibers. Spindle fibers attach to the chromatids and help in the movement of chromatids.

9. List the phase of mitosis during which
   a. The nuclear membrane is broken into fragments.
   b. The equatorial plate of the mitotic spindle is formed.
   c. The centrioles divided and start moving to towards the opposite poles.

   Answer:
   a. Prometaphase
   b. Metaphase
   c. Prophase

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10. Differentiate between anaphase I and anaphase II

Answer:During anaphase I the homologous chromosomes separate and move to opposite poles of the cell. But, during anaphase II the centromeres split and the sister chromatids are pulled apart to opposite poles of the cell.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

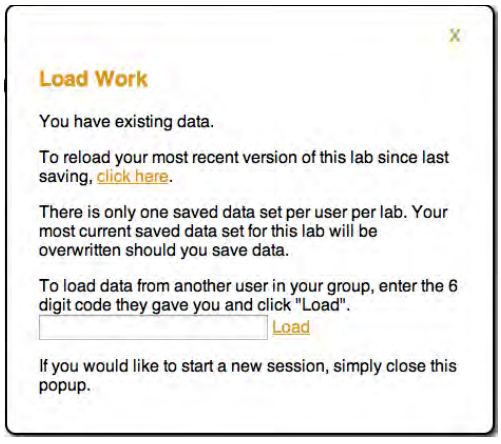
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

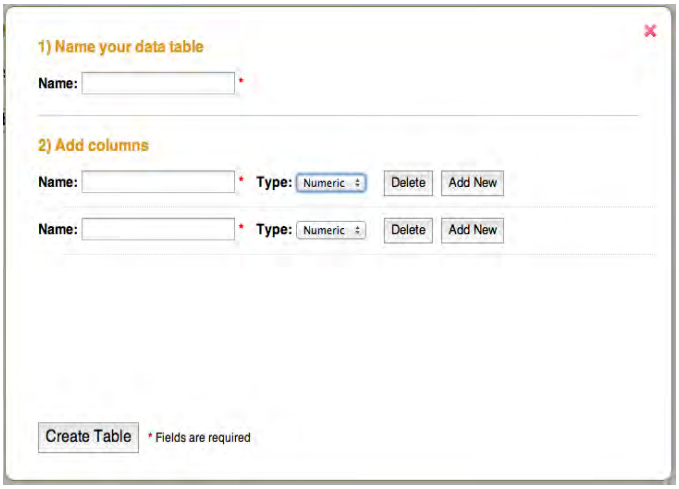
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



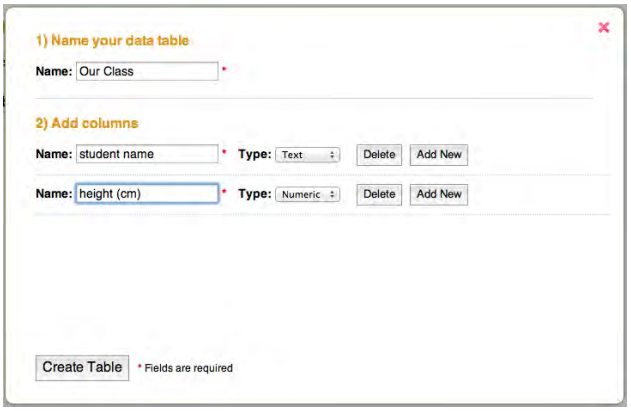
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

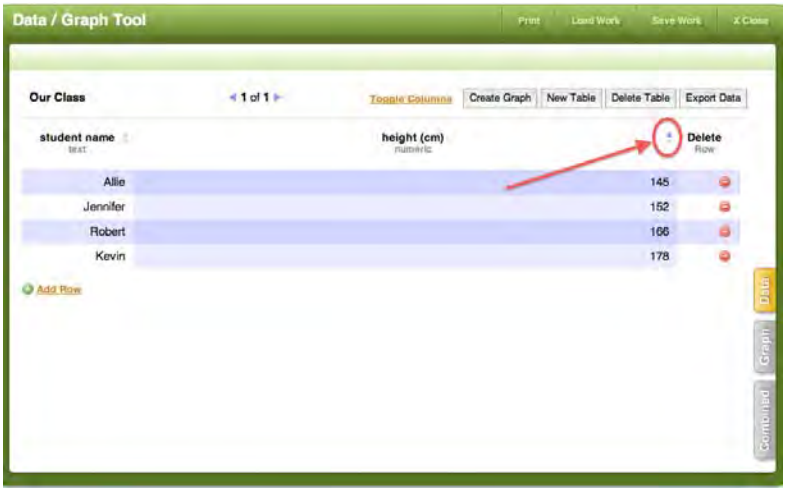
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

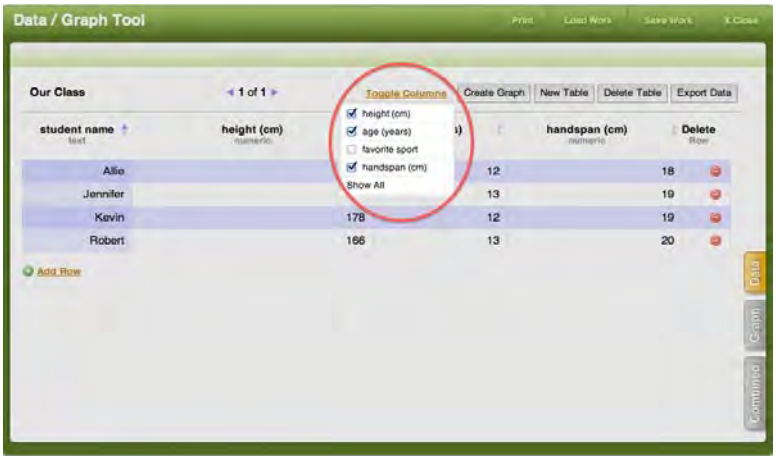


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

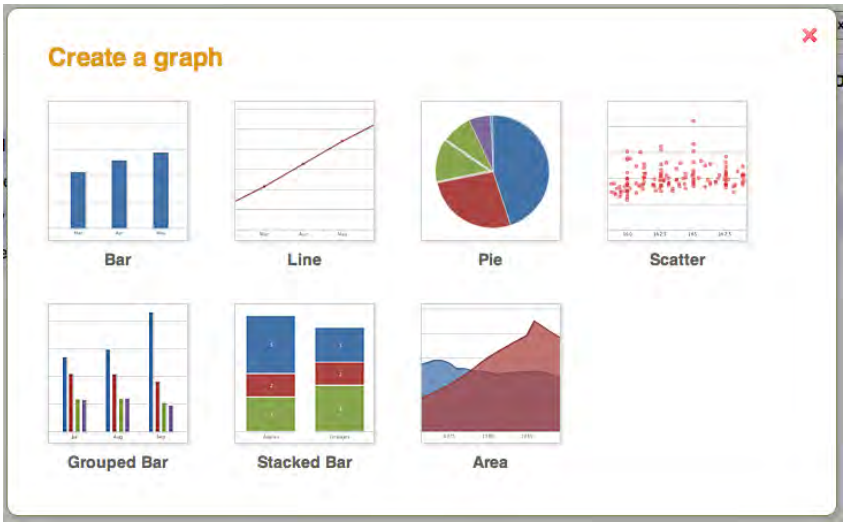
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

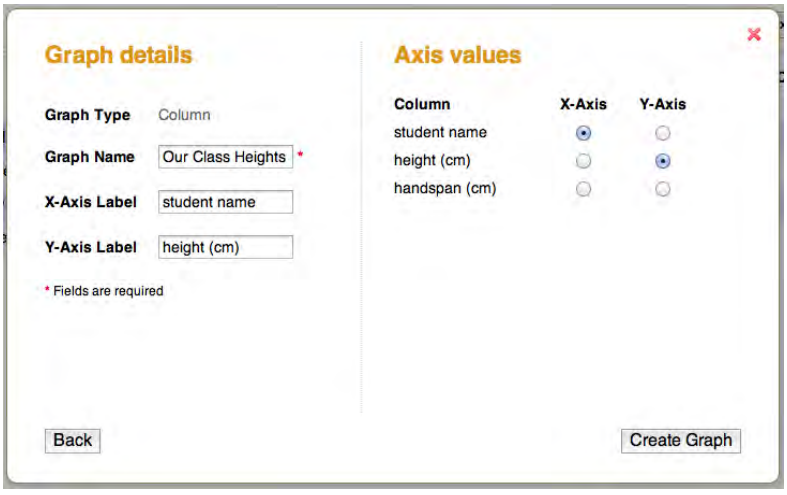
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

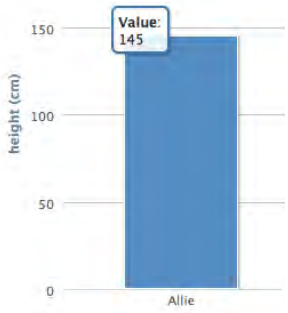


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

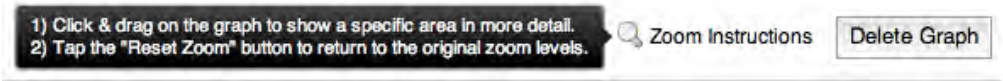
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Activity

Investigating DNA

During meiosis, chromosomes pair up. These pairs are called *homologous chromosomes*. These chromosomes can twist around each other, leading to an exchange of genetic information called *crossing over*. In this activity, students will model how homologous chromosomes pair up and exchange genetic material.

Safety Precautions:
Remind students to follow all general lab safety rules, wear closed-toe shoes, and not to eat or drink anything in the lab. Students should use care when handling scissors.

Suggested Materials:
Per group:

- scissors
- paper, cut into 4 strips
- colored pencil, red
- colored pencil, blue
- tape

To introduce the activity, have students read the Reading Passage titled **How DNA Works.** Introduce the term *homologous chromosomes* and ask them to identify references to homologous chromosomes in that passage.

Procedure:

1. Direct students to write *A* and *B* on a strip of paper with the red pencil. Then, students should write *A* and *B* on a second strip of paper, also with the red pencil. For each strip, write the *A* at the bottom of the strip and *B* close to the center.
2. On a third strip of paper, students should write *a* and *b* with the blue pencil. Then, students should write *a* and *b* with the blue pencil on a fourth strip of paper. For each strip, write the *a* at the bottom of the strip and *b* close to the center.
3. Direct students to use tape to create homologous chromosomes.
4. Next, instruct students to model crossing over using their chromosome models.

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Analysis and Conclusions

1. How did you model homologous chromosomes?
   Answers should indicate that the strips with A *and* B *were joined together (likely with tape) and the strips with* a *and* b *were joined together.*

2. What did the letters on the strips of paper represent?
   The letters represented genes.

3. What did you do to represent crossing over between the homologous chromosomes?
   Answers should indicate that students at least crossed strips with the same letters—that is, B *with* b *or* A *with* a*. Some students may have actually cut the "genes" from strips and taped them to the other chromosome.*

4. The "arms" of a chromosome are called the *chromatids*. A chromosome consists of sister chromatids. The chromatids are attached to each other with a structure called a *centromere*. What represented the centromere in your model?
   Students likely used tape to join the chromatids (strips of paper) together. Students should at least understand that the centromere is the location where the chromatids are attached to each other, even if they did not physically attach the strips of paper with tape.

5. How does the exchange of DNA through crossing over increase genetic variation?
   Crossing-over results in unique combinations of genes from the parent organisms. This recombination of genetic material results in more variation in a population.

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing

- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)

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Hands-On Activity

The Fertilization and Development of Clay

Objective:
Students will model the process fertilization and development in sexual reproduction.

Estimated time to complete: 15 minutes

Materials:

For each group:

- colored pencils
- two different colors of clay
- tools for cutting clay such as string, floss, or a ruler (optional)

Procedure (Answer all questions in your notebook)

1. Choose one color of clay to represent the sperm cell and one color to represent the egg.
2. Combine the colored clays together. *What process does this represent?* (fertilization)
3. Combine the clays until the colors are completely blended into one new color. *Why do you blend them until one single color is made? How does this better model the process?* (It models the two sets of chromosomes, one from each parent, combining to form a new set of diploid chromosomes.)
4. Form the clay into a ball. *What does the ball of clay represent?* (the zygote)
5. Use the diagram **Gastrulation** from **Explore** section titled **Development of an Embryo** to make each stage of development with your ball of clay. Before moving on to the next stage, draw an observation of your clay at each stage. Include labels on each drawing.

Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing.
- Gather Data
  - Uses senses to observe:
    - Seeing (color, shape, size, texture, motion)
- Patterns and Systems
  - Patterns and Change
    - Patterns in nature may be simple repeating patterns or complex growing or

changing patterns.

- Scientific Endeavor
  - Characteristics of Science
    - Scientists are curious about wanting to know how things work.

Hands-On Activity

Meiosis Simulation

In this lesson, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated.

Materials:

- Foam noodles sold for pool play: 12 pink and 12 blue.
- If foam noodles are not available or you prefer to do the hands-on activity on a small scale, substitute 12 pink and 12 blue pipe cleaners for the foam noodles.
- Paper and pen for each group to record the final genetic content of their gametes
- Video camera (optional)

Cut 4 pink foam noodles in half to make 8 short pink noodles. Cut 4 blue foam noodles in half to make 8 short blue noodles. The final materials should include: 8 short and 8 long pink noodles; 8 short and 8 long blue noodles (32 noodles total). *Variation: Substitute pipe cleaners for the foam noodles and carry out the activity on a large table that eight students can gather around.*

Take students to a soccer field or basketball court where there is plenty of room for each group to work without bumping into another group. Divide students into groups of eight. If you have a group with fewer than eight, either divide those students to work with existing full groups or find volunteers from another class to make up the difference. Another option is to assign extra students the task of recording the simulations using video cameras.

Tell students that each group will simulate the chromosomal replication and movement in a cell undergoing meiosis. The cell begins with a full diploid set of chromosomes—half from the mother (pink) and half from the father (blue). To keep things simple, the cell has only two pairs of chromosomes: two short and two long chromosomes.

Each group of eight should receive the following: two short pink, two long pink, two short blue, and two long blue noodles. Each student is responsible for one noodle. Each group should also have a piece of paper and a pen to record the outcome of the activity.

Tell students that they represent the chromosomes in a cell that has just undergone replication of its chromosomes. Tell students that they need to identify their replicated sister chromatid by standing next

to the person holding an identical copy of their chromosome. Allow students to group themselves this way, providing assistance where needed.

Then, tell students that meiosis will begin and that they must work as a group to choreograph the movements of the chromosomes to accurately simulate the actual movements of chromosomes in a cell undergoing meiosis. Students must work as a group to decide how to represent each stage of meiosis using their pool noodles to represent the chromosomes. They are to do this simulation in the form of a walking “dance” in which they walk in a particular pattern inside a perimeter to designate the cell. This walking “dance” is to represent the pattern of movement of the chromosomes inside the cell during each stage of meiosis.

You may wish to prompt students to realize that their first task must be to determine which chromosomes are homologous (the long blue and long pink are homologous; the short blue and short pink are homologous). Then they can start thinking about how to line up and begin the chromosome movement.

Provide 15 to 20 minutes for each group to work out its choreography. When a group is ready, use a video camera to record the group’s meiotic “dance.”

Be sure that at the end of each group’s dance, two students are standing together in each final gamete cell and that one of each chromosome is represented (i.e., one long and one short noodle of any color combination). Have one member of each group record the color and size of each chromosome in each gamete formed. This information will be used in a later session.

Final Note: This activity lends itself to allow students to focus on the genetic variety in the final gamete cells. Because there are two homologous pairs of chromosomes, there are 2^n or 4 possible gamete types: 1) short pink, long pink; 2) short blue, long blue; 3) short pink, long blue; 4) short blue, long pink. Not all groups will end up with all of these combinations, however. Depending on how they sort during Meiosis I, different groups will end with different combinations of colors in their gametes. All gametes, however, should have one long and one short chromosome.

Once students have completed this activity, bring them together to discuss the benefits and limitations (pros and cons) of this activity to accurately model or simulate meiosis. In the discussion, touch on the usefulness of using models in general to communicate or aid in the understanding of science concepts.

Hands-On Activity

The Same or Different?

Objective:
Students will model the advantages and disadvantages of asexual and sexual reproduction.

Estimated time to complete: 10 minutes

Materials:

For each student:

- several beads of one color
- colored pencils
- string, approximately 30 centimeters long

Procedure:

1. String your beads on the piece of string to make a bracelet.
2. Draw a colored sketch of your completed bracelet at the bottom of the Hands-On Activity Sheet.
3. Find a classmate with differently colored beads.
4. Together, use the beads to make a new bracelet with both colors. Feel free to make a creative pattern with the beads.
5. Draw a colored sketch of your completed bracelet at the bottom of the Hands-On Activity Sheet.
6. Use the processes of making the bracelets as your guide to label each bracelet as either "Asexual Reproduction" or "Sexual Reproduction".

Inquiry and Nature of Science Skills in this Activity:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
- Scientific Endeavor
  - Characteristics of Science
    - Scientists are curious about wanting to know how things work.

Exploration Teacher Guide: Circulatory System

Overview

The circulatory system helps in transporting blood to different parts of the body. In this Exploration, students explore the various parts of an open and a closed circulatory system and trace the path of blood through the human circulatory system.

Student Learning Objectives

- Investigate the structure and functions of various parts of an open circulatory system.
- Investigate the structure and functions of various parts of a closed circulatory system.
- Trace the path of blood through the human circulatory system.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Explore* tab, students investigate the structure of various parts of the open and closed circulatory system. They select the type of organism they want to explore using the two radio button options. An image of an open circulatory system is displayed if *Invertebrates* is selected. An image of the closed circulatory system is displayed if *Vertebrates* is selected. When the students click on a part of the selected circulatory system, information about the structure and functions of the selected part is displayed.

In the *Circulate* tab, students trace the path of blood through the human circulatory system. They have to identify the correct order in which blood flows through different organs of the circulatory system. In the *Trace Path* section, organ names are available as buttons. Students click these buttons in the correct order to examine the blood flow. Negative feedback appears if an organ is not selected in the correct order and the students are asked to select another organ and try again. Positive feedback appears if an organ is selected in the correct order and an animation shows the flow of blood from the previously selected organ to the current organ. The *Path Taken* section maintains a timeline of the organs selected in the correct order. Some distracters are also present in the *Trace Path* section.

The students may use the *Reset* button to undo what they have done and trace the path of blood again. The *Start Over* button shuffles the order of appearance of organs in the *Trace Path* section.

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Answers to Questions in the Student Worksheet

1. Name any three parts of a circulatory system found in invertebrates.

   Answer: Pump, ostium, and, valve are three parts of an open circulatory system found in invertebrates.

2. Name any three parts of a circulatory system found in vertebrates.

   Answer: Lungs, heart, and, arteries valve are three parts of a closed circulatory system found in vertebrates.

3. Describe the arteries present in an open circulatory system.

   Answer: The arteries in an open circulatory system are open-ended. They open into the body cavities called hemocoels.

4. Explain the functions of the heart in a closed circulatory system.

   Answer: A closed circulatory system has one heart. It is made up of four chambers, two atria and two ventricles. The atria collect blood from different parts of the body while the ventricles send blood to different parts of the body.

5. Explain the importance of lungs in the circulatory system.

   Answer: Deoxygenated blood enters the lungs and gets oxygenated. It is then transported to other cells and tissues in the body. The lungs are responsible for oxygenating blood and hence, are an important part of the circulatory system.

6. Explain the function of vena cavae.

   Answer: The primary function of the superior and inferior vena cavae is to collect oxygen-poor blood from all parts of the body and bring it to the heart.

7. Differentiate between the right and the left atrium.

   Answer: The right atrium receives oxygen-poor blood from the superior and inferior vena cavae and transports it to the right ventricle. It is separated from the right ventricle by the tricuspid valve. The left atrium, on the other hand, receives oxygen-rich blood from the lungs and transports it to the left ventricle. It is separated from the left ventricle by the mitral valve.

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8. Identify whether blood entering the pulmonary arteries is oxygen-rich or oxygen-poor.

   Answer: The pulmonary artery receives blood from the right ventricle and transports it to the lungs. Oxygenation of blood takes place in the lungs. Hence, blood entering the pulmonary arteries is oxygen-poor.

9. Use this Exploration to identify how oxygen-rich blood is transported to different parts of the body.

   Answer: The left ventricle transports oxygen-rich blood to the aorta which, in turn, transports it to different parts of the body.

10. Blood has entered the right ventricle. Use this Exploration to trace the path of blood through the remaining organs of the human circulatory system.

    Answer: Oxygenated blood from the right ventricle enters the lungs by the pulmonary artery. It gets oxygenated and is then transported to the left atrium by the pulmonary vein. It then enters the left ventricle and is transported to other parts of the body by the aorta.

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Exploration Teacher Guide: Digestive System

Overview

The digestive system helps in the digestion of ingested food and absorption of nutrients. In this Exploration, students explore the structure and function of different parts of the digestive system. They also examine the digestion and absorption of different types of food by the digestive system.

Student Learning Objectives

- Identify the function of the parts of the digestive system.
- Examine the digestion and absorption of food by the digestive system.
- Analyze the process of digestion.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Structure and Function* tab, students identify the various parts of the digestive system. They also identify the functions of these parts. This is a two-step activity. In step 1, an image of the human digestive system with empty slots to label the organs in the respiratory system, is available on the activity area. Students drag the organ labels from the *Select Organ* section and drop them to their corresponding slots. When all the labels are dropped correctly, students use the *Proceed* button to move on to step 2. They may use the *Reset* button to undo what they have done and drop organ labels again.

In step 2, an image of the human digestive system with empty slots to label the functions of the organs in the digestive system, is available on the activity area. Students drag the function labels from the *Select Function* section and drop them to slots of the corresponding organs that perform that function. The function, chemical digestion, is performed by both the stomach and the salivary glands. The stomach also performs the function, muscular churning. The students may use the *Reset* button to undo what they have done and drop function labels again. They may use the *Start Over* button to go back to step 1.

In the *Digestion* tab, students examine the digestion and absorption of different types of food by the digestive system. They select the food they want to explore from the *Select Food* section. The students then use the *Digest* button to observe an animation of digestion and absorption of the selected food by the respiratory system. Feedback will explain the process of digestion of the food type and the nutrients absorbed. Students may use the *Reset* button to select another food type.

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In the *Tracker* tab, students can track the organs and functions that they have identified correctly in the *Structure and Function* tab. They can also view an image of the various organs.

Answers to Questions in the Student Worksheet

1. List the different parts of the digestive system.

   Answer: The digestive system consists of the mouth, salivary glands, esophagus, stomach, small intestines, pancreas, liver, and large intestine.

2. Describe the process of digestion.

   Answer: Digestion is a process in which food is ingested and broken down into smaller particles. These smaller particles are absorbed by the body and the undigested material is eliminated as waste.

3. Explain the importance of the stomach.

   Answer: The stomach is the part of the digestive system where ingested food is digested completely. It secretes gastric juices which help in chemical breakdown of ingested food. It also consists of smooth muscles which help in muscular churning of ingested food.

4. Analyze and describe the significance of the large intestine.

   Answer: The large intestine is responsible for eliminating toxic waste from the body. It is also helps in absorption of water.

5. Describe the structure of the small intestine and explain its importance.

   Answer: The small intestine is a tubular, coiled structure present below the stomach. It is important as it absorbs nutrients from digested food and transports the absorbed nutrients to the blood stream.

6. Describe how chemical and mechanical digestion is performed by the mouth.

   Answer: The wall of the mouth is lined with tiny glands which secrete acidic juices. This helps the mouth perform chemical digestion. The chewing action of the tongue and teeth present in the mouth help in mechanical digestion.

7. Identify the function of the liver and the pancreas.

   Answer: The liver secretes bile and the pancreas secretes pancreatic juices. This helps in chemical digestion.

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8. Explain the function of the salivary glands.

   Answer: The salivary glands produce saliva and secrete enzymes to perform chemical digestion. Enzymes like amylase, present in the salivary glands, help in breaking down food chemically.

9. Identify the nutrients obtained from green leafy vegetables. Also, explain their significance.

   Answer: Green leafy vegetables are a rich source of vitamins. They contain fat-soluble and water-soluble vitamins. They are required for growth and development.

10. Explain why it is important to include carbohydrates in the diet. Also, name two foods rich in carbohydrates.

    Answer: When carbohydrates breakdown, they yield glucose, which acts as a source of energy. It is required for the proper functioning of the brain and all other cells of the body. Hence, it is important to include carbohydrates in the diet. Rice and potatoes are foods rich in carbohydrates.

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Hands-On Lab

The Hierarchy of Organ Systems

Timing: one 90-minute class session or as an extended series of projects

Objective(s):
Students will model the hierarchy of cell types, tissues, organs, and organ systems within living things, and use their models to portray how they interact to perform the functions of life.

Materials:
Make available a variety of materials to support student choices. Student models may be physical models that can be manipulated, or they may be conceptual models that are portrayed on the computer, or students may even choose to create a dramatic skit in which they act out the roles of the different cell types.

Teacher Notes:

- Have students propose the nature of the model in advance of the lab so that you can approve their ideas based on feasibility and availability of materials or other necessary support.
- Gather materials in advance of students performing the lab.
- You may want to have different groups prepare models for each system, with the awareness that later they will need to work across lab groups to show how the systems interact.

Procedure

Part I: Organ System Hierarchy

1. Each lab group should discuss a way to model one or more of the following body systems:
    a. Nervous System
    b. Muscular System
    c. Skeletal System
    d. Cardiovascular System
    e. Respiratory System
2. The model should contain a way to portray the relationships between cell types, tissues, organs, and organ systems within the chosen system(s).
3. The model also should portray how the cells, tissues, organs, and the entire system carry out its primary functions.
4. Once the plans for the model are approved, lab groups can proceed to create the model(s).
5. Lab groups should present to the class and explain how each model portrays the hierarchy and function of the organ system.

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Part II: Organ System Interactions

6. For the interactions described, students should identify ways in which the systems interact on the different levels of the organ system hierarchy: individual cells, tissues, organs, and entire systems.
7. Lab groups assigned to the nervous, muscular, and skeletal systems should work together to use their models to show how these humans use these systems to move and interact by responding to stimuli.
8. Lab groups assigned to the cardiovascular and respiratory system should work together to use their models to show how blood is oxygenated and delivered to muscles.

Analysis and Conclusions

1. Identify how your model portrayed the relationships between cell types, tissues, organs, and organ systems.
Sample Answer: Our model used a computer animation to show an individual nerve cell, then to zoom out to show how many of these nerve cells make up a nerve fiber that is part of the brain that is part of the nervous system.

2. Which aspects of your model were most like the system being modeled? Which aspects were unlike the system being modeled? Explain.
Sample Answer: Our model showed what the different items in the nervous system hierarchy (cell, tissue, organ, and organ system) looked like, but it did not accurately portray the functioning of these parts. We just showed a pulse of light to symbolize the nerve signal traveling through the system.

3. Explain how your model portrayed interactions at multiple levels among systems.
Sample Answer: Our model showed that when a nerve impulse leaves the brain and travels down the nerves, it ends with a muscle cell that is part of muscle tissue, causing the larger muscle to contract and pull on the bones that are attached to the muscle tissue, so movement occurs.

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - simulate the real thing that cannot easily be studied or manipulated
    - have as many details as possible replicated from the real thing
    - function exactly like or similarly to the real thing

- Communication in Science
  - Report results using:
    - peer presentation

- Patterns and Systems
  - Systems:
    - A system, such as the human body, is composed of subsystems.
    - Physical and biological systems tend to change until they reach equilibrium and remain that way until their surroundings change.
    - A system usually has some properties that are different from those of its parts but appear because of interaction of those parts.

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Exploration Teacher Guide: Homeostasis

Overview

Students will observe the effect of change in environmental temperature on the human body. They will identify the steps taken by the human body to maintain homeostasis. The students will also examine the principle and working of a surface temperature sensor.

Student Learning Objectives

- Examine the principle and working of a surface temperature sensor.
- Observe the effect of change in environmental temperature on the human body.
- Identify the actions taken by the body to bring the body temperature back to normal.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In this Exploration, the students observe the effect of environmental temperature on human body temperature and maintain homeostasis through various body actions.

In the In the *Apparatus* tab, the students learn about the experimental setup used when this experiment is done in real-life. Information is also provided about the surface temperature sensor used in the setup.

In the *Explore* tab, the students select environmental temperature from the *Select Environmental Temperature* slider. Body temperature changes with a change in the environmental temperature. The values of environmental temperature and body temperature are displayed. The students select an action from the *Select Action* section to bring the body temperature back to normal and maintain homeostasis. Positive or negative feedback is given based on the action selected.

The students may use the *Reset* button to undo what they have done and change the environmental temperature.

In the *Tracker* tab, the students can observe the environmental temperature and the corresponding body temperature. They can also observe the actions they have taken to maintain homeostasis and examine whether the selected action helped in maintain homeostasis or not.

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Answers to Questions in the Student Worksheet

1. Explain what you understand by homeostasis of the human body.

   Answer: Body temperature changes with a change in the environmental temperature. The human body takes various steps to bring the body temperature back to normal. This process of maintaining stable internal conditions is known as homeostasis.

2. List three actions that may be taken to maintain homeostasis.

   Answer: Sweating, shivering, and wearing warm clothes are three actions taken that may be taken to maintain homeostasis.

3. Name the gland that controls and maintains homeostasis in relationship to temperature in humans. Explain how it works.

   Answer: The hypothalamus controls and maintains homeostasis. It detects a change in the body temperature and sends signals to the brain and other parts of the body to take appropriate actions to maintain homeostasis.

4. Explain how the body maintains homeostasis by shivering.

   Answer: Shivering leads to an increase in the muscular activity of vital organs. Heat is generated as a byproduct of this activity and brings the body temperature back to normal.

5. The body temperature of a man is 38°C (100.4°F). Use this Exploration to list the steps that can be taken to bring the body temperature back to normal.

   Answer: The body temperature of this man can be brought back to normal by sweating, removing warm clothes, and entering shade.

6. The body temperature of a man is 38°C (100.4°F). Analyze whether his body temperature will come back to normal if he stand under the sun.

   Answer: The body temperature of this man will not come back to normal if he stands under the sun. The sun radiates heat and this heat is absorbed by our bodies. This leads to an increase in the body temperature. Thus, entering shade will help bring the body temperature back to normal.

7. Explain why we wear warm clothes during winter.

   Answer: Warm and thick clothes help in trapping heat. This increases the body temperature and helps maintain homeostasis. Thus, we wear warm clothes during winters.

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8. Explain why we sweat when we stand under the sun for a long time.

   Answer: The sun radiates a lot of heat energy which gets absorbed by the body and the body temperature rises. This heat is released when sweat evaporates off the skin surface and the body cools off. This, in turn, brings the body temperature back to normal and maintains homeostasis.

9. The body temperature of a man is 42°C (107.6°F). List the actions that can be taken to bring the temperature back to normal.

   Answer: Actions that can be taken to bring the body temperature back to normal are
   a. Sweating.
   b. Removing warm clothes.
   c. Entering shade.

10. The body temperature of a man is 34°C (93°F). List the actions that can be taken to bring the temperature back to normal.

    Answer: Actions that can be taken to bring the body temperature back to normal are
    a. Shivering.
    b. Wearing warm clothes.
    c. Standing under the sun.

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Hands-On Lab

Homeostasis and Heart Rate

Timing: one 90-minute class session

Objective(s):

In this activity, students will make predictions regarding their heart rates at rest and after light and vigorous exercise. They will learn how to take a pulse and measure heart rate before and after exercise. They will compile a table of results and discuss how and why the body adjusts heart rate in response to exercise.

Safety Precautions:
Remind students to wear closed-toe shoes. During the Hands-On Lab, students should spread apart from each other so that they do not collide during physical exercise. Some of the students will be experiencing vigorous exercise. Make sure you are aware of any students' medical conditions that may be affected by vigorous exercise.

Materials:
Per student pair:

- stopwatch or timer

Teacher Preparation:
Check that all stopwatches are in working order. You may wish to conduct at least part of this lab outside where students will have adequate space for certain exercises.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be

used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

1. Before beginning the lab ask the following questions:
   - **What is the function of the heart?** *[It pumps blood through the blood vessels to the organs of the body.]*
   - **Why do cells in the organs need a constant supply of blood?** *[to provide oxygen for cellular respiration, to provide food, and to remove the waste products of metabolism]*
2. Have students predict their own heart rate while they are at rest. Ask them to record their prediction and then share these predictions with the entire class.
3. Demonstrate how to measure a pulse (two fingertips on the wrist is usually the most effective). Explain that the pulse is an indirect measure of heart rate. Show them how to determine heart rate by counting the pulse beats over a specific period of time (1 minute).
4. Divide the students into groups of three. Have the students measure their own pulse. Each student should create a table in their notebook and record their predictions and the actual heart rates of all the members of their group. Some students will require help locating their pulse. Go around to the groups and clarify the pulse taking procedure.

5. Ask the questions**: How accurate were your predictions? Did everybody in your group have the same resting heartbeat rate? If not can you suggest why? What was the range of heartbeat rate for your group? What do you think your heart rate would be if you had just taken vigorous exercise?**
6. Next, explain to the class that they are going to plan, design, and carry out an investigation of how the heart behaves before and after different amounts of exercise. Have students brainstorm and agree upon a short form of light exercise (e.g., walking a specific distance or getting in and out of a chair a certain number of times). Then have students suggest a rigorous exercise they can do (e.g., running 100 meters, running up and down three flights of stairs). Make sure students consider the factors of time and risk in making their suggestions for the experimental design.
7. Ask students to suggest when they should take the heart rate in relation to the time of exercise (typically before, immediately after (0) minutes, at 2 minutes, 5 minutes, and if time 10 minutes). Why should we bother taking the heart rate at these times? How many trials should be run in order to have confidence about the accuracy of the data? Work with the class to create a class data table on the board. The data table should include columns for each measurement time for both light and vigorous exercise.
8. Groups should conduct the first investigation of light exercise. One person only should exercise, one use the stopwatch and take the pulse, and one record the data before and at the agreed upon intervals after exercise. Groups should repeat the procedure with a different group member doing the agreed upon vigorous exercise, according to the investigation plan they developed.
9. Have each group calculate the mean heart rates for each type of exercise. Groups should transfer group data to the class data table. As a class, calculate the class mean.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions or assigning them as homework. Insist students justify their answers using means or specific examples from the data the class has collected.

1. What happens to the heart rate during exercise? *[it increases]*

2. Does everyone's heart rate change the same amount during light exercise? *[No]*

3. Does everyone's heart rate change the same amount during vigorous exercise? *[No]*

4. How does the heart rate compare between rest, light exercise, and vigorous exercise? *[Heart rate is greater after rigorous exercise than after light exercise and greater after light exercise than at rest.]*

5. What happens to heart rate after exercise? *[it decreases gradually]*

6. Estimate how long after vigorous exercise it takes for the heart rate to return to its resting heart rate level. *[Students may make a rough estimate or use graphical means to calculate this.]*

Additional Questions

7. \Why do you think the heart rate changes during exercise? Did you observe any other changes in the body that may support your answer? *[Sample answer: Because the muscles doing the work need more energy and, therefore, they must respire more. For this, the muscles need more blood to transport oxygen and glucose to them and move carbon dioxide away from them.]*

8. What evidence suggested that your body was able to maintain homeostasis after your heart rate increased? *[Sample answer: My heart rate returned to its normal rate after two minutes of rest.]*

9. What do you think would happen if your heart rate failed to increase during exercise? *[Sample answer: I would only to be able to support a very light level or duration of exercise.]*

10. Why do you think some people's heart rates during exercise are slower than others? *[Answers may refer to body weight, athletic training, and heart size.]*

11. Use the Internet to investigate the feedback mechanism involved in the regulation of heart rate. Draw a flow chart indicating how it works.

12. Explain how your plan for the design of the investigation included measures to make sure the data was accurate? *[Sample answer: Instead of just performing this test with one student, we used several students and performed the test three times with each of them.]*

13. What limitations are there on the precision of the data you collected? *[Sample answer: We could only perform as many tests as fit into a single class period. We were measuring pulse using the wall clock in the classroom and taking our own count, rather than a device that times and counts the pulses.*

Guided Inquiry

1. Before beginning the lab, ask the following questions:
   - **What is the function of the heart?** *[It pumps blood around the blood vessels to the organs of the body.]*
   - **Why do cells in the organs need a constant supply of blood?** *[to provide oxygen for respiration, to provide food, and to remove the waste products of metabolism]*
2. Demonstrate how to measure a pulse (two fingertips on the wrist is usually the most effective). Explain that the pulse is an indirect measure of heart rate. Ask students how they could determine their heart rate?
3. Explain to the class that they are going to plan, design, and carry out an investigation of how the heart behaves before and at different times after different amounts of exercise. Have students divide into groups and brainstorm an experimental procedure and data protocols for this investigation, including how many trails to be run so students can be confident about the accuracy of the data. Visit each group during this time to discuss their ideas and approve their procedures. Make sure student procedures have accounted for constraints of time and risk in their experimental design.
4. Students should conduct their procedures according to their plan and record their data.

Analysis and Conclusions

Students should write a paragraph analyzing their results and providing conclusions supported by data from their investigation.

Questions

1. Why do you think the heart rate changes during exercise? Did you observe any other changes in the body that may support your answer? *[Sample answer: Because the muscles doing the work need more energy and, therefore, they must respire more. For this, the muscles need more blood to transport oxygen and glucose to them and move carbon dioxide away from them. In support of this suggestion I observed that during exercise, breathing rates increased and the person exercising took deeper breaths.]*

2. What evidence suggested that your body was able to maintain homeostasis after your heart rate increased? *Sample answer: My heart rate returned to its normal rate after two minutes of rest*.

3. What do you think would happen to your heart rate failed to increase during exercise? *[Sample answer: I would only to be able to support a very light level or short duration of exercise.]*

4. Why do you think some people's heart rates during exercise are slower than others? *[Answers may refer to body weight, athletic training, and heart size.]*

5. Use the Internet to investigate the feedback mechanism involved in the regulation of heart rate. Draw a flow chart indicating how it works.

6. Explain how your plan for the design of the investigation included measures to be sure that the data was accurate. *[Sample answer: instead of just performing this test with one student, we used several students and performed the test three times with each of them.]*

7. What limitations are there on the precision of the data you collected? *[Sample answer: We could only perform as many tests as fit into a single class period. We were measuring pulse using the wall clock in the classroom and taking our own count, rather than a device that times and counts the pulses.]*

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop predictions/hypotheses that:
    - State the expected cause and effect (if-then statement) in an investigation based on prior knowledge and experience (hypothesis)
- Design Investigations
  - Design and conduct investigations using:
    - Fair test—changing only one variable at a time makes comparisons valid
    - Independent variable—the one variable the investigator chooses to change
    - Dependent variables—what changes as a result of, or in response to, the change in the independent variable
  - Practice lab safety by:
    - Following lab safety procedures
- Gather Data
  - Use senses to observe:
    - Seeing (color, shape, size, texture, motion)
    - Kinesthetic (balance, position)
  - Use the appropriate format to record data:
    - Table
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Reporting trends and patterns in the data
    - Comparing results to hypothesis

- Patterns and Systems
  - Systems:
    - A system, such as the human body, is composed of subsystems.
    - Some systems (such as heating or cooling systems) have feedback mechanisms that serve to keep changes within specified limits.
    - Physical and biological systems tend to change until they reach equilibrium and remain that way unless their surroundings change.
- Scientific Investigation
  - Scientific Data and Outcomes:
    - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
- Scientific Endeavor
  - Characteristics of Science:
    - An important part of science is the critical review and analysis of any idea or conclusion.

Exploration Teacher Guide: Nervous System

Overview

Students will explore the different parts of the nervous system. They will identify the correct combination of body part, the nervous system region it belongs to, and its response to a nervous stimulus.

Student Learning Objectives

- Observe the structure and function of various parts of the nervous system.
- Examine body parts controlled by various regions of the nervous system.
- Identify the response of different body parts to different stimuli.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In this Exploration, the students will explore the various parts of the nervous system and identify the correct combination of body part, nervous region, and response.

In the *Basic Elements* tab, the students will observe the structure of various elements of the nervous system. When they click on a part of the brain or spinal cord, information about the structure and function of the selected part is displayed.

In the *Nerves* tab, the students select a body part from the *Select Body Part* section by clicking on it. They select a nervous region and a response from the *Select Nervous Region* and *Select Response* sections respectively by clicking on a nervous region and a response. Students can make these selections in any order.

Positive, partially correct, or negative feedback appears in a pop-up box after one option is selected in each of the three sections. When the student identifies a combination correctly, positive feedback appears. The student is asked to use the *Reset* button and select another set of body part, nervous region, and response. If the student's selection is partially correct, the feedback indicates which section has an incorrect selection and the student is encouraged to make another selection in that section. When the student makes all selections incorrectly, negative feedback is displayed.

In the *Tracker* tab, the students can observe the body part, nervous region, and response that they have identified correctly.

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Answers to Questions in the Student Worksheet

1. Name three parts of the nervous system found in the brain.

   Answer: Three parts of the nervous system found in the brain are the cerebrum, cerebellum, and the pons varolii.

2. Name two parts of the nervous system found in the spinal cord.

   Answer: Two parts of the nervous system found in the spinal cord are the caudaequina and the dura matter.

3. Explain why the cerebellum is a very important part of the nervous system.

   Answer: The cerebellum is the motor controlling area of the brain. It is highly involved in the movement-related functions of the brain. Hence, it is a very important part of the nervous system.

4. Name the structure that protects the spinal cord.

   Answer: The vertebral column protects the spinal cord.

5. Use this Exploration to identify the body parts controlled by the thoracic nervous region.

   Answer: The thoracic nervous region controls the shoulder and the biceps.

6. Use this Exploration to identify how the body parts controlled by the thoracic region respond to stimuli.

   Answer: The shoulder responds to a stimulus by moving up and down. The biceps respond to a stimulus by flexing the elbow.

7. Use this Exploration to identify the body part controlled by the lumbar region of the nervous system. Also identify the response of this body part to a stimulus.

   Answer: Feet are controlled by the lumbar region of the nervous system. The response of the feet to a stimulus is enabling movement.

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8. Explain how the feet and the bladder respond to a stimulus.

   Answer: The feet respond to a stimulus by enabling movement. The bladder responds to a stimulus by contracting the bladder walls.

9. Explain what would happen if the nose and the eyes were not controlled by the cranial region of the nervous system.

   Answer: The nose and the eyes would not respond to stimuli if they were not controlled by the cranial region of the nervous system. This means that these body parts will not be able to perform normal functions like detecting smell and dilating pupils.

10. Explain the importance of the nervous system.

    Answer: The nervous system is important as it sends messages from the brain and spinal cord to different parts of the body. It also sends messages from different parts of the body to the brain. This helps the different body parts perform their respective functions.

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Exploration Teacher Guide: Respiratory System

Overview

The respiratory system helps in the exchange of gases and in breathing. In this Exploration, students explore the various parts of the respiratory system. They identify the function of various parts of the respiratory system and also examine the exchange of gases through the respiratory system.

Student Learning Objectives

- Observe the structure of various parts of the respiratory system.
- Identify the function of the parts of the respiratory system.
- Examine the exchange of gases through the respiratory system.
- Analyze the effect of inhaling carbon monoxide and particulate matter.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion.

Using this Exploration

In the *Basic Elements* tab, students explore the various parts of the respiratory system and identify their functions. This is a two-step activity. In step 1, an image of the human respiratory system with empty slots to label the functions of the organs in the respiratory system, is available on the activity area. Students drag the function labels from the *Select Function* section and drop them to slots of the corresponding organs that perform that function. When all the labels are dropped correctly, students use the *Proceed* button to move on to step 2. They may use the *Reset* button to undo what they have done and drop function labels again.

In step 2, students observe the structure of various parts of the respiratory system. When students click on a part, information about the structure and function of the selected part is displayed. The students may use the *Start Over* button to go back to step 1.

In the *Gas Exchange* tab, students examine the exchange of some gases through the respiratory system. They select the gas molecules they want to explore from the *Select Molecule* section. The students then use the *Breathe* button to observe an animation of the flow of the selected gas molecules through the respiratory system. They may use the *Reset* button to select another gas molecule.

In the *Tracker* tab, students can track the organs and functions that they have identified correctly in the *Basic Elements* tab. They can also view an image of the various organs.

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Answers to Questions in the Student Worksheet

1. List the different parts of the respiratory system.

   Answer: The respiratory system consists of the nose, lungs, trachea, bronchi, diaphragm, larynx, pharynx, alveoli, and bronchioles.

2. Explain the importance of the lungs.

   Answer: The lungs carry out gas exchange. They also filter inhaled air and transport oxygen to various parts of the body.

3. Describe the structure of alveoli. Also, explain their function.

   Answer: Alveoli are very small, thin-walled sacs present in the respiratory system. They are surrounded by capillaries. The exchange of gases takes place in the alveoli. Oxygen diffuses into blood from the alveoli and carbon dioxide diffuses into the alveoli from blood.

4. Analyze and describe the significance of the diaphragm in the respiratory system.

   Answer: The diaphragm is a muscle in the respiratory system. It is large and flat and stretches across the base of the ribs. It contracts and expands when air is inhaled and exhaled and hence, assists in breathing.

5. Name the part of the respiratory system that is responsible for producing voice.

   Answer: The larynx is a part of the respiratory system responsible for producing voice.

6. List two functions of the nose.

   Answer: Two functions of the nose are:
   a. Help inhale and exhale
   b. Filter air

7. Describe the process of respiration.

   Answer: Oxygen is inhaled and carbon dioxide is exhaled during respiration. Oxygen from the atmosphere is inhaled and transported to all the cells and tissues of the body. Various organs of the respiratory system help in the transfer of oxygen. Carbon dioxide is released out of the body.

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8. Explain why it is important to inhale fresh, non-polluted air.

   Answer: Air pollution leads to an increase in the concentration of pollutants like carbon monoxide and particulate matter. These pollutants interfere with the respiration process and may cause many diseases. Hence, it is important to inhale fresh, non-polluted air.

9. Explain why one may suffocate by inhaling smoke.

   Answer: Smoke contains high concentration of carbon monoxide. It competes with oxygen molecules to bind to the delivery molecule hemoglobin. It combines with hemoglobin molecules and is transported to different cells of the body. As a result, the body does not get enough oxygen and one can feel dizzy and suffocate.

10. Analyze the information provided in the Exploration and interpret why exhaust gases released from cars and trucks are harmful.

    Answer: Exhaust gases released from cars and trucks contain a high concentration of particulate matter. When inhaled, the particles flow through the trachea and bronchi and get deposited in the airways. As a result of this, the particles build up in the airways and the flow of oxygen becomes less efficient. The lungs produce mucus to trap these particles. This leads to excessive coughing and causes difficulty in breathing. The deposition of small particulate matter deep into the alveoli may also cause cancer. Hence, exhaust gases released from cars and trucks are harmful.

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Hands-On Lab

The Respiratory System

Timing: one 90-minute class session

Objective(s):
Students will investigate the changes that take place in heart rate and respiration rate as a result of physical activity. Students will also observe microscope slides of mammalian respiratory tissues and identify anatomical structures within the tissues.

Safety Precautions:
Exempt from the exercise portion any student who has a health issue that would prevent them from performing this lab safely. Warn students to handle glass slides carefully; they are breakable and have sharp edges. Tell students not to clean up any broken glass themselves.

Materials:
Per student pair:

- compound microscope
- prepared microscope slides of mammalian respiratory tissues: trachea, lung, and bronchi
- stopwatch or clock with second hand
- functional model of lung, one per class (optional)

Teacher Preparation:
You will need to obtain three different prepared microscope slides containing different mammalian respiratory tissues: trachea, lung, and bronchi. If possible, obtain a functional model of a lung for students to observe. Designate an area on the board for students to share their data with pre-made data tables for them to fill in: one for effects of exercise on

heart rate and one for effects of exercise on respiration rate. Prepare a copy of the student investigation sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>
Have students place their hands on their abdomens and take three deep breaths: three inspirations followed by three expirations. Ask students to describe what they felt during each inspiration and each expiration. Then have students place their hands on their chests and repeat the three deep breaths. Ask them to describe what they felt this time.

Briefly review the structures and functions of the respiratory system, allowing students to refer to their notes as needed. Relate the discussion to the deep breathing exercise.

Review the following three parts of the lab activity before students begin working in their groups. Be sure to demonstrate how to find the pulse at the brachial or carotid artery in order to record heart rates.

Part 1:

1. Predict how exercise will affect heart rate and respiration rate.
2. Have one partner lay down quietly for one minute. After one minute, measure his or her resting heart rate by locating the pulse and counting the number of beats per minute for one minute. Record the results in your notes and on the board.
3. While your partner is still lying down, record his or her respiration rate by counting the number of breaths per minute for one minute. Record the results in your notes and on the board.
4. Have the resting partner now jog in place for one minute.
5. Immediately after exercising, record your partner's heart rate and then respiration rate by measuring each for one minute. Record the results in your notes and on the board.
6. Repeat Steps 1 through 5 with the other partner.

Sample Data Table1: Exercise and Heart Rate

	Resting Heart Rate (beats per minute)	Heart Rate Following Exercise (beats per minute)
Student 1	*62*	*117*
Student 2	*67*	*125*

Sample Data Table 2: Respiration Rate and Exercise

	Resting Respiration Rate (breaths per minute)	Resting Rate Following Exercise (breaths per minute)
Student 1	*14*	*23*
Student 2	*16*	*30*

Part 2:

1. If available, observe a functional model of a lung. Identify the trachea, bronchi, lungs, and diaphragm.
2. Observe the prepared slides of mammalian respiratory tissues. Draw sketches of each tissue you observe, and label the following structures if possible:
   In lung tissue: alveoli, blood cells, diameter of bronchus
   In trachea tissue: epithelial cells, mucosa, hyaline cartilage
   In bronchi tissue: epithelial cells

Guided Inquiry

Students can perform the deep-breathing exercise with a partner and record their observations in their notes. They should summarize their observations by relating what they felt in their abdomens and chests to the structures of the respiratory system. For example, students may write they felt their chests expand during inhalation as air entered the nose, the trachea, and filled the lungs.

Students can design their own methods for collecting data based on the objective, materials provided, and their knowledge of the respiratory system. If needed, allow students to research ways in which heart rates and respiration rates are measured.

Ask the students some guiding questions to help them focus their inquiry:

- What types of abdominal and chest cavity movements are observable during breathing?
- What are the different anatomical components of the respiratory system?
- What is the unique structure and function of each component?
- Trace the movement of oxygen from the nose (or mouth) to the blood stream and the movement of carbon dioxide from the blood stream out of the body.
- When measuring heart rate and breathing rate after exercise, what will be your control?
- What are your independent and dependent variables?
- What structures will you look for when observing the prepared slides?

Make sure students receive approval before starting Part 1 of the lab activity. All students should share their data by writing it on the board. Have students work individually to display the class data as a graph. Discuss with them the graph format that would best display the data, and guide them to choose an appropriate scale for the axes.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. Did all of the students in the class have the same resting heart rate and breathing rate? If not, what do you think might cause variations in these numbers? *Heart rates and breathing rates varied among the students in the class. These can vary depending on physical fitness and many other factors; in general, trained athletes have lower resting heart rates than they would if they were not trained.*

2. How did the change in your heart rate compare with the change in your breathing rate after exercise? *The two rates changed similarly. They both increased.*

3. Why do you think that heart rate and breathing rate increase with exercise? *During exercise, the muscles demand more oxygen. Blood must flow faster through vessels to supply additional oxygen; thus, breathing must be faster to supply additional oxygen to the blood.*

4. If you observed alveoli under the microscope, you might have observed that they have many small chambers, very much increasing the surface area available for gas exchange. In the disease emphysema, the structure of the many small chambers collapses. What effect would this likely have on gas exchange, and what symptoms might emphysema cause? *If the surface area on which gas exchange takes place is reduced, then less gas exchange occurs, resulting in a buildup of carbon dioxide in the blood.*

5. How did the cells differ in the different types of respiratory tissue? Why were they different?
The cells were different in shape and size. For example, blood cells were more rounded and depressed in the center, while epithelial cells tended to be more amorphic. Hyaline cartilage cells appeared thicker and more dense. The lung

alveoli cells were thin and flat to increase surface area for gas exchanges in the lungs. The cells differ because they are each specialized for their particular function.

Inquiry and Nature of Science Skills in this Lab:

- Identify Questions
  - Develop predictions/hypotheses that:
    - state what may happen in an investigation based on prior knowledge or experience (prediction)
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
    - can be answered with a science investigation or observational study.
- Design Investigations
  - Design and conduct investigations using:
    - Independent variable - the one variable the investigator chooses to change
    - Dependent variables - what changes as a result of, or in response to, the change in the independent variable
    - Constant- identify variables that must remain unchanged
    - Control (control group) - used for comparison in which the independent variable is not changed
- Gather Data
  - Use tools and the SI (metric) system to accurately measure:
    - Time
  - Chooses appropriate tools to conduct an investigation
    - Clock/stopwatch
    - Microscope
  - Uses the appropriate format to record data
    - Graph

        - Writing (journal, worksheet, electronic text)
        - Sketch
    - Use senses to observe:
        - Seeing (color, shape, size, texture, motion)
        - Touching
- Interpret Data
    - Identify and interpret patterns using:
        - Trends in data
        - Tables and graphs
        - Based on an analysis of data collected during an investigation
- Evaluate Evidence
    - Draw and support a conclusion by:
        - Using data to determine the cause effect relationship observed in the investigation
        - Comparing results to hypothesis
        - Answer the testable question
        - Formulating scientific explanations/arguments
        - Show the application of the scientific concept or process being investigated
- Communication in Science
    - Report results using:
        - Scientific illustration with proper labeling
        - Table/graph showing data
- Analyze Scientific Results
    - Participate in critiquing/peer review by:
        - Evaluating a conclusion
    - Systems
        - A system, such as the human body, is composed of subsystems

        - A system usually has some properties that are different from those of its parts but appear because of the interaction of those parts.
        - In some systems, it may not always be possible to predict accurately the result of changing some part or connection.
- Scientific Investigation
    - Scientific Investigation:
        - Science investigation begins with a testable question
    - Scientific Data and Outcomes:
        - People are more likely to believe ideas if good reasons are given for them.
        - Scientific claims are based on data and reliable scientific sources.
        - Collecting and analyzing data is the best way to understand a changing pattern.
- Engineering and Technology
    - Uses of Technology
        - Human beings have made tools and machines, such as x-rays, microscopes, and computers, to sense and do things that they could not otherwise sense or do at all, or as quickly, or as well

Hands-On Activity

Becoming Aware of Resource Use

In this activity, students will identify natural resources used in daily life and monitor how much they use them.

Estimated time to complete: 50 minutes

Materials
For each student:

- Pencil and paper or science notebook

Procedure:
Have students keep a record of resources that they use for an entire day, as shown in the sample table below. A blank copy of this table is available in the Student Investigation Sheet for this activity.

Sample Record

Time	Resource Use	Natural Resource(s)	Estimated Energy Usage
7:30 a.m.	Turned on lights	Fossil fuels, metals, glass	60 W bulb for 1 hour = 60 W of energy
7:45 a.m.	Made toast	Fossil fuels, metals, bread	1 kW to run toaster
8:00 a.m.	Washed up	Water, fossil fuels (for heating water)	Approximately 3 kW for a 10-minute shower
8:15 a.m.	Got dressed for school	Cotton and other textiles, leather	???
8:30 a.m.	Turned off lights; rode bus	Fossil fuels, metals, rubber	???

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Analysis and Conclusions

1, What resources did you use the most?
Sample Response: *Fossil fuels were the resource used the most, because they were required for transportation, to generate electricity, to heat the home, and to heat water for washing and cooking.*

2. What activities used the most resources?
Sample Response: *Showering used both water resources and fossil fuels.*

3. Were you surprised by the number or diversity of resources you use each day? Explain why or why not.
Sample Response: *Yes, because most days I don't consider what resources things are made of.*

4. If you wanted to cut back on your resource usage, what is one action you could take immediately?
Sample Response: *I could shorten the length of my shower. One way would be to get wet, then turn the shower off while lathering up, and then turn it back on to rinse.*

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In this activity, students will demonstrate the following Inquiry and Nature of Science Skills:

- Gather Data
  - Use the appropriate format to record data:
    - Table
    - Writing (journal, worksheet, electronic text)
- Interpret Data
  - Sort and classify using scientific reasoning by:
    - Developing a classification scheme for objects, substances, or organisms
  - Identify and interpret patterns using:
    - Trends in data
  - Societal Issues:
    - Some materials — such as recycled paper, cans, and plastic jugs—can be used over again.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

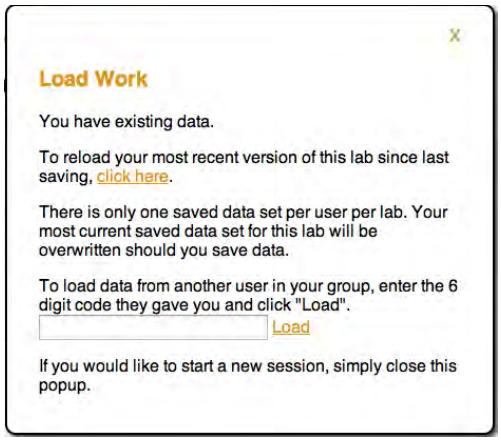
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

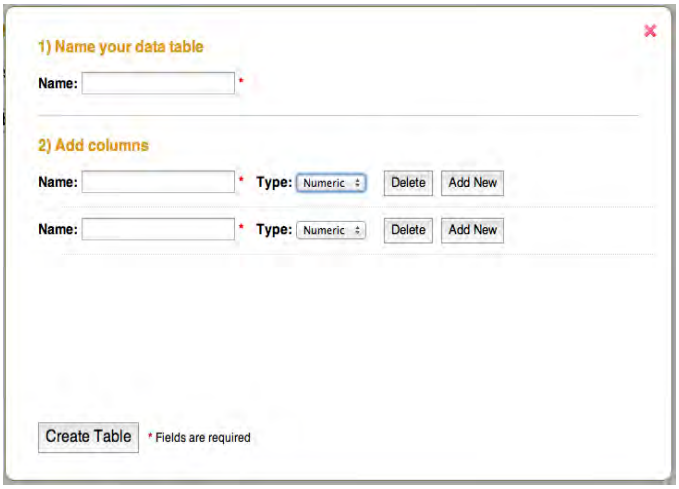
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



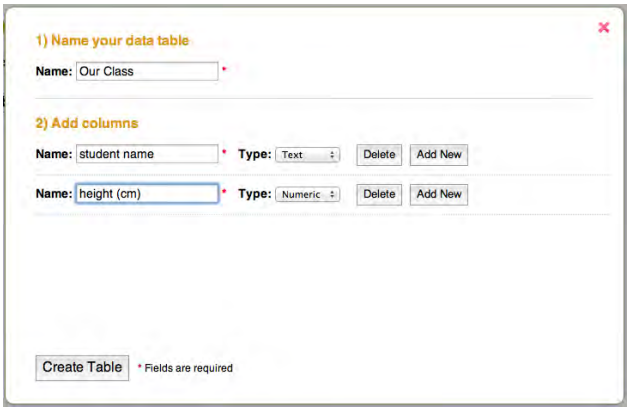
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

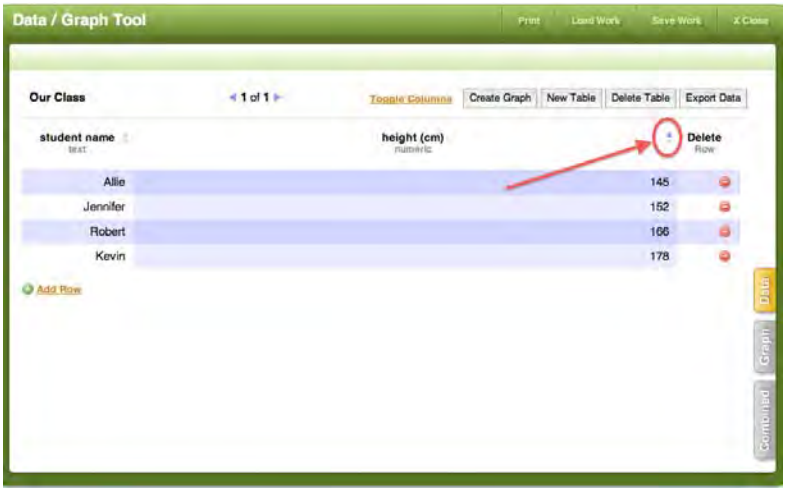
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

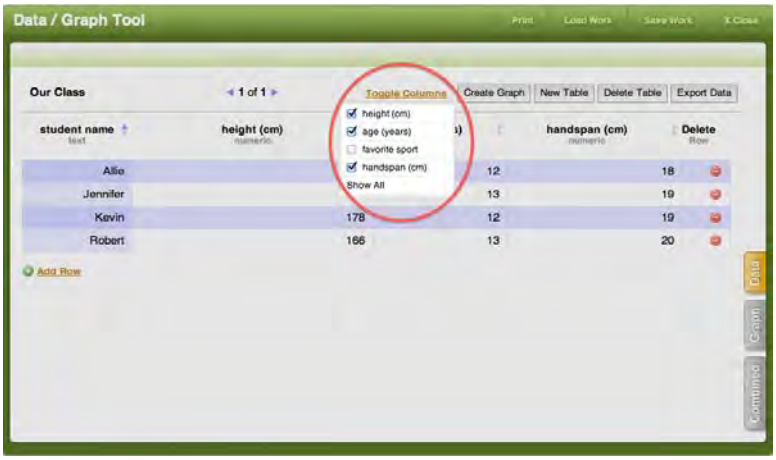


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

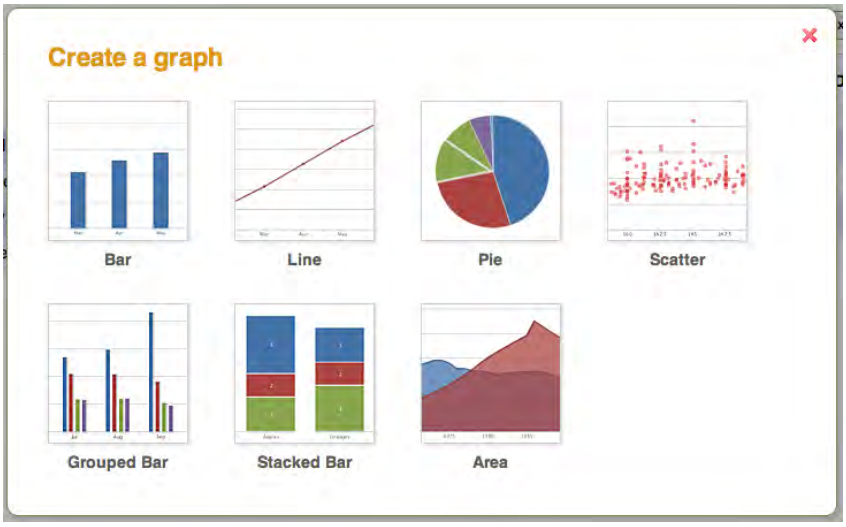
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

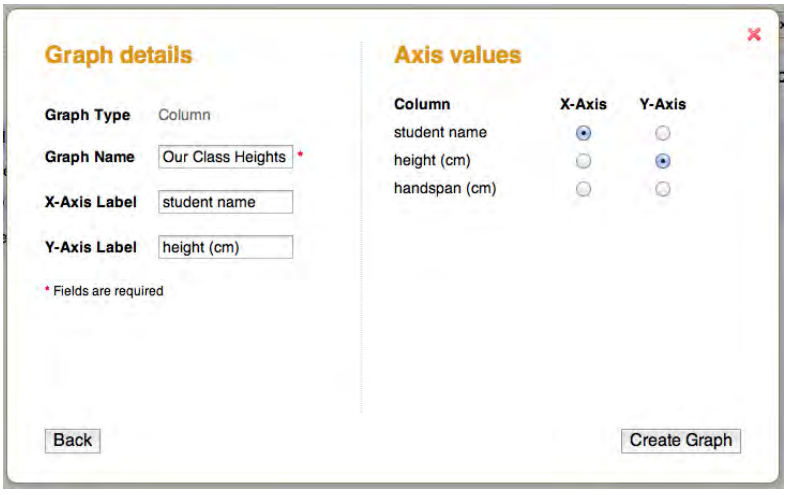
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

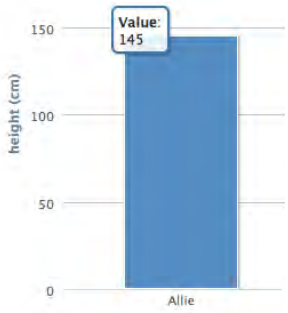


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

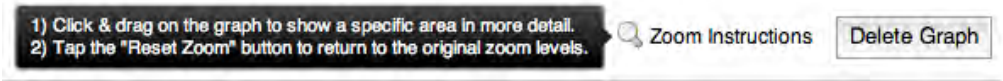
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Lab

Design an Off-the-Grid Home

Timing: One 90-minute class session for combined Directed and Guided Inquiry

Objective(s):

- Identify renewable energy resources.
- Apply knowledge of renewable energy resources to building design.
- Design a house that gets all of its energy from on-site, renewable energy resources.

Safety Precautions:
There are no safety concerns for this lab.

Materials:
Per student pair:

- Calculator
- Large-format art paper or drafting paper
- Ruler
- Compass or protractor
- Pencil and scrap paper

Teacher Preparation:
Gather sufficient supplies for each student pair. Print a copy of the Student Investigation Sheet for each student.

Procedure:
The Hands-On Labs include both Directed and Guided Inquiry approaches. If your students are new to the investigational methods being used in the Hands-On Lab, it is recommended that the Directed Inquiry approach be used to provide scaffolding that will ensure student safety and support the success of their investigations. Often, the Directed Inquiry approach involves modeling the basic laboratory techniques and methods to be used in the activity. A discussion of each step in the investigative process will also be included. In some cases, students may then be asked to create a procedure based on the one modeled for them. This may involve changing specific variables or adjusting the procedure to determine the effect on the outcome.

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

Directed Inquiry

Explain to students that the goal of this activity is to design a house that meets all of its energy requirements through on-site renewable resources. To help students get started, place them in small groups where they can brainstorm answers to the following questions:

- *What are the main uses of energy in a home?*
- *How will you know how much energy a house needs?*
- *What types of renewable energy resources would work best for a typical home?*
- *How can you estimate the amount of energy you can harvest from renewable energy resources?*

Give groups 5–10 minutes to brainstorm, then discuss their ideas as a class. Record responses on the board so that all students have a pool of ideas from which to draw while planning.

Students should work in pairs to plan their homes. Provide each pair with some basic information and reminders to assist in the planning:

- Most of a house's energy requirements go to heating its air and water.
- Larger homes have more area to heat and light.
- The electrical energy requirement of an average home is 4,400 watt-hours per day. This energy is used to power appliances like refrigerators, lights, computers, TVs, stereo equipment, and motors in furnace fans and washing machines. Reductions in appliance use will reduce the electrical energy requirements.
- A typical solar panel can generate 70 milliwatts (mW) per square inch over about 5 peak hours during the day, or 350 milliwatt-hours per day. Solar panels should face south for maximum efficiency.
- Home-scale wind turbines range in size from 250 W to 50 kW. The hours of operation depend on wind conditions.

Allow students time to plan and draw their home designs. Students' drawings should include both a "birds-eye" and ground-level perspective of their house, drawn to an appropriate, consistent scale. Students should also indicate the surrounding environment and add a "north" arrow to orient the house on their chosen site. Have students provide a written estimate of energy requirements for the house and inputs from the on-site renewable resource technologies.

When students finish, they should display their drawings around the classroom and present their plans to the class. Encourage students to ask questions and offer feedback on each other's designs.

Guided Inquiry

Working in pairs, students will develop plans for an off-the-grid home based on their own research into household energy requirements and renewable resource use. Suggest to students that they first research their own energy use by examining labels of household appliances and light bulbs. Instruct

students to conduct Internet research on energy outputs of various renewable resource technologies. Remind students to take into consideration the geographic location of the home. Ask guiding questions such as:

- *In what geographic area would you like to locate your home? What types of natural resources are available there?*
- *What are your energy needs? How can you combine different energy sources to meet those needs? How can different resources provide light, heat, and electricity?*
- *How will the orientation of the house on the property affect energy resources?*

When students finish, they should display their drawings around the classroom and present their plans to the class. Encourage students to ask questions and offer feedback on each other's designs.

Analysis and Conclusions:
In order to help students analyze and interpret their results, consider discussing some or all of the following questions, or assigning them as homework:

1. Do you think your planned home would successfully generate enough energy for light, heat, and electricity? Defend your response with research data on energy use and generation. *Students' answers will vary, but if they successfully completed the lab, they should be able to answer* yes *to this question.*

2. How does your design compare to those of other students? How did different designs approach the problem of generating all energy requirements on site? *Students' answers will vary, but they will likely mention such factors as the affect of the surrounding environment on the design and the specific energy requirements of the people living in the home.*

3. What improvements would you like to make to your design? *Students' answers will vary, but encourage them to consider how they might lower the cost of their designs without sacrificing energy efficiency.*

Further Questions:

1. List and describe all the ways energy was used in making your morning breakfast. *Students answers will vary, however they may explain that energy was used to cool or heat their drink. They may also explain that energy was used to cook their food, harvest their food, and manufacture their food .*

Why is reducing packaging, reducing waste, reusing materials, and recycling important to conservation of energy resources? *Students answers may vary, but they should explain that manufacturing goods, packaging, and materials takes enormous amounts of energy. It also takes energy to transport these goods. Reducing, reusing, and recycling reduces the amount of waste that goes into landfills, but also reduces the amount of energy used.*

Inquiry and Nature of Science Skills in this Lab:

- Design Investigations
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing
    - Apply mathematical operations and principles to replicate the real thing.
    - Are based on logic and evidence
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Examining how investigations can be improved
- Communication in Science
  - Report results using:
    - Peer presentation
    - Scientific illustration with proper labeling
    - Images or video
    - Scientific explanations/arguments
- Engineering and Technology
  - Uses of Technology:
    - An invention can be used in different ways, such as a radio being used to get information and for entertainment.
    - Technology extends the ability of people to make positive and/or negative changes in the world.
    - Each part of a mechanical device contributes to the purpose of that device.
    - Not every problem has a technological solution.
    - Engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems.
    - Constraints, such as gravity or materials characteristics, must be taken into account as a new design is developed.
  - Societal Issues:
    - Scientific discoveries have benefited people in many ways

Hands-On Lab

Modeling Global Deforestation

Timing: one 90-minute class session

Objective(s):
Students will investigate the deforestation rates of several countries. They will display their research in a table, calculate deforestation rates to make a computational model of deforestation, and use their model to make predictions about future forest area. Their findings and predictions will be presented in computer-generated graphs.

Safety Precautions:
Remind students to follow all general lab safety rules and not to eat or drink anything in the lab.

Materials:
Per group:

- access to the Internet or library for research
- science journal
- writing paper
- computer graphing program or graph paper
- writing tools
- calculator

Teacher Preparation:

- Gather materials in advance of students performing the lab.
- If possible, assign the research portion in advance. Alternatively, you could provide students with the research data.
- Have some sample graphs. Explaining how the sample graphs convey information is also advisable.
- Demonstrate computer graphing techniques to the students in advance of the lab, if necessary.

Research

1. Remind students what they have learned about Greenhouse gases and how CO_2 is produced and absorbed by Earth. Share the video segments Science in Progress: Deforestation and Experiment 3: Reforestation if students need more information.
2. Explain to students that they will be researching the forestry practices of individual countries. Then, in their lab groups, they will be manipulating the data through computation, analysis, and by graphing it. The result will be a computational model that describes the way each nation uses and/or depletes its forest resources. Students will then use their models make predictions about the future of those forests.
3. Explain to students that if different lab groups examine a variety of countries with different forests and economies, the global picture will be more accurate. Each group should choose some countries with tropical rainforests, deciduous forests, and some with third- and first-world economies. The list

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of suggested countries below, taken together, should provide such a range of data. You may wish to assign specific countries to each group, as a place to start. However, students should not be limited to the countries on this list, especially if their research turns up good data for other countries.

Suggested Countries to Begin Research on Deforestation

- Argentina
- Brazil
- Canada
- China
- Democratic Republic of the Congo
- Guatemala
- India
- Indonesia
- New Zealand
- Russia
- South Africa
- United States of America

4. Students should gather in their lab groups and decide on which countries they would like collect the following information: country's population, number of hectares of forest cover, number of hectares cut each year, basic economic status including the kinds of products that are important to the economy, what the country uses their forest area for (clearing for farmland, logging for wood products, or burning for fuel), and the number of certified sustainable hectares of forests. In addition, to make better predictions, students should look for the most recent figures. Finding figures from two time periods if possible, such as 2000 and 2010, will allow more accurate prediction in trends.
5. Allow students the time for the research.

Procedure

1. Have students meet in their groups with their data. Together they should collate their findings in a table, such as Sample Data Tables below.
2. Once they have entered the data they found, students should use the data to find the following additional figures: total number of hectares of forest per capita and number of years the current forests will last at the same rate of deforestation.
3. If they have the figures from two different time periods, students should also find the percent change over the time periods to look for a positive or negative increase.
4. Share with students this method of finding percentage differences between two numbers:
   - Find the difference between the two numbers, subtracting the earlier from the later number.
   - Next, divide the difference by the earlier number. Next, multiply that answer by 100. That answer is the percent change. If it is a negative number, then the answer is a percentage decrease. If it is a positive number, it is a percentage increase.
5. Have students find the percentage of the forests that are certified sustainable. (Certified forest area/total forests area. Answer multiplied by 100 to find the percentage)

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6. Students should discuss the best way to present the original data and their new calculated data in an easy to understand form. Show them some examples of graphs. Pie charts, world maps with a key indicating what different shading means, or bar graphs are possibilities. If computer software is not available, have students draw the graphs on paper.
7. Groups should display all of their data in some way. Then the groups should analyze their data for the following and record their answers in their science journal:
   - Which countries have the most forest coverage?
   - Which countries have the most certified sustainable forest area? Are they also the ones with the biggest forests?
   - What factors determine how much forest land a country certifies as sustainable?
   - Looking at population figures, hectares cut each year, and the percentage of certified area a country has, can the model be used to make predictions about which countries will lose more forest area due to deforestation?
   - How about which countries can maintain their forest area?
   - Can the model be used to predict which countries could increase their forest coverage?
   - Given that population continues to grow, which is a better predictor for forest maintenance, population or sustainable area?
   - If students have two sets of data from different times, can they make a prediction of how population numbers affect deforestation?
8. The answers to these questions can be displayed in additional graphs indicating that they are predicted results.
9. Using the information in the concept Natural Resources and what they have learned from this lab, have groups suggest an approach that could be created to stop deforestation. They should consider sustainable farming, legislation, consumer changes, etc.
10. Have students present this approach to the class.

Sample Data Table A: Area of Forest Area and Consumption

Forests	Millions of hectares of forest	Population (millions)	Millions of hectares per capita	Millions of hectares cut per year	Millions of hectares of certified sustainable forest	Percentage of total forest area certified	Number of years forests will last at same rate of deforestation
Canada	397.3	35	11	1	150.5	38%	397.3
USA	302.3	314		4	40		75.58
Russia	850	143.5		2	30		
Indonesia	94.5	247		1.5	1.0		
Brazil	477.7	198.7		3.5	0.8		
Dem.Rep. Congo	154	65.5		0.3	---		

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Sample Data Table B: Changes in Total Forest Cover Over Time

Region	Total Forest cover in million hectares ---2000	Total Forest cover in million hectares ---2010	Percentage change
Africa	709	674	−4.93%
Asia	570	593	
Europe	998	1005	+0.7%
North and Central America	705	705	0%
Oceania	198	191	
South America	904	864	

Analysis and Conclusions

1. Why may the results of your investigation not be completely accurate?

It may have been difficult to find accurate figures when researching. The data came from many different sources and was difficult to verify. Data from different sources may not be comparable. Forests are vast areas and it is difficult to get accurate measurements of what is cleared.

2. Did any of the rates of deforestation surprise you? Why?

Perhaps, the rate of deforestation of some of the countries showed a very short time before they would all disappear. The USA is an example, because at the current rate with no sustainable efforts in place, its forests would be gone in 75.58 years.

3. What was the most difficult part of collecting the data? Why do you think that was?

It may have been difficult finding figures in the same measurements or from the same years to compare them. Global awareness of climate change has made consumers more careful in their purchases. Some countries may not like to release figures that may damage their reputations.

4. What are some of the reasons you think it may make it difficult to predict future forest reserves of some countries?

Some countries have unsteady governments and it is difficult to predict if they will follow the rules. If economic conditions change, so can how the forest area is used. For example more farm land may be needed. Forest fires can unexpectedly eliminate large areas of forest coverage.

5. How might the type of data you collected and the model you made be useful in making future policy decisions about forest protection?

Governments need to examine this same kind of data to predict how long their natural resources will last and how best to protect them for the future.

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Design and conduct investigations using:
    - Sampling - a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements
  - Make or use models that:
    - Have as many details as possible replicated from the real thing
- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)
  - Uses the appropriate format to record data:
    - Table
    - Graph or chart
    - Writing (journal, worksheet, electronic text)
- Interpret Data
  - identifies and interprets patterns
    - Trends in data
    - Graphed data points
    - Tables and graphs
    - Analyzes data collected during an investigation
- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause effect relationship observed in the investigation
    - reporting out trends and patterns in the data.
  - Assessing the conclusion by:
    - Identifying alternative explanations
- Communication in Science
  - Report results using:
    - Table/graph showing data
    - Peer presentation
- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

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Exploration Teacher Guide: Natural Resources

Overview

In this Exploration, students will learn about different natural resources found on Earth. They will identify some of the natural resources as renewable or nonrenewable. They will also identify how items that come from natural resources can be treated (reused, recycled, or used less) in order to produce less waste.

Student Learning Objectives

- Examine the different types of natural resources.
- Classify natural resources as renewable and nonrenewable.
- Describe how resources can be reduced, reused, and recycled.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion. Some questions may require critical thinking or application of knowledge that is not referred to explicitly in the Exploration. These questions are better suited for discussion than assessment.

Using this Exploration

In this Exploration, students classify the different energy resources as renewable or nonrenewable. In the *Identify* tab, students click on an energy source card and then a card labeled renewable or nonrenewable to classify the energy source. As students classify energy sources correctly, the cards disappear from the screen and a scene under the cards unfolds. After all the energy resources are classified correctly, the entire scene is visible and different energy sources are available as elements in the scene. As students select an energy resource, information about it appears in the text pane. Students can use the *Start Over* button at any time of the Exploration.

The *3Rs* tab has a scene with various household items. It also has three areas that are dedicated to *Reuse, Recycle, and Reduce*. Students drag and drop the items to these areas to identify whether they should be reused or recycled, or whether it is simply important to use less of them (reduce). A timer displays the amount of time the students take to classify all the items. The score and energy level in the energy meter get updated with every correct and incorrect drop. The energy meter displays the amount of energy that the student has. Each correct drop adds energy to the energy meter while incorrect drops reduce the energy level. Note that most items can be conserved in more than one way.

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Answers to Questions in Student Worksheet

1. Identify three different water-based natural resources.

   Answer: Groundwater; hydroelectric energy; tidal energy; geothermal energy.

2. Why are coal, petroleum, and natural gas called “fossil fuels”?

   Answer: All three form from the remains of organisms that lived millions of years ago.

3. Explain why rocks and minerals are considered an important natural resource.

   Answer: Rocks and minerals are natural resources used for a variety of purposes. All metals used in different industries come from metal ores like iron and copper ores. Rocks such as limestone, marble, and granite are used as building materials.

4. Would you consider rocks and minerals to be renewable or nonrenewable resources? Explain your answer.

   Answer: Either answer can be supported. Student may say that they are nonrenewable because rocks and minerals take a long time to form. Once they are used up, they are not replenished. On the other hand, most rocks and minerals can be reused for different purposes over and over. (Unlike energy resources, which are burned and whose energy cannot be recovered.) In this way, they are renewable resources.

5. List some advantages of geothermal energy.

   Answer: Geothermal energy is a clean source of energy as it can be generated without burning fossil fuels. Also, this energy is generated close to the plant and hence helps reducing the transportation and processing cost.

6. Why is coal, which forms from the remains of plants, considered a nonrenewable resource while biomass is not?

   Answer: Coal takes millions of years to form, whereas biomass only takes seasons to years to form. Coal can form again, but within a human lifetime. People can grow more biomass after they use it up.

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7. Groundwater is considered a renewable resource as long as the rate at which groundwater is withdrawn is less or the same as the rate at which it is recharged. Explain.

   Answer: Groundwater is the water present beneath the surface of Earth in a zone where the pores of rocks and sediments are saturated with water Groundwater comes from rain water that percolates through the soil and into the rock. Groundwater can also flow underground. As long as the rate that the groundwater is replaced matches the rate that people take it out of the ground, it will not run out. But if people start taking out more, or if there is less rain to recharge the groundwater, it will run out. (Groundwater may also be considered non-renewable if it is polluted heavily.)

8. The price of petroleum and other fossil fuels is likely to increase over time. Why do you think this would happen?

   Answer: Petroleum and other kinds of fossil fuels are nonrenewable resources, which cannot be replenished once used. They take millions of years to form. There are several reasons why prices might increase.
   1) The law of supply and demand states that as supply decreases or demand increases, price increases. As we use fossil fuels, the supply decreases. If demand does not also decrease, price is likely to go up.
   2) If the demand does not decrease, engineers will need to use fossil fuel sources that are harder and more expensive to extract the resources from.
   3) Governments might increase taxes in order to increase the price and decrease the demand, so people won't use as much.
   4) Mining, drilling, and using fossil fuels causes a lot of pollution. The costs of cleaning up the environment might be added to the cost of the fuel, which would increase the price.

9. Describe two ways to conserve natural resources at home.

   Answer: Installation of solar panels and using energy from wind turbines could help conserving electricity. We can also replace incandescent bulbs with compact fluorescent bulbs.

10. A person decides to buy a used bicycle instead of a new car to get to and from work. Describe 4 ways that this decision helps the environment.

    Answer:
    1) Using a bike reduces overall use of petroleum because bikes don't require gasoline.
    2) Buying a used bike means that the natural resources used to make the bike are being reused.
    3) Not buying a new car means not using natural resources to make the parts of the car.
    4) Not using energy to make those materials or put them together.

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11. A person has just bought a new electric car. She says that because she has an electric car, she does not use any non-renewable resources when she travels. How correct is she? Explain your answer.

    Answer: Depending on how the electricity is generated, she may or may not be using non-renewable resources to power the car. Much electricity comes from coal-fired power plants. Even if the electricity comes from wind, solar, hydroelectric, or some other renewable resource, the car itself

12. Explain how reducing the amount of soda you drink could reduce the amount of fossil fuels that are consumed as well as the amount of aluminum that is consumed.

    Answer: A lot of energy goes into extracting the aluminum ore from the ground, getting the aluminum out of the ore, building the cans from the aluminum, and transporting the cans and the soda to the store and then to your home. Recycling cans saves energy, but recycling uses more energy than not using a can at all.

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Hands-On Lab

Designing Solutions: Wind Energy

Timing: one 90-minute class session

Objective(s):
First, students will design and build a model of a wind turbine that they will use to convert wind energy into electrical energy. Next, they will use their model to determine the propeller blade angle that results in the production of the maximum amount of electrical energy for their system. Then, they will have an opportunity to improve on their design and test the improved design, if time allows.

Safety Precautions:
- Follow all lab safety guidelines.
- Be careful when handling all electrical equipment.
- Do not touch the metal contacts on the electrical wires when current is flowing through the circuit.
- Tie back long hair.
- Do not eat or drink anything in the lab.

Materials:
Per group:
- motor, 1.5 V DC
- voltmeter
- cork, cylindrical with 1–2 cm length
- toothpicks
- glue
- needle
- cardboard
- wires, 2 insulated
- alligator clips, 4
- tube, cardboard with wide diameter
- hair dryer
- protractor

Teacher Preparation:
- Gather materials in advance of students performing the lab.
- If students are not aware of basic circuitry including the proper operation of a voltmeter, a brief introduction should be given before the start of the lab.
- If a hair dryer is not available for each student group, one wind tunnel (as described in the first step of the Procedure) can be set up for the entire class and groups can take turns collecting data.

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Procedure

1. Construct the wind tunnel by placing the hair dryer at one end of the cardboard tube. Place a small mark at the opposite end of the tunnel where the model wind turbine will be placed.
2. Cut six rectangles from the cardboard. Each should be 1.5 cm x 4.0 cm.
3. Glue a toothpick to one end of each of the cardboard rectangles. Be sure each toothpick is positioned similarly with respect to the cardboard rectangle to which it is glued. Allow the glue to fully dry before continuing.
4. Insert the toothpicks into the cork. Make sure that they are equally spaced around the circumference of the cork. Adjust the position of the propeller blades so that they are edge on in the direction of the hair dryer, which would be perpendicular to the axis of the cork. This is the reference position of the blades (0°).
5. Use a needle to make a small hole in the center of the base of the cork that is farthest away from the propeller blades.
6. Place the cork on the shaft of the motor. Make sure that the hole in the cork is just wide enough to fit snugly over the shaft. The cork and the shaft should turn as one unit without slipping. The shaft must be centered exactly in the middle of the cork and run vertically along its axis.
7. Attach alligator clips to both ends of the two insulated electrical wires. Clip one end of both wires to the motor terminals. Attach the other ends to the voltmeter.
8. Turn on the voltmeter. Spin the propeller blades by hand to check that the voltmeter registers a voltage.
9. Place the model wind turbine on the marked test position of the wind tunnel. The base may have to be held in place. Turn on the hair dryer at the low-temperature setting (for blowing air without heating it). Record the voltage value on the voltmeter in a data table. Also record observations on the rotational motion of the propeller.
10. Tilt the propeller blades so that they make an angle of 10° with the direction of the hair dryer and the vertical axis of the cylindrical cork. Repeat the voltage measurements.
11. Continue taking data in 10° increments until the blades can't be rotated any farther.
12. Graph the voltage versus the angle of the propeller blades. The angle of the propeller blades is the independent variable and should be placed on the horizontal axis. The voltage is the dependent variable and should be placed on the vertical axis.
13. Lab groups should use their graphs to identify the propeller blade angle that resulted in the largest amount of electrical energy produced.
14. The experiment involved a six-bladed propeller with measurements taken at only increments of 10°. Challenge students to improve their designs. If time allows, have them test their improved designs.

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Analysis and Conclusions

1. What forces act on the wind turbine while it is in motion? *[The oncoming wind pushes against the blades creating a lift force that causes the turbine to spin. As the blades spin, they also experience a drag force due to air resistance that opposes the rotational motion of the turbine.]*

2. Why did a 0° blade angle produce little or no rotational motion? *[A 0° blade angle does not expose any surface area against which the oncoming wind can exert a push.]*

3. Which blade angle produced the largest amount of electrical energy? Suggest a possible explanation for this result. *[Answers will vary depending on individual results, but the optimal angle is expected to be around 30°. At this angle, there is a fairly large amount of blade surface area exposed to the oncoming wind, so there will be a large lift force while still keeping the drag force small.]*

4. What other variable could be adjusted in order to maximize the amount of electrical energy generated by the wind turbine? *[The shape of the blades, size of the blades, weight of the blades, construction material, wind speed, and length of wind tunnel will all affect the amount of electrical energy generated.]*

5. Was all of the energy supplied by the hair dryer converted into electrical energy by the system? If not, where did the extra energy go? *[The wind turbine is not 100% efficient because there are many losses in the system. Not all of the oncoming wind was used to push the blades. There were loses due to friction in the coupling of the propeller to the motor. There were also losses in the motor itself.*

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In this lab, students will demonstrate the following Inquiry Skills:

- Identify Questions
  - Develop questions that:
    - Specify a cause-effect relationship
    - Require the changing of one variable at a time
    - Can be answered with a science investigation or observational study

- Design Investigations
  - Design and conduct investigations using:
    - Independent variable—the one variable the investigator chooses to change
    - Dependent variables—what changes as a result of, or in response to, the change in the independent variable
  - Make or use models that:
    - Simulate a real thing that cannot easily be studied or manipulated
    - Allow the testing of a hypothesis with results that can be extrapolated to the real thing

- Gather Data
  - Uses the appropriate format to record data:
    - Table

- Interpret Data
  - Identifies and interprets patterns
    - Trends in data
    - Graphed data points
    - Analyzes data collected during an investigation

- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Reporting out trends and patterns in the data.
  - Assessing the conclusion by:
    - Answering the testable question
    - Extrapolating results beyond the investigation

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Hands-On Lab

Designing Solutions: Powering the Island of Nolight

Timing: one 90-minute class session

Objective(s):
Students will research the different ways electricity can be produced and apply this knowledge to their own power-supply design. Students will design and write a proposal to provide sufficient power to an island community of 1 million. Students must consider current technologies, economics, aesthetics, environmental concerns, and societal opinion. Groups will then present and be prepared to defend their design.

Safety Precautions:
Remind students to follow all general lab safety rules and not to eat or drink anything in the lab.

Materials:
Per group:

- the island description
- access to the Internet or library for research
- data on power technologies and their relative costs and pros and cons (include wind, solar, nuclear, tidal, hydroelectric, geothermal, fossil fuels, and waste burning)
- graph paper
- drawing paper
- poster board
- writing tools

Teacher Preparation:

- Gather materials in advance of students performing the lab.
- If desired, assign the research portion of the lab in advance of the design portion.
- If desired, provide students with descriptions of various energy technologies listing their pros and cons.
- Provide an area to display the designs so that students have time to view and consider alternate proposals.

Procedure

Island Nolight Needs Power

Your company has been asked to submit a design and proposal to the island community of Nolight. This island community has an old, coal-fed power station that needs rebuilding. Before islanders spend the money, however, they are interested to know what other possibilities exist. There are 1 million people living on the island, and they rely on tourism for their economy. Up to 200,000 more tourists may visit the island in a given year. Tourists come to look at the scenery, visit the beaches, scuba dive, and walk the tall cliffs on the western side. The islanders work very hard to avoid polluting their environment. The island has a hot summer with lots of sunshine and mild, wet winters. The winds blow strong all year on the western side, and tall trees forest the north. The beaches and hotels are found on the southern side, and the eastern side has most of the community homes. Interesting sea life is found all around the island, but access for divers comes from the south. Your job is to design a solution to their power needs, using one or several energy sources. Your design should have the least impact on the environment and consider the needs of the island economy (tourist activities). The design should consider aesthetics and, although economic considerations are important, the islanders would like a sustainable, long-term plan. You will draw a map of the island with the locations of the proposed electricity generating technologies. You will also write a proposal that explains the reasoning behind your design.

1. Introduce the problem to the class.
2. Explain to the class that to design the correct power system(s) for the island, they will need to research the different technologies available. They should consider the relative costs, environmental impact, aesthetic qualities, transportation of raw materials, and possible implications to the tourist industry. Some technologies to consider are: wind, solar, nuclear, tidal, hydroelectric, geothermal, fossil fuels, and waste burning.
3. Divide the class into lab groups.
4. Have students make a sketch of the island that includes the information they learned in the written problem.
5. In their lab groups, have students divide up the research work and write their findings in their science journals.
6. Once the groups have completed the research, have them share with each other the information they discover, including benefits and challenges of each energy producing technology.
7. Have students reread the requirements of the Island of Nolight.

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8. Groups must discuss the possible power sources that could be installed on the island. They should consider the relative costs of the technology, the number of units they would need of each, the aesthetic affect on the island, the power needs of the island, and the environmental impact of each technology.
9. As they consider each type of technology, groups should decide if one or more than one type of technology should be used.
10. Next, groups should draw a large representation of the island, including the geographic features, and add pictorial representations of the power technology they propose.
11. Finally, groups should write a proposal that details the choice of power technology, the location of each piece of technology, and the reasoning behind their choice.
12. Once all groups have completed their design and proposal, have students present them to the class.
13. Have students evaluate each presented design by giving it a grade out of ten, using the same original criteria for the design.
14. Once students have listened to all the other proposals, have them rejoin their original group and discuss if they wish to make any changes to their design to improve it.

Analysis and Conclusions

1. Did your group decide on one power source or a combination of several? Explain why. *[Answers will vary, but most groups should have had a combination of power sources because the islanders held the environment and their tourist industry in high regard. Using alternative energy sources that are cleaner in combination may be a design that would be accepted by the community.*

2. Was it difficult to come to a consensus in your group on power sources? Explain. *[Answers will vary. Deciding on power sources brings a great deal of opinion into the mix. Strong opinions on cost or the environment can be difficult to handle.]*

3. How heavily did aesthetics weigh in your design? Explain why. *[Answers will vary. The islanders rely on tourism, so the aesthetics of the island are important to the livelihood of the islanders. Unsightly power lines, smokestacks, or even large wind turbines might deter tourists from visiting.]*

4. Did your group consider the risks of each technology? Which was more important for your design, risks or costs? Explain. *[Answers will vary. All technology comes with a certain amount of risk, but cheap power for a long time may outweigh the risks for some. Because the islanders depend on keeping the island in pristine condition, the risks of transporting oil there might be considered too risky.]*

5. Did you consider the surrounding ecosystem and other living things when you made your design? Why or why not? *[Answers may vary. An ecosystem should be important to the islanders for their continued tourism. Impact on both sea and land will need to be considered. Underwater tidal generators, for example, may affect the living things in the sea.]*

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that:
    - Simulate the real thing that cannot easily be studied or manipulated
    - Have as many details as possible replicated from the real thing
    - Function exactly like or similarly to the real thing.

- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)

  - Uses the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)

- Evaluate Evidence
  - Assessing the conclusion by:
    - Identifying alternative explanations

- Communication in Science
  - Report results using:
    - Peer presentation

- Analyze Scientific Results
  - Participate in critiquing/peer review by:
    - Evaluating an investigative design
    - Identifying alternative explanations

- Engineering and Technology
  - Uses of Technology
    - Technology extends the ability of people to make positive and/or negative changes in the world.

  - Engineering Design
    - Even a good design may fail even though steps are taken ahead of time to reduce the likelihood of failure.

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Exploration Teacher Guide: Natural Resources

Overview

In this Exploration, students will learn about different natural resources found on Earth. They will identify some of the natural resources as renewable or nonrenewable. They will also identify how items that come from natural resources can be treated (reused, recycled, or used less) in order to produce less waste.

Student Learning Objectives

- Examine the different types of natural resources.
- Classify natural resources as renewable and nonrenewable.
- Describe how resources can be reduced, reused, and recycled.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion. Some questions may require critical thinking or application of knowledge that is not referred to explicitly in the Exploration. These questions are better suited for discussion than assessment.

Using this Exploration

In this Exploration, students classify the different energy resources as renewable or nonrenewable. In the *Identify* tab, students click on an energy source card and then a card labeled renewable or nonrenewable to classify the energy source. As students classify energy sources correctly, the cards disappear from the screen and a scene under the cards unfolds. After all the energy resources are classified correctly, the entire scene is visible and different energy sources are available as elements in the scene. As students select an energy resource, information about it appears in the text pane. Students can use the *Start Over* button at any time of the Exploration.

The *3Rs* tab has a scene with various household items. It also has three areas that are dedicated to *Reuse, Recycle, and Reduce*. Students drag and drop the items to these areas to identify whether they should be reused or recycled, or whether it is simply important to use less of them (reduce). A timer displays the amount of time the students take to classify all the items. The score and energy level in the energy meter get updated with every correct and incorrect drop. The energy meter displays the amount of energy that the student has. Each correct drop adds energy to the energy meter while incorrect drops reduce the energy level. Note that most items can be conserved in more than one way.

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Answers to Questions in Student Worksheet

1. Identify three different water-based natural resources.

   Answer: Groundwater; hydroelectric energy; tidal energy; geothermal energy.

2. Why are coal, petroleum, and natural gas called “fossil fuels”?

   Answer: All three form from the remains of organisms that lived millions of years ago.

3. Explain why rocks and minerals are considered an important natural resource.

   Answer: Rocks and minerals are natural resources used for a variety of purposes. All metals used in different industries come from metal ores like iron and copper ores. Rocks such as limestone, marble, and granite are used as building materials.

4. Would you consider rocks and minerals to be renewable or nonrenewable resources? Explain your answer.

   Answer: Either answer can be supported. Student may say that they are nonrenewable because rocks and minerals take a long time to form. Once they are used up, they are not replenished. On the other hand, most rocks and minerals can be reused for different purposes over and over. (Unlike energy resources, which are burned and whose energy cannot be recovered.) In this way, they are renewable resources.

5. List some advantages of geothermal energy.

   Answer: Geothermal energy is a clean source of energy as it can be generated without burning fossil fuels. Also, this energy is generated close to the plant and hence helps reducing the transportation and processing cost.

6. Why is coal, which forms from the remains of plants, considered a nonrenewable resource while biomass is not?

   Answer: Coal takes millions of years to form, whereas biomass only takes seasons to years to form. Coal can form again, but within a human lifetime. People can grow more biomass after they use it up.

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7. Groundwater is considered a renewable resource as long as the rate at which groundwater is withdrawn is less or the same as the rate at which it is recharged. Explain.

   Answer: Groundwater is the water present beneath the surface of Earth in a zone where the pores of rocks and sediments are saturated with water Groundwater comes from rain water that percolates through the soil and into the rock. Groundwater can also flow underground. As long as the rate that the groundwater is replaced matches the rate that people take it out of the ground, it will not run out. But if people start taking out more, or if there is less rain to recharge the groundwater, it will run out. (Groundwater may also be considered non-renewable if it is polluted heavily.)

8. The price of petroleum and other fossil fuels is likely to increase over time. Why do you think this would happen?

   Answer: Petroleum and other kinds of fossil fuels are nonrenewable resources, which cannot be replenished once used. They take millions of years to form. There are several reasons why prices might increase.
   1) The law of supply and demand states that as supply decreases or demand increases, price increases. As we use fossil fuels, the supply decreases. If demand does not also decrease, price is likely to go up.
   2) If the demand does not decrease, engineers will need to use fossil fuel sources that are harder and more expensive to extract the resources from.
   3) Governments might increase taxes in order to increase the price and decrease the demand, so people won't use as much.
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   Answer: Installation of solar panels and using energy from wind turbines could help conserving electricity. We can also replace incandescent bulbs with compact fluorescent bulbs.

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    Answer:
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    Answer: Depending on how the electricity is generated, she may or may not be using non-renewable resources to power the car. Much electricity comes from coal-fired power plants. Even if the electricity comes from wind, solar, hydroelectric, or some other renewable resource, the car itself

12. Explain how reducing the amount of soda you drink could reduce the amount of fossil fuels that are consumed as well as the amount of aluminum that is consumed.

    Answer: A lot of energy goes into extracting the aluminum ore from the ground, getting the aluminum out of the ore, building the cans from the aluminum, and transporting the cans and the soda to the store and then to your home. Recycling cans saves energy, but recycling uses more energy than not using a can at all.

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Hands-On Activity

Predicting Global Energy Consumption

In this activity, students will collect data concerning 10 countries' total energy use and their population numbers. Students will develop some questions they can answer using the data based on global predictions for energy use. They should calculate the percent changes in their data and analyze the two sets of data to find any relationships. Using what they have learned in the concept, they will make predictions about future energy use and possible effects on the environment.

Suggested Materials
Per group:

- access to research sources: library or computer with Internet access
- science journal to record research findings
- graph paper
- writing tools
- computer technology to create and display graphs

To introduce the activity, explain to students that energy use depends on the type of society and the number of people using it, as well as the climate. Some countries use a great deal of the world's resources and others use less. In addition to cultural differences, climate and the economy may also affect the amount of energy a country consumes.

Part 1: Collecting Research Data

Procedure

Explain to students that to perform this Activity they will first need to collect data. They will be collecting the following information from books, magazines, or Internet sources:

- Annual energy consumption from 10 different countries of their choice. Energy is measured in different ways, and they should collect data measured in the same form (e.g., all figures in terawatt hours, kwh/person, or MTOE).
- The data should include 2 different time periods (e.g., current numbers and those from 20 years ago).
- Total population numbers from those countries at each of those times.
- Some basic facts about lifestyle, economy, and climate for each country.

1. Have students meet in their lab groups and chose the countries they would like to study. Encourage students to choose a range of different countries, different in geographical size, location, and culture. If time is an issue, have each group member choose 1 country to research.
2. The group should divide up the research and may choose to divide the work by country or by data sets.

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3. Once the data has been collected, groups should meet to put all of it into one chart. They may use a computer or record it by hand. A sample chart follows below.
4. Remind students to make sure the data that is recorded has the same measurements (e.g., all energy use in terawatts OR kwh/person).
5. Have students write some questions in their science journals about energy predictions that they will answer with their data.

Part 2: Crunching the Numbers

Students will begin to work with the numbers and calculate new data from their research. They will need to find the percent change in fuel consumption over the time frame (e.g., 20 years), the percent change in population between the two time periods, and the percent change in CO_2 emissions. Share with students this method of finding percentage differences between two numbers:

- Find the difference between the two numbers, subtracting the earlier from the later number.
- Next, divide the difference by the earlier number. Then, multiply that answer by 100. That answer is the percent change. If it is a negative number, then the answer is a percentage decrease. If it is a positive number, it is a percentage increase.

Next, students should decide on a way to display the new data, as well as indicate some of the facts they found in their research, like economy, cultural differences, and climate, so that they can make comparisons. Bar graphs or pie charts work well for this. Once students have created a series of graphs to display their findings, they will need to analyze them for patterns or relationships.

Students should analyze their data for the following:

- Correlation between energy consumption and population.
- Correlation between economy and energy consumption.
- Correlation between climate and energy consumption.
- Correlation between cultural or societal differences and energy consumption.

Next, have students write some predictions based on their analysis. They may develop the predictions themselves or use the ones below.

- Can students predict which countries will continue to increase their consumption of energy?
- Can students predict which countries will continue to see an increase in population?
- Which country's energy consumption is most likely to have a greater environmental impact in the future?
- Is there a correlation between energy consumption and CO_2 emissions? Explain.
- Do you think energy consumption corresponds directly with population increase? Explain how you came to that conclusion.
- Does climate seem to play a role in energy consumption?

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Sample data collection chart: **Energy Consumption and Population Figures**

Country	Total energy usage 1990	Total energy usage 2011	% change	CO_2 metric tons/capita 1990	CO_2 metric tons/capita 2009	% change	Total population 1990	Total population 2010	% change
Canada	208 million tons of oil equivalent (MTOE)	250 MTOE	20%	16.2	15.3	–5.5%	27,512,000	33,739, 859	23% increase
United States	1,910 MTOE	2,200 MTOE	15%	19.1	17.2	–9.9%	248,709,873	313,232,000	26% increase
India	313 MTOE	736 MTOE	135%	0.79	1.66	110%	849,000,000	1,189,173,000	40% increase

Analysis and Conclusions

1. Did any of the figures in your research surprise you? Why? *[Answers will vary. The percentage increases of some countries' populations are staggering. India has had a 40% increase in only 20 years. India's energy consumption increase indicates not only population increases but also changes in their society.]*

2. What were the limitations of making predictions with the data you collected? *[Answers will vary. The collection of data was for only two periods and may not be enough to offer trends. There was not enough information about the type of energy consumption for each country, and it is difficult to predict what that country may use in the future.]*

3. What was the most difficult part of collecting the data? Explain. *[Answers will vary. Finding energy data in the same measurement may have been difficult. Also finding data for the same time period may have been hard.]*

4. Is it possible to predict future environmental impact based on energy consumption figures alone? Why or why not? *[Answers will vary. It is not known what sources produce the energy or how the energy is used. The environment may be less affected if the energy produced is from alternative sources. The energy may be used for things that are helping the environment such as building greenhouses.]*

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Design and conduct investigations using:
    - Sampling—a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements

- Gather Data
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)

  - Uses the appropriate format to record data:
    - Table
    - Graph or chart
    - Writing (journal, worksheet, electronic text)

- Interpret Data
  - Identifies and interprets patterns
    - Trends in data
    - Graphed data points
    - Tables and graphs
    - Analyzes data collected during an investigation

- Evaluate Evidence
  - Drawing and supporting a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Reporting on trends and patterns in the data

  - Assessing the conclusion by:
    - Identifying alternative explanations

- Communication in Science
  - Report results using:
    - Table/graph showing data
    - Peer presentation

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns.
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

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Hands-On Activity

Climate Time Machine

In this activity, student groups will work together to create a box plot of annual average temperatures using global NASA data from 1885 to 2005. Each group will be assigned a timeframe for which they will be responsible for compiling worldwide temperatures and will then make a box plot of their data. At the conclusion of the activity, groups will post their box plots in a central location in the classroom so that they form a continuous time series. After reviewing the plots and analyzing the data, students will answer questions (individually or in groups) about the combined time series box plot.

Safety Precautions:

- Follow all lab safety guidelines.
- Do not eat or drink anything in the lab.
- Only press lightly when writing on the paper or transparency fixed to the computer monitor.

Suggested Materials

Per group:

- Internet access
- transparency slides or plastic wrap
- permanent marker
- tape
- graph paper
- ruler
- pencil
- colored pencils or markers (optional)
- tape or thumbtacks for classroom display

Procedure

1. Divide the class into small groups. Each group should have access to a computer with Internet access (or rotate computer access per group while also working on another activity).
2. Assign each group a time period between 1885 and 2005. Each date range should be covered by one and only one group (for example, with five groups, each group could be assigned a date range: 1885–1910, 1910–1935, 1935–1960, 1960–1985, 1985–2005).
3. Once students are in their groups, have each group load the NASA Climate Time Machine: https://climatekids.nasa.gov/time-machine/.
4. Have each group set up a data table.
    a. The data columns each should be headed by a year in their date range in 5-year increments (for example: 1885, 1890, 1895, 1900, 1905, 1910).
    b. The data rows will represent different world locations and should be labeled from 1 through 16.
    c. At the bottom of the table, below the row for data location 16, students should draw a horizontal line. Below the numbers 1–16, they then should write “Range”, “Median”, “First Quartile”, and “Third Quartile”.

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5. Have each group set up a graph, with date on the *x*-axis and temperature on the *y*-axis. Students should label the *x*-axis with their assigned years (in 5-year increments) and label the *y*-axis with a range of temperatures (-3.6°F to + 3.6°F or -2°C to +2°C). *Important note: Make sure that the* x *and* y *scales and units are the same for each group's graph. For instance, specify that each five-year period and each degree of temperature in Fahrenheit are equal to one inch (or each degree of temperature in Celsius is equal to two inches).*
6. Have each group identify and mark 16 locations on the world map of the Climate Time Machine for which they will track average temperature throughout their assigned date range.
    a. To do this, have one student from each group hold a blank sheet of paper up to the computer screen so that the top of the paper is aligned with the top of the computer screen and temporarily tape the paper in place. Have another student in the group carefully trace the rectangular outline of the world map onto the sheet of paper. Take care not to press too hard on the screen.
    b. Students should then overlay their transparency slides or plastic wrap onto the sheet of paper, making sure that the top of the transparency is aligned with the top of the paper. They should then (very carefully, especially if using plastic wrap) use a permanent marker to mark the four corners of the rectangle, and then to make a small dot at 16 approximately evenly distributed locations. It may help for students to use a ruler to divide the rectangle into quadrants, and then mark four dots within each quadrant.
    c. Have each group tape their transparency slide or plastic wrap onto the computer screen so that the corners of the rectangle align with the corners of the world map (and so that the tape is not attached to the screen itself).
7. To collect data, students will scroll through various dates within the Climate Time Machine and record the approximate temperature at each of their 16 designated locations.
    a. Students will need to estimate the temperature for each date using the color bar legend.
    b. Make sure students understand the importance of recording the temperature exactly at each location rather than at a nearby location (even if it appears to be more "interesting" or dynamic).
    c. For data consistency, students should self-assign roles within their group. For instance, one or more students may interpret temperature for each location while another student records the data. Another student may operate the mouse to scroll between dates in five-year intervals.
8. After groups have finished recording their data, they should plot the data points on their graph. It is not necessary for them to keep track of which location is which, as long as all 16 points for each date are vertically aligned.
9. Once all data points are plotted, students should create box plots for their data by connecting the minimum and maximum points with a vertical line, and calculating the range, median, first quartile, and third quartile for each year of data. Have students connect the medians for each date across their plot. Make sure that students use a ruler to draw straight lines.
10. Once all group's graphs are complete, students should post their graphs with *y*-axes aligned, as a continuous time series, in a central location in the classroom.
11. Students then should individually analyze the relationships between and within each group's plot and answer the questions about the plots.

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Analysis and Conclusions

1. What, if any, trends can you see across the entire time series? If trends are apparent, how clear are they? Compare and contrast your observations of the whole time series with any trends that were apparent in your group's plot on its own.
   Sample answer: Analyzing data across the entire date range, it became clear that median global temperatures rose over the time period. It was also clear that both the upper and lower ends of the boxes (third and first quartile) rose in value. The warming trend was much more obvious when looking at the entire data set rather than just a piece of it. In our data from 1885 to 1910, I thought a slight warming trend may have been apparent, but I was not sure because the spread of data was small. The upper ends of the boxes (third quartile) seemed to widen toward the later years, but the trend was not very clear.

2. What struck you most about the changing color patterns in scrolling through the Climate Time Machine? Was there a particular time or location in which the temperature patterns surprised you? What do you think the cause of the changing pattern was? Do you also see this pattern reflected in the box plot time series?
   Sample answer: I was surprised by how many small patches of yellow and orange there were in the early years, representing small localized areas that experienced a few warm years in a row due to climatic variation. But then those colors started becoming more common globally, and in the 1990s, the map suddenly seemed to be mostly orange and red. I think this was probably due to population growth and increased greenhouse gas emissions. Yes, this pattern is reflected in the box plot time series by the overall upward shift in points over time, but it is also striking to see it color-coded on the map.

3. Do you think it was valuable to create a box plot of the data rather than just a scatter plot? Were there any trends or observations that were easier to see within a box plot, or is there another type of plot that you think would have worked better to display this data?
   Sample answer: Yes, I think it was valuable to see how the various quartiles changed over time, as well as just the spread of data shown by the scatter of data points. I think the box plot was a good type of plot to use, although a line plot connecting the mean temperatures also would be useful.

4. Analyze the quality of your data. Identify the source of the data and say whether you trust its accuracy. Why or why not? How reliable was your group's method of data collection? What could you do differently to improve the quality of the data sampling method?
   Sample answer: The data came from NASA's Jet Propulsion Laboratory and the California Institute of Technology. Overall, I trust the data source because those are both reputable research institutions. However, I would like to know how the data was measured. Overall, I think our group did a good job at sampling the global map of data, but often it seemed like there were major temperature changes that our sampling did not capture. Also, we had to estimate the temperature based on the temperature scale rather than read an exact number. To improve the quality of the data sampling method, I would look at many more data points and increase the frequency to every year instead of every five years.

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In this activity, students will demonstrate the following Inquiry Skills:

- Interpret Data
  - Identify and interpret patterns using:
    - Trends in data
    - Tables and graphs
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Reporting trends and patterns in the data
    - Extrapolating results beyond the investigation
    - Formulating scientific explanations/arguments
- Communication in Science
  - Report results using:
    - Written report
    - Scientific explanations/arguments
    - Table/graph showing data
- Scientific Investigation
  - Scientific Data and Outcomes:
    - Scientific claims are based on data and reliable scientific sources.
    - Collecting and analyzing data is the best way to understand a changing pattern.
    - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
    - It is important in science to keep honest, clear, and accurate records.
- Scientific Endeavor
  - Characteristics of Science:
    - Scientific claims can be substantiated using data and observation.
    - An important part of science is the critical review and analysis of any idea or conclusion.

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Hands-On Lab

Using Climate Models to Forecast Impacts of Climate Change

In this investigation, students will choose a type of climate data for their city, state, or region. They will use their data to identify trends and patterns. These trends and patterns can form the basis of a calculation- or graph-based climate model. Students use their models to make predictions about future climate change for the area they chose and compare results with other groups.

Timing: One 90-minute class session for identifying and graphing data and one 90-minute class session for student group comparison and discussion

Objective(s):
In this investigation, lab groups will graph and analyze climate data, make a forecast on future climate change, and then compare results with other groups.

Safety Precautions:
There are no safety-related concerns with this lab activity.

Materials:
Per group

- graphing calculator, computer graphing software, or graph paper
- pencil
- access to the Internet
- poster board for group comparisons

Teacher Preparation:

- Gather materials in advance of students performing the lab.
- Likely sources for climate data sets include the U.S. NOAA and its National Climatic Data Center and the historical climate data provided by Environment Canada.

Procedure
Student lab groups should

1. conduct an Internet search for reliable climate data
2. identify a variable that they want to consider for their climate model
   Possible examples include average temperature, high temperature, low temperature, humidity, air pressure, precipitation amounts. Lab groups may want to choose to analyze changes in the annual averages of these values or focus in on how the values for a specific month changed from one year to the next.
3. Make a graph, with years on the *x*-axis, and their variable on the *y*-axis. (Note that some climate data set websites include an automatic graphing feature.)
4. Try to identify trends, cycles, and other patterns.
5. Make a forecast of future trends based on the data collected.
6. Compare results among all student groups.

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Student graphs may be printed out and enlarged so they can be placed on poster boards for ease of presentation and comparison. Be certain to have students indicate in their presentation how the data they found supports their forecasts.

If time allows, you may ask students to combine groups and pool their datasets to come up with a more complex model that accounts for trends in more than one variable.

Analysis and Conclusions

1. Which source(s) did you choose to extract data from and why? How reliable do you think your primary data source was, and why did you choose to use data from that source? Of all the sources you looked at, were there any in particular that seemed more or less reliable? What evidence did you use to evaluate the reliability of each source? *Answers will vary. Even if students chose sources based on a teacher's recommendation, look for a critical evaluation of the source(s) and an understanding that not all sources are equally credible. Evidence could include study size/duration, type of publication/journal/ government agency, peer review, agreement of data between multiple sources, or funding source.*

2. How would obtaining results from a variety of different sources strengthen your climate forecasts?
Data from multiple sources will represent actual conditions and patterns more accurately. Data from only one source may be incomplete or may suggest a pattern when one really isn't there.

3. Develop a summary statement regarding the conclusion of your data analysis.
Student answers will vary. Sample answer: Indiana seems to be entering a period of increased precipitation, as the past 15 years have only had two years below the 100-year average.

4. One student claims that the climate has never changed and never will. What evidence from the data your lab group and other lab groups collected suggests otherwise?
Student answers will vary. Sample answer: Indiana's climate has changed. During the first 15 years of the 1900s, there were seven years of drought. In the last 15 years of data, from 1997 to 2012, there were only two drought years.

5. Another student says that climate change means that every place will become hotter and drier at all times of the year. What evidence from the data your lab group and other lab groups collected suggests otherwise?
Student answers will vary. Sample answer: Climate change will have many effects. In some areas, there may be increased temperatures at certain times of the year. But in the case of Indiana, the change in climate has brought more rain instead of less rain.

6. Do you think that global warming will have a major impact on your life in the future?
Answers will vary among students. Students should consider both global and regional climate change and how that will affect both Earth systems in general and their own activities in particular. Example answer: While increased rainfall may be helpful for growing some crops in Indiana, it also may damage crops due to the potential for flooding and for mold-and-mildew-based crop diseases.

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In this lab, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Design and conduct field studies using
    - observational study–compares changes in data points over time
    - sampling–a portion of the affected elements in an investigation used to extrapolate what would have happened to a larger set of elements
  - Make or use models that
    - simulate a real thing that cannot easily be studied or replicated
    - function exactly like or similarly to the real thing

- Gather Data
  - Uses the appropriate format to record data
    - table
    - graph or chart
    - sketch
    - diagram

- Interpret Data
  - Identifies and interprets
    - trends in data
    - repeating physical or data pattern
    - graphed data points
    - analyzed data collected during an investigation

- Evaluate Evidence
  - Drawing and supporting a conclusion by
    - using data to determine the cause-effect relationship observed in the investigation
    - reporting on trends and patterns in the data.
    - extrapolating results beyond the investigation

- Communication in Science
  - Report results using
    - peer presentation
    - table/graph showing data
    - sketch
    - diagram

- Patterns and Systems
  - Patterns and Change
    - Patterns in nature may be simple repeating patterns or complex growing or changing patterns.
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.
    - Things that change may do so in steady, repetitive, or irregular ways.
    - Many patterns in nature occur in cycles.

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- Scientific Investigation
  - Scientific Data and Outcomes
    - Different explanations can be given for the same evidence, and it is not always possible to tell which one is correct without further inquiry.
    - Some scientific knowledge is derived from experiments (which involves the identification and control of variables), while other scientific knowledge is the result of other forms of scientific investigation.
    - People are more likely to believe ideas if good reasons are given for them.
    - Scientific claims are based on data and reliable scientific sources.
    - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
    - Data are biased when they include systematic distortions due to errors in data-collection procedures.
    - Scientists must take care to avoid bias by not allowing their own opinions or preconceptions to affect their interpretation of data collected.
    - Accurate record keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.
    - Statements not based on hard data ("Leading doctors say . . .") are questionable and do not meet scientific standards.
    - When similar investigations give different results, it often takes further studies to decide what is right.
    - Arguments and conclusions are invalid if based on very small samples of data, biased samples, or samples for which there was no control sample.
    - While scientific data may support or fail to support a claim, it does not offer conclusive proof.

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Hands-On Activity

Cost Benefit Analysis of Fossil Fuels

In this activity, students will perform a cost-benefit analysis of the usage of fossil fuels. They will consider quantifiable costs and benefits including those that relate to the environment. They will also evaluate the degree to which their sources' claims are supported by reasoning and evidence.

Suggested Materials

Per Group:

- Internet access
- poster board or access to presentation software

Teacher Notes

For students who have not done a lot of Internet research, you may want to take some time before the activity and discuss how to seek out sources of information that are less likely to be biased, along with discussing some of the signs of biased information.

Procedure

1. To introduce the activity, have students brainstorm uses for fossil fuels. Share this list with all groups.
2. Within the lab groups, students should identify costs and benefits for each usage, along with information about supplies or reserves. Alternatively, you can assign different lab groups to investigate different usages.
3. Groups should work together to see if they can identify reliable sources online from which to gather quantitative information about the costs and benefits of the different uses of fossil fuels. Encourage them to also keep track of non-quantitative costs and benefits. For example, drilling for oil can disrupt an ecosystem, and there is not an easily quantifiable cost for that. By the same token, being able to travel anywhere within a city relatively quickly because gasoline is plentiful is a benefit that is not easily quantifiable either.
4. Once students have had a chance to look through several resources, they should choose one or two resources to focus on in which they analyze the extent to which the author's claims are supported by reasoning and evidence. These criteria are particularly important for students to keep in mind when researching environmental issues, as many sources may be the products of special-interest lobbies or the fossil fuel industry.
5. After a suitable time, have students work on a poster board or computer presentation that sums up their findings about the costs and benefits of the usages they were able to research. Each group should also include a statement or paragraph summarizing their analysis of the extent to which claims were supported by reasoning and evidence.

As different groups finalize their data, you may want to summarize their cost-benefit results and total the costs and benefits across groups on a board at the front of the classroom. As part of a class discussion, have students share their analyses of the degree to which their sources' claims were supported by reasoning and evidence.

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Analysis and Conclusions

1. What new information did you learn about the current use of fossil fuels in the United States?

Answers will vary but should include the associated costs of each type of fossil fuel and the current expectations as to how long each type of fossil fuel will last with projections into the future, as energy demands increase and the supply decreases.

2. Which fossil fuels are used in the United States? Which were the most common uses of each of these types of fuels?

Coal, natural gas, and oil are the fossil fuels most often used in the United States. Coal is used for generating electricity. Natural gas is used for heating and cooking. Oil is used for transportation.

3. Name a significant cost and benefit for each type of fossil fuel mentioned.

Coal is relatively inexpensive and easy to transport because it is a solid, but it produces pollution when burned, and mining for coal can be harmful to ecosystems. Natural gas burns cleaner than other fuels but it is hard to control and transport because it is a gas. Some approaches to retrieving natural gas from underground, including hydraulic fracturing or "fracking" may cause problems with geological formations and aquifers. Oil is so widely used that it is a leading contributor to greenhouse gases that may affect climate change, and oil spills during drilling, refining, and shipping can cause significant environmental damage. Use of oil makes many modern conveniences possible including fuel for air travel and for cars. Many people are employed in the oil industry and related industries.

4. Did the figures your lab group came up with for the amounts of fossil fuels available match with those of other groups? Give a reason why there may be differences.

Sample Answer: The values didn't match because we used different sources. Our source came from government statistics, but another group used figures provided by the oil and gas industry.

5. Were your sources' claims supported by clear reasoning and verifiable evidence? Explain how you know.

Answers will vary. Students may consider the authors, funding sources, quantity or quality of data, and the degree of speculation vs. presentation of actual data.

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
  - Make or use models that
    - simulate the real thing that cannot easily be studied or manipulated
    - have as many details as possible replicated from the real thing
    - function exactly like or similarly to the real thing

- Communication in Science
  - Report results using
    - peer presentation

- Engineering and Technology
  - Uses of Technology
    - Technology extends the ability of people to make positive and/or negative changes in the world.
    - Technologies, such as pesticides, often have drawbacks as well as benefits.
    - Technology has strongly influenced the course of history and continues to do so.

- Scientific Investigation
  - Scientific Data and Outcomes
    - Scientific claims are based on data and reliable scientific sources.
    - Statements not based on hard data ("Leading doctors say . . .") are questionable and do not meet scientific standards. Arguments and conclusions are invalid if they are based on very small samples of data, biased samples, or samples for which there was no control sample.

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Data/Graph Tool

Teacher's Guide

Introduction

The skill of analyzing and communicating quantitative data is essential in science and is an expected mathematics skill. The Data Graphing Tool can be used to create a data table and then transform this data into one of a variety of graphs. This tool enables students, either individually or in groups, to carefully examine, critique, analyze, and display their data.

Data used in the tool can come from any number of sources:

- data collected by students from hands-on investigations
- data from Virtual Labs
- data from Explorations
- data from resources such as reading passages, the Internet, historical documents, reference books, and primary documents

Overview of Features

The Data/Graph Tool can be configured by the user to generate data tables with any number of columns and any number of rows. The user is prompted by the software to name the data table and identify the columns. Data can be entered in numeric, text, or formula-based format. Once a table has been created, individual columns can be toggled on or off as well as sorted from least to greatest values or vice versa. The data table can be saved, printed out, or converted into graphical form. Data can also be saved for later use.

Once a user has created a customized data table, it can be converted into one of several types of graphs: bar, line, pie, scatter, grouped bar, stacked bar, or area. After selecting a graph type, the user is guided to set up the details of the graph. The specific details will vary depending on the type of graph chosen. Once a graph has been generated, the user can zoom in on a specific area of the graph in order examine the data in closer detail.

If multiple data tables and graphs are constructed, it is easy to move back and forth between them to examine multiple sets of data. Tabs allow the user to easily move back and forth between a data table and the corresponding graph. It is also possible to view both data table and graph on the same screen.

Notes for Implementation

The following instructions are provided for you, the teacher, and, with modification, your students. How you introduce this powerful tool to your students will of course depend on your students' skills and previous experience with data tables, data entry, data analysis, and graphing. Much like a calculator can free a student to focus on the results and significance of calculations, the Data/Graph Tool can do much the same when working with real and virtually collected data. And, like a calculator, the Data/Graph Tool can be a valuable aid to inquiry and critical thinking.

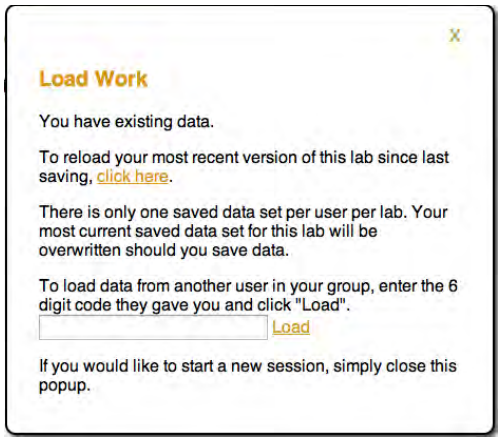
Transforming data from a table into a graph requires some planning ahead. The terms in the graph creator such as x-axis and y-axis may be new to students. The idea that there can be more than one way to display the same data in a graph may also be new to students. Therefore, you will want to take students through the steps using a think-aloud approach so they can follow the choices you make as you demonstrate them.

Once you're comfortable with the tool, you can present it to your students in a variety of ways. Because there are a number of distinct steps to go from initially setting up a data table to examining a completed graph, it would be helpful in your presentation to be able to switch back and forth between the different steps as you demonstrate this tool to your students. One way to be able to do this is to create a new tab in your browser for each of the steps. If you do this ahead of time, you can smoothly jump to a particular step if, for example, you want to respond to a student's question. **Be aware: do not** use your browser's "previous page" (back-button) function while proceeding through the steps presented below. Any data or other entries you have made will be lost.

How to Use the Data/Graph Tool

Creating a Data Table

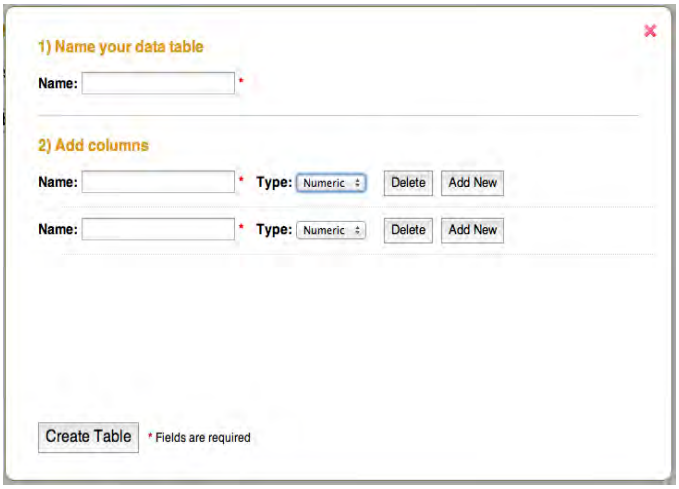
When you first open the Data/Graph Tool, you will be invited to create a new data table using the Table Creation Wizard by clicking on "Create Data Table."



Note: If the computer you are using has previously been used to create a data table, a pop-up window will appear and present three options.

a) reload the most recent data from a lab since you last saved your work
b) load data from another user by typing in the 'Save Code'
c) start a new data session

Once you choose to create a new data table, the following pop-up window will appear:



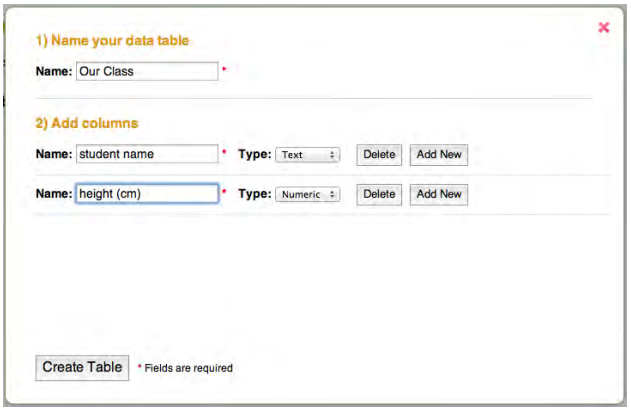
There are several elements to enter on this screen.

- Name the data table: select a descriptive title or name for the data table.
- Name each of the columns in the data table. Additional columns can be added as needed. With the drop-down menu you tell the computer if the data for a given column is to be numeric, text, or formula-based.

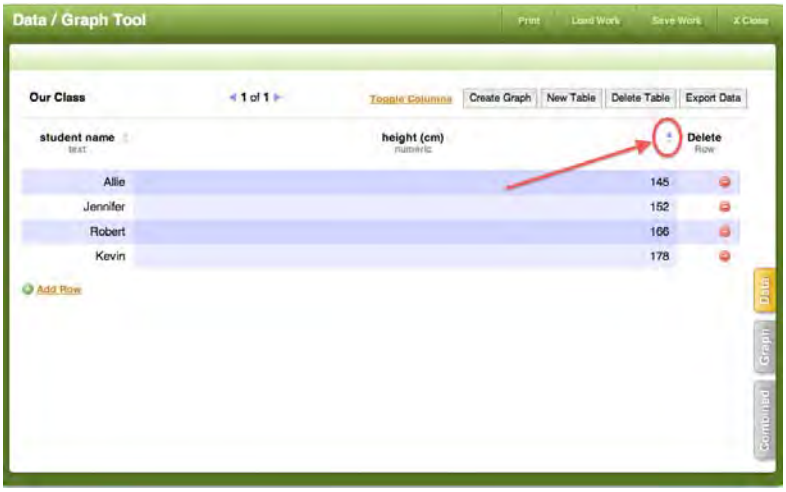
Further details on data types are found at the end of this guide. Columns can include variables (e.g. x and y), trial number, or any type of data element (e.g. student name).

For example, here are the inputs that would be used to set up a data table of the heights of members of the class.

Once these choices have been made, click on “Create Table” and the computer will generate a data table with the elements properly labeled.

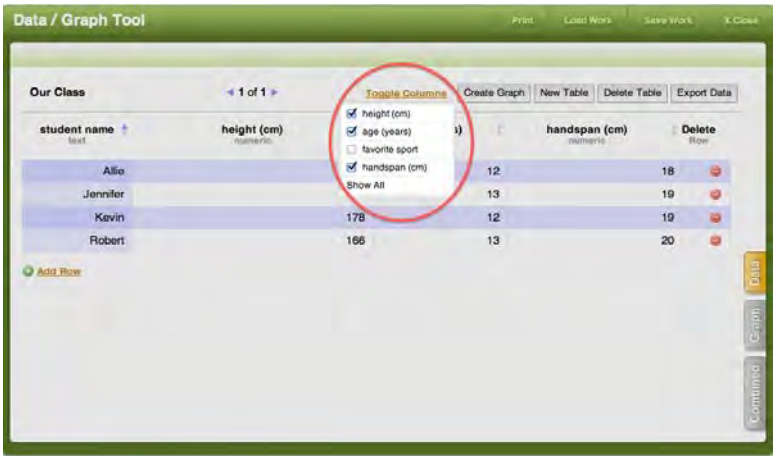


Data can then be manually entered into the appropriate field. For each data point to be added, add a row and then type the data into the correct columns.



In this example, the height (cm) column has been selected and the heights have been ordered from least to greatest by clicking on the sorting arrows at the top of the column. This order can be reversed using the same arrows. (This feature, and others, is similar to features often found in computerized spreadsheets and was developed in part to expose students to the power and utility of spreadsheets.)

If the data table includes more than two data columns, students may find it useful to temporarily hide selected columns using the Toggle Columns link at the top of the table. Selecting the Toggle Columns link opens a pop-up window such as the one shown on the right. Students uncheck boxes to hide a column or check boxes to display a column. You might mention that they are turning the column on or off, hence the term 'toggle.'



The ability to toggle on and off columns can facilitate students' initial attempts to analyze their data. If, for example, students wanted to see if there were a connection between handspan and height, they could easily turn off all the columns except height and handspan and look for a connection by comparing adjacent columns.

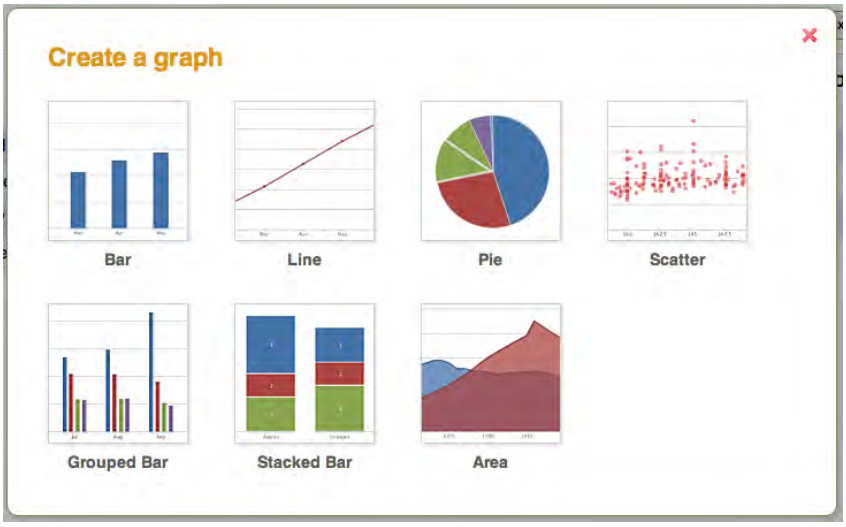
student name (text)	height (cm) (numeric)	handspan (cm) (numeric)	Delete (Row)
Allie	145	18	
Jennifer	152	19	
Kevin	178	19	
Robert	166	20	

Note that data can be printed or saved using the controls found along the top. Load Work will allow you to create a new data table using another person's (or group's) work if you have their Save Code.

A new data table can be created (New Table) for another set of data, if, for example, students wanted to compare heights in their class with the height of students in another class.

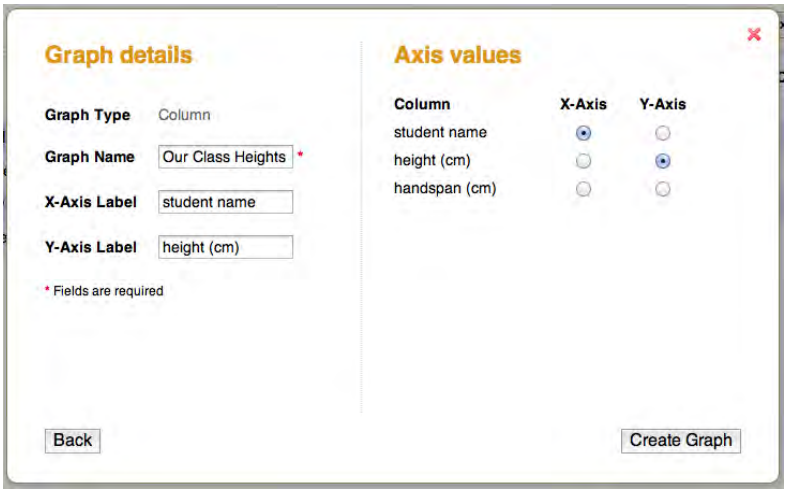
Generating a Graph

When you are ready to create a graph from a data table, simply click on Create Graph. The following screen will appear.



The type of data you have might determine the type of graph you select.

You will be prompted in the following screen to enter the appropriate details for the new graph. For most graphs, you will need to identify which element goes with which axis.

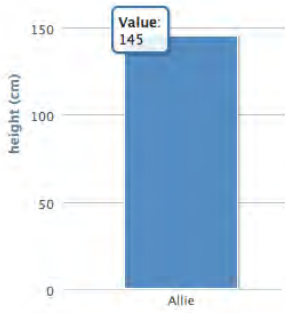


Note that the name of the graph (Our Class Heights) needs to be different than the name of the data table on which it was based (Our Class).

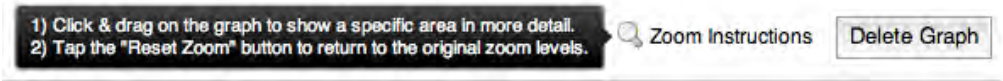
When you click Create Graph, a graph of the type you selected will be generated using the data in the data table.

Controls for viewing the data and/or the graph are along the right side of the window.
The user can move between displaying the data table, the graph, or both the data table and graph in one window as seen below.

Holding the cursor over a location on the graph will display the value of that element. Only one value can be shown at a time.



Clicking on the Zoom Instructions icon near the top right of the window will reveal an option to zoom in on sections of the graph in order to view the data in closer detail.



When applied to Our Class data set, the zoom function produces the following graph.

Notice how the scaling of the y-axis has been changed and results in an exaggerated height of the values of the bars.

With practice, students will begin to understand the ways in which they can produce graphs as a picture of data that can be used to analyze and explain science phenomena.

Hands-On Activity

Meltdown: Glaciers and Climate Patterns

In this activity, students will examine and compare two photographs of Neumayer Glacier, one from 2005 and one from 2016. They will answer questions about the impact of climate patterns and geographical conditions (such as, latitude, elevation, and proximity to the ocean) on the changes observed in the glacier.

Suggested Materials:
Per Group:

- Images of Neumayer Glacier
- World atlas, for determining latitude and longitude of Neumayer Glacier

To introduce the activity, ask students to discuss what they already know about climate patterns and the effects they have on glacial size. Describe a recent news story dealing with glacial ice (such as the iceberg the size of Delaware that broke off the Antarctic ice shelf in July 2017), and ask students to consider the reasons behind this and similar changes. Then, inform them that they will be performing an analysis of changes to a glacier, located on South Georgia Island off the coast of South America, between 2005 and 2016.

Procedure

Print or project the images to be examined and compared are below for student use.

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Caption: Neumayer Glacier, 2005
Image Source: NASA Earth Observatory.

Caption: Neumayer Glacier, 2016
Image source: NASA Earth Observatory.

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1. Direct students to discuss the changes they observe between the 2005 photograph and the 2016 photograph.
2. Ask students to consider what factors might have led to these changes.
3. Have students develop a hypothesis and then compare it to the evidence they discover in their research.
4. Encourage students to use an atlas as they consider the latitude, climate, and geography of South Georgia Island.

Analysis and Conclusions

1. Describe the differences between the two photographs.
Sample answer: The main glacier is significantly smaller in the 2016 photograph than in the 2015 photograph. This melting has also exposed the glacier in the top left to salt water and the action of the sea.

2. How would you best explain the differences between the 2005 photograph and the 2016 photograph of Neumayer Glacier?
Sample answer: The differences between the 2005 photograph and the 2016 photograph can best be explained by changes in the climate patterns that occurred in the years between 2005 and 2016. Specifically, the differences between the photographs can best be explained by a general increase in temperature, since details about the glacier's geographical location remain the same.

3. What role does geography (including latitude, elevation, and proximity to the ocean) play in the changes observed in Neumayer Glacier?
Sample answer: The latitude and elevation of South Georgia Island help explain why there would be a glacier in that location. The island's latitude is 54 degrees S, which is close to the Antarctic region, and it has mountains that reach more than 2,000 meters above sea level. At such altitudes, considerable snow will be precipitated and will accumulate to "feed" the glacier. The glacier in the photographs is located near the ocean, however, and changes in ocean temperatures have a strong effect on changes in glacier size.

4. What climate patterns do you believe could have led to the changes observed in Neumayer Glacier?
Sample answer: Increases in global temperature could have led to new climate patterns, bringing warmer air and ocean water to South Georgia Island. These new and warmer climate patterns could have led to the changes observed in Neumayer Glacier.

5. Much of the discussion around global climate change and glacial retreat focuses on the polar ice caps. Why is it important to consider the impacts of climate patterns on other parts of the world?
Sample answer: While the changes to the polar ice caps are a crucial part of global climate change, considering the impacts of climate patterns on other parts of the world reminds us that global climate change is not limited to any one area. It impacts all parts of the world, including the places where we live.

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In this activity, students will demonstrate the following Inquiry Skills:

- Patterns and Systems
  - Patterns and change:
    - Patterns in nature may be simple repeating patterns or complex changing patterns
    - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

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Hands-On Activity

Track Your Greenhouse Gas Emissions

Objective:
Students will keep track of all their activities that result in greenhouse gas emissions for one day.

Estimated time to complete: One day

Materials:

For each student:

- **Greenhouse Gas Emissions Tracking Sheets**
- **Student Investigation Sheets**

Procedure: Part 1:
For homework, prior to completing Part 2 of this activity, students should complete the **Greenhouse Gas Emissions Tracking Sheets**, below. Students should record on this tracking sheet all of their activities that result in greenhouse gas emissions. Students should track their activities for one full day from the time they wake up until the time they go to bed. Remind students that some activities directly release greenhouse gases (e.g., driving a car burns fossil fuels), and some activities indirectly release greenhouse gases (e.g., using electricity that was generated by a fossil-fuel burning power plant).

Students can add more lines or pages to their tracking sheets as necessary. Instruct students to return to class with their tracking sheets to complete Part 2.

Procedure: Part 2:
In class, break students into small groups. Have group members share their tracking sheets with one another, summarizing the main activities in their daily lives that result in greenhouse gas emissions. Students may find that they need to add to their lists after talking with others. Then, instruct students to brainstorm ways to cut down on or modify these activities in order to reduce greenhouse gas emissions Have students answer the Analysis and Conclusion questions.

Greenhouse Gas Emissions Tracking Sheets

Electricity

Most buildings use electricity that comes from burning fossil fuels. Record each use of electricity throughout the day, including lights, appliances, electronics, and computers. Don't forget appliances that are on all the time. When identifying the source of energy for each device (third column), be as specific as you can about the source of the energy that generated the electricity. (For example, rather than simply writing "fossil fuels," try to determine whether the fuel was coal, oil, or natural gas.) If you cannot locate more specific information, at least try to determine whether the source of energy was renewable or nonrenewable.

If necessary, add more rows to the sample tables below, or reconstruct them in your notes.

Electrical Device	Time Used	Source of Energy (e.g., coal, oil, batteries, wind, etc.)

If you can, look at your family's last energy bill. The bill should include information about the sources of energy used to generate electricity for your home. Where does your electricity come from?

_____

_____

_____

Heating and Cooking

Some homes use electricity for heating systems and stoves, but others use oil and gas. Try to find out which your family uses. (If the systems are all electric, include them in the table above.)

System	Time Used	Energy Resource (e.g., oil, gas, coal, wood)

Transportation

Most forms of transportation are powered by burning fossil fuels, which releases greenhouse gases. Record all of your trips that are powered by fossil fuels. Note the type of vehicle and the time of the trip. Public transportation results in fewer emissions per person than most private cars.

Destination to/from	Type of Vehicle	Total Travel Time

Other

Record any other activities that result in greenhouse gas emissions, including eating beef (cows release methane gas) and using products that have been shipped long distances.

Analysis and Conclusions

1. What could you do to reduce your family's greenhouse gas emissions related to electricity?

   Sample Response: *To reduce my family's greenhouse gas emissions from electricity, I could make sure that lights are off when no one is in a room, replace incandescent light bulbs with lower energy kinds of bulbs, and unplug electronic devices when they are not in use.*

2. What could you do to reduce your family's greenhouse gas emissions related to heating?

   Sample Response: *To reduce my family's greenhouse gas emissions related to heating, I could set the thermostat lower at night or during the day if no one is home, and use extra blankets on the bed.I could ensure that all doors and windows are tightly closed.*

3. What could you do to reduce your family's greenhouse gas emissions related to transportation?

   Sample Response: *To reduce my family's greenhouse gas emissions related to transportation, we could all agree to run errands at a particular time each week, to avoid multiple trips to the same places. I could walk or ride my bike to friend's houses or to go shopping. We could use public transport rather than a private car.*

Inquiry and Nature of Science Skills in this Activity:

- Gather Data
  - Use the appropriate format to record data:
    - Writing (journal, worksheet, electronic text)
- Interpret Data
  - Identify and interpret patterns using:
    - Trends in data
- Evaluate Evidence
  - Draw and support a conclusion by:
    - Using data to determine the cause-effect relationship observed in the investigation
    - Extrapolating results beyond the investigation
- Engineering and Technology
  - Uses of Technology:
    - Technologies, such as pesticides, often have drawbacks as well as benefits.
    - Not every problem has a technological solution.

Exploration Teacher Guide: Understanding Climate

Overview

Climate is the average weather conditions prevalent in a region, over a long period of time. It is influenced by factors like latitude, topography, elevation, proximity to oceans, and general air circulation. In this Exploration, students examine different climatic regions and identify the characteristics associated with each type of climate. Students also examine the effects of greenhouse gases on Earth.

Student Learning Objectives

- Identify the latitude range, temperature, annual precipitation, and representative flora and fauna of different climate types.
- Examine the effects of greenhouse gases on Earth.
- Identify the natural and anthropogenic source of greenhouse gases.
- Identify the ways in which Earth's climate zones are likely to change as more greenhouse gases are added to the atmosphere.

Student Worksheet

The student worksheet includes questions for students to focus on. Students may review questions before going through the Exploration and can respond either during or after completion. Some questions require critically thinking and application of other concepts. These questions are better used for discussion than assessment.

Using this Exploration

In the *Identify* tab, students select the climate they want to explore using the options in the *Select Climate* dropdown list. Based on the selected climate, the regions associated with the selected climate get highlighted. Students then identify the latitude range, temperature, annual precipitation, and representative flora and fauna of the selected climate using the radio button options in the *Characteristics* section. They use the *Check* button to validate their selections. The correctly identified latitude range, temperature, annual precipitation, and representative flora and fauna of the selected climate get populated in the table. Students may use the *Reset* button to undo what they have done. They may also use the *View Zones* button to view the regions associated with all the climate zones.

In the *Examine* tab, students select a greenhouse gas using the options in the *Select Greenhouse Gas* dropdown list. Students select the concentration, for the selected greenhouse gas, using the options in the *Select Concentration* dropdown list. After making selections in the dropdowns, students use the *Start* button to examine the effect of the selected greenhouse gas on Earth. Students then identify the natural and anthropogenic source of greenhouse gases. They also identify the ways in which Earth's climate zones are likely to change as more greenhouse gases are added to the atmosphere.

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In the *Tracker* tab, students track the characteristics of the climate type they have identified correctly. They may also use the buttons in the *View World Map* column to view an image of the climate zone on the world map.

Answers to Questions in the Student Worksheet

1. Explain the term climate. Identify the factors that influences climate.

   Answer: Climate is the average weather conditions prevalent in a region, over a long period of time. It is influenced by factors like latitude, topography, elevation, proximity to oceans, and general air circulation. It is also influenced by the concentration of greenhouse gases in the atmosphere.

2. Describe how mountains can influence the annual precipitation received by a region.

   Answer: Mountain ranges can cause the moisture bearing clouds to precipitate on the windward side of the range. As a result of this, the leeward side receives less precipitation. Hence, mountains can influence the annual precipitation received by a region.

3. Explain the term global warming potential (GWP). Identify the GWP of methane, and explain what this means.

   Answer: The global warming potential (GWP) is the measure of the relative potential of a particular mass of the greenhouse gases to trap heat over a specific amount of time. The GWP of greenhouse gases is given as a ratio in which the GWP is compared to the GWP of carbon dioxide, where the GWP of carbon dioxide is 1.The GWP of methane is 25. This means that one gram of methane traps 25 times more heat than one gram of carbon dioxide over the same period of time.

4. What is the main difference between temperate climates and continental climates?

   Answer: Regions associated with temperate climate are found in both northern and southern hemisphere while the regions associated with continental climate are found only in the northern hemisphere. Precipitation is generally in the form of rain in temperate climate and in the form of both rain and snow in continental climate. Continental climates tend to have greater extremes of temperature between winter and summer.

5. Water vapor is a strong greenhouse gas. Explain how an increase in carbon dioxide can cause an increase in water vapor in the atmosphere.

   Answer: Burning fossil fuels causes an increase in carbon dioxide and water vapor in the atmosphere. An increase in carbon dioxide increases the amount of heat trapped by the atmosphere, and the temperature of the air. This increase in air temperature increases the

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moisture bearing capacity of the atmosphere and causes evaporation. Hence, an increase in carbon dioxide causes an increase in water vapor in the atmosphere.

6. Earth's moon and Earth are equidistant from the Sun. However, the temperature range on the Moon is different from that on Earth. Explain how the greenhouse effect plays a role in this.

   Answer: Earth's moon does not have an atmosphere, which is why there is no natural greenhouse effect on the Moon. In the absence of natural greenhouse effect, the Moon cannot trap the heat received from the Sun. Thus, the Moon cools off much more drastically at night than the Earth. Earth's atmosphere traps heat during the day and can reradiate it out at night to keep Earth warm at night.

7. A friend points out that concentration of carbon dioxide in the atmosphere has increased by only about 1000 parts per billion in the last 200 years. Your friend says that it is insignificant. How do you respond?

   Answer: It is important to look not only at the absolute increase, but the *relative* increase. The natural concentration is 700 parts per billion, so although 1000 parts per billion does not seem significant, it is equal to a 140% increase, which is significant and can have a significant effect on Earth's climate.

8. Compare the latitude ranges of the various climate regions. Describe how latitude and climate are related. Why are they are not correlated perfectly?

   Answer: The latitude ranges of arid climate is 0°- 50° N and S; continental climate is 40° - 80° N only, polar climate is 65° - 90° N and S; temperate climate is 0° - 60° N and S; and tropical climate is 0°- 25° N and S. Climate is defined by the annual temperature and annual precipitation patterns of a region. The amount of solar energy received from the Sun at lower latitudes is greater than the amount of solar energy received from the Sun at higher latitudes. The amount of solar energy influences the annual temperatures and evaporation rates of a region. Hence, the annual temperatures of regions in the lower latitude are higher than that of the regions in the higher latitudes.

   Latitude and climate are not correlated directly because of altitude and topography. High altitude regions at lower latitudes have colder climates that are generally associated with higher latitudes. Ocean currents also influence air temperature. Regions at high latitude can be warmed by warm ocean currents, while regions at low latitude can be cooled off by cool currents.

9. Antarctica can be classified as arid as well as polar. Explain.

   Answer: Arid regions are characterized by rates of low annual precipitation relative to evaporation. The annual precipitation in Antarctica is generally than or equal to 15 to 25 cm

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in the form of snow. Hence Antarctica can also be classified as a cold desert, an arid climate.

10. It is very difficult to predict the effects that increasing greenhouses gases will have on a particular climate region. Scientists think that some regions will experience cooling instead of warming. Explain why this is.

    Answer: Although an increase in greenhouse gases can cause an overall warming of the global climate, the local effects are hard to predict. For example, warming could cause one region to become drier and another to become wetter. Warming can also change the paths of important ocean currents like the Gulf Stream. Right now, the Gulf Stream brings warm water to northern Europe, keeping places like Great Britain much warmer than they would be without the current. If the Gulf Stream current moves, the climate of places like Great Britain could become cooler.

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Hands-On Lab

How Does Trampling Impact Plant Species Composition, Diversity, and Percentage Cover?

Timing: One 90-minute class session

Objective(s)
In this activity, students will investigate how organisms respond to external factors. They will investigate the impact of trampling on grassland.

Safety Precautions
Remind students to avoid handling toxic plants and other harmful organisms that may be found in the field.

Materials
Per pair or group:

- Quadrat
- Plant identification guides (optional)
- Access to a computer with graphing software

Teacher Preparation
Locate a site where there exists in close proximity an area of grass that is heavily trampled and one that is not. Alternative options may exist, such as mowed or unmowed grass. You may obtain plant identification guides for students to use. However these are not essential for this exercise. Students can simply give the species they find a number or letter. Survey the area you have chosen for the presence of toxic plants and other organisms. Small quadrats (25cm x 25 cm) work best. Quadrats can be constructed out of coat hanger or fence wire.

Procedure

You may choose to use the Guided Inquiry path on its own or after completing the Directed Inquiry activity. During Guided Inquiry, students are allowed to conduct the investigations more independently. They will be given opportunities to formulate their own questions, develop their own procedures, and/or manipulate variables of their own choosing. It may be necessary to provide additional materials and supplies for students using Guided Inquiry. It will also be important to set clear limits on students' activities to ensure their safety and the relevance of their inquiry experience to the content you are teaching.

<u>Directed Inquiry</u>

1. Explain that the objective of this lesson is to determine whether trampling (by human feet) impacts the numbers of species and percentage cover of different species present in an area of grassland.

2. Have the students make predictions and formulate a hypothesis.
3. Provide students with an outline table for their results.
4. Take students to the study area. Indicate the areas—trampled and untrampled—to be studied.
5. Explain the use of the quadrats. The students should:
    - Simulate random location of the quadrat by dropping it over their shoulders.
    - Sample at least five quadrats in each area.
    - Identify the species of plant in each quadrat. These can be identified using a field guide, or students can remove samples and label them as separate species (Species A, B, C, etc.).
    - Estimate the approximate percentage cover of each species.
6. Have students conduct the survey.
7. Return to the classroom. Have students plot their cumulative results of species present and percentage cover on separate histograms.
8. Facilitate a discussion of the differences between the trampled and untrampled areas.
9. Have students write their conclusions and answer the questions.

Guided Inquiry

1. Take students to the study area.
2. Provide students with the objective.
3. Ask them what they could measure to determine the impact of trampling on an area of grassland.
4. Have them make predictions as to what they may find.
5. Provide pairs of students with time to devise a possible procedure.
6. Discuss procedures from samples of pairs with the class. Guide students towards the use of a standardized sampling technique, including the use of quadrats, taking multiple samples, and simulated random sampling.
7. Have students conduct their surveys. They should collect data in tables of their own design.
8. Have students return to the classroom. Students can select their own methods for compiling and presenting data, including the use of technology.
9. Have students present their data and conclusions as part of general discussion about the lab.

Analysis and Conclusions

In order to help students analyze and interpret their results, consider discussing some or all of the following questions. Emphasize that they should support their answers with evidence from the data.

1. How did the species composition differ from the trampled and untrampled areas? *Descriptions will vary, but usually trampled areas have many of the same species present except for a few species that are found in only either the trampled or untrampled areas.*
2. Did the number of species (species diversity) differ in the two areas? *Descriptions will vary, but generally the untrampled areas have a higher species diversity than the trampled areas.*
3. Did the percentage cover of species differ between the two areas? *Species found in both areas usually differ in their percentage cover.*

4. Write a short paragraph summarizing how trampling impacts the plant species present in your grassland area. *This should be a synthesis of questions 1–3 plus additional observations about specific plants or groups of plants.*

Further Questions

1. How could the information you collected help gardeners or groundsmen? *By studying the plants present in the trampled areas, they may identify varieties of grasses that are resistant to trampling. They could plant these in areas where trampling is likely to occur. The information may also help them to identify weeds that are likely to appear in trampled areas. This information could be used to develop weed control strategies.*

Inquiry and Nature of Science Skills in This Lab

- Identify Questions
  - Develop a question that:
    - Asks a question about a specific science concept or process
  - Recognize and develop testable questions that:
    - Specify a cause-effect relationship
- Design Investigations
  - Design and conduct investigations using:
    - Fair test—changing only one variable at a time makes comparisons valid
    - Independent variable—the one variable the investigator chooses to change
    - Dependent variables—what changes as a result of, or in response to, the change in the independent variable
    - Control (control group)—used for comparison in which the independent variable is not changed
  - Explain the investigative processes by:
    - Describing the logical sequence that was used to conduct the investigation
    - Properly citing all equipment and materials
    - Describing it so that it can be easily repeated by a fellow scientist
  - Practice lab safety by:
    - Following lab safety procedures
    - Recognizing safety equipment and materials and knowing their proper use
- Gather Data
  - Choose appropriate tools to conduct an investigation
    - Glassware
  - Use senses to observe
    - Seeing (color, shape, size, texture, motion)
- Evaluate Evidence

    - Draw and support a conclusion by:
        - Using data to determine the cause-effect relationship observed in the investigation
        - Reporting trends and patterns in the data
        - Comparing results to hypothesis
- Communication in Science
    - Report results using:
        - Peer presentation
- Analyze Scientific Results
    - Participate in critiquing/peer review by:
        - Evaluating an investigative design
        - Evaluating a conclusion
- Scientific Investigation
    - Scientific Data and Outcomes
        - Results of similar scientific investigations may turn out differently because of inconsistencies in methods, materials, and observations.
        - It is important in science to keep honest, clear, and accurate records.
- Scientific Endeavor
    - Characteristics of Science
        - One way to make sense of something is to think of how it relates to something more familiar.

Hands-On Activity

Investigating Adverse Impacts of Human Activity on Biodiversity

In this investigation, students will examine the impact humans are having on biodiversity. By collecting evidence about human activities, students will design a simulation that shows how these activities may impact biodiversity and then suggest solutions to the problems. Students will also engage in a discussion about the impacts of global warming on biodiversity.

Suggested Materials

Per group:

- Internet access and/or library resources
- art and craft materials

Procedure

Part 1: Discussion of Human Activities

If desired, prepare supplies of art and craft materials including such items as craft wood sticks, polystyrene foam, pipe cleaners, scrap fabric and plastic, glue, and tape. To introduce the activity, read the students the following passage:

We have been studying evolution and the origin of new species. However, in the history of life, the great majority of species that ever lived have become extinct. Think of all the species of dinosaurs you have read about. Not one of them survives today. The reason for extinctions is that species are unable to adapt to changes in the environment. Today, humans are changing the natural environment. Look around you. There is evidence of those changes everywhere. Deforestation, water and air pollution, and industrial or urban development are examples of how human activity can adversely impact the environment. Because these changes are so rapid and widespread, most species are unable to adapt, and may become extinct. This loss of species is already dramatically reducing biodiversity, the variety of life on Earth.

1. Engage students in a discussion on biodiversity and why it is important.
2. Have students discuss ways in which human activities can reduce biodiversity.
3. Have students break into teams and select one human activity (other than global warming) that adversely affects biodiversity. Have them address the questions below.

   a. What human activity did you select?
   b. How does this activity impact the environment?
   c. How do these impacts reduce biodiversity?
   d. What efforts have been made to reverse the effects of the activity?
   e. What other ways can you think of to reduce this activity's impacts on biodiversity?

4. Students will present their findings to the rest of the class. If time and materials allow, students can create a simulation or model of the human activity being discussed to clarify how it changes

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the environment and reduces biodiversity. For example, nutrient runoff from agriculture can be modeled by spraying a food coloring solution on artificial grass and rinsing it with a watering can or similar to simulate rain. Examining the colored water that runs off can clarify how harmful chemicals enter watersheds even a significant distance from fields and farms. In addition, students should demonstrate or present a way for the adverse effects of the human activity to be remediated.

Part 2: Focus on Global Warming

Divide students into two teams and have them research the topic of global warming and its possible effects on biodiversity. Students should focus on the question, "How could global warming affect biodiversity?" Students should include data about the effects of global warming on biodiversity. This could include loss of species due to extinction or migration of species to different areas, for example.

1. Have students investigate one specific effect of global warming on biodiversity, making sure to clarify the connection between the change in environment and the way this change affects organisms. Students should also consider the effects that the loss of one species has on others; for example, acidification of an ocean can kill delicate coral, which serve as a source of shelter and food for many fish and marine invertebrates.

2. Each group should present their findings to the rest of the class. Once both groups have presented, discuss with the class other ways that the selected effects could impact biodiversity which have not already been covered.

Analysis and Conclusions

1. What are the specific consequences of the human activity you selected?
   Answer will vary depending on which impact students selected.

2. How can you be certain that these consequences are caused by the human activity and not just correlated to it?
   Answers will vary depending upon which activity was selected. But answers should provide a clear link showing how the activity caused the consequences.

3. What methods are in place to remedy the impact of human activity you selected?
   Answers will vary depending upon which activity was selected.

4. What effect of global warming did you investigate as it relates to biodiversity? Given what you know about human impacts, what steps can humans take to prevent further loss of biodiversity and environmental change?
   Answers will vary depending upon which activity was selected.

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In this activity, students will demonstrate the following Inquiry Skills:

- Design Investigations
    - Make or use models that:
        - Simulate the real thing that cannot easily be studied or manipulated
        - Have as many details as possible replicated from the real thing
        - Function exactly like or similarly to the real thing.

- Patterns and Systems
    - Patterns and change:
        - Patterns in nature may be simple repeating patterns or complex changing patterns
        - Some events can be predicted with certainty, such as sunrise and sunset, and some cannot, such as storms.

- Evaluate Evidence
    - Drawing and Supporting a Conclusion by:
        - Using data to determine the cause effect relationship observed in the investigation
        - Report out trends and patterns in the data

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Exploration

TEACHER guide

Something Fishy

Exploration Summary

Students will test rates of harvest for North Atlantic swordfish over several time periods to identify a sustainable rate.

Student Learning Objectives

- Explain that sustainable use of resources means that the resource is being used at a rate equal to or less than the rate of recovery; unsustainable means the resource is being used at a faster rate than the rate of recovery.
- Recognize that renewable resources, like nonrenewable ones, can be used up completely if they are harvested at a rate greater than their rate of recovery.
- Discover that our buying choices can contribute to overexploitation of a resource.

Student Worksheet

The student worksheet includes questions to check understanding, instructions for how to use the Exploration, and a section for recording Exploration data. Why do the questions come first? In following best practices for teaching science, students are asked to review questions before participating in an activity. When the questions come first, students are more focused on the intended content of the activity. Then they can respond to the questions during the activity or after completion of the activity.

Exploration Procedure

Explain that the purpose of this Exploration is to learn that a species can become extinct from overharvesting. Follow the appropriate procedure below.

Student Performs Exploration

1. Tell students how much time they will have to complete the Exploration and the student worksheet.
2. Explain how students should proceed:
   - Read the questions before starting the Exploration.
   - Follow the instructions on the worksheet to perform the Exploration.
   - Take notes or record data as necessary.
   - Respond to the questions in writing.
3. Explain that you will be available to help any students who raise their hands.
4. Tell students to begin the Exploration.
5. When time is up, ask students to share their answers.
6. Talk about the Discussion Question below.

Exploration

TEACHER guide

Something Fishy

Teacher Performs Exploration

1. Display the questions from the student worksheet and ask students to tell you what they think they will learn from the Exploration based on its questions. Highlight key words.
2. Read the Introduction and click the Continue button.
3. Read the text along the bottom and then select a rate of harvest and an amount of time. Click on the Play button.
4. Point out the starting and ending populations. Read the text and ask the questions posed.
5. Continue with all the combinations.
6. Pose each of the questions below and ask for answers from the class. Replay parts of the Exploration as necessary to illustrate the answers.
7. Talk about the Discussion Question below.

Optional: Use this Exploration as a small-group activity at a computer station. Assign it to students who need specific reinforcement of the concept.

Questions

1. Define overharvesting.
   Answer: When a resource is taken at too high a rate to maintain a healthy population.
2. What would happen if we continued to overharvest swordfish?
   Answer: The fish would become scarce and eventually extinct.
3. Which rate of harvest is twice the sustainable rate?
   Answer: 26,740 metric tons/year
3. What can governmental agencies do to help with over-harvesting?
   Answer: Set limits of the amounts harvested and require less harmful fishing methods.

Discussion Questions

A major international scientific study released in November 2006 in the journal *Science* predicts that, if current trends in the decline of fish stocks continue, all fish stocks worldwide will collapse within fifty years. Discuss what can be done to reverse the trend.

Possible ideas

- Stop eating fish that are being overexploited.
- Countries should organize a joint effort to promote sustainable fishing.
- Fisheries that conform to the sustainable fishing practices can be certified. Then traders and retailers would purchase fish products only from certified fisheries.