Exploring our Environment

Inquiry based learning

with the Labdisc

Table of Contents

Globisens

www.globisens.com

Why Teach Environmental Science?

Environmental literacy stems from a strong connection to the natural world and an understanding of the interconnectedness of all living things. Environmental Science is more important now than ever before. With the world's changing climate, increasing threats to wild places, and declines in science in the classroom and in civic engagement in local communities, Environmental Science has never been more necessary. Labdisc Environmental Science lessons build environmental literacy (or environmental know how), connect young people to the natural world, and meaningfully transfer what they learn in school to their daily lives at home, at school, and in their communities.

Your students are the stewards and leaders of tomorrow, and Environmental Science lessons inspire personal connections to the natural world and responsible actions to sustain it. Labdisc Environmental Science lessons focus on scientific principles, critical-thinking skills, hands-on scientific research, and inquiry based learning. Yet we recognize that environmental literacy requires more than scientific knowledge, and these lessons also build self-esteem and confidence and empower young people to make a difference.

What Is Data Logging?

The term datalogger refers to educational hardware and software that can be used for real time data acquisition, display, and analysis with a computer, laptop or tablet. By connecting the Labdisc to a computer /tablet running Globilab, students can observe data displayed in a variety of formats as it is being collected. When used in an inquiry based learning context, this capacity can significantly increase and speed learning. Datalogging has been used widely in science, mathematics, and technology education.

The Labdisc contains of sensors that convert physical properties into an electrical signal. The Labdisc's software then changes the electrical signal from the sensor into a form that can be read by computers and displayed in the Globilab software. More than 40 kinds of probes are used in education, although temperature, light, and distance probes are most common.

The Globilab software used with the Labdisc can represent the data from the probe as a number, a dial, a line or bar graph. There is tremendous educational value in having students see the display change in "real time" as the physical input changes. Students can quickly associate the physical changes happening with the way the data representation changes. The Globilab software can also be used to analyze the data once it has been collected. Students can use it to quickly determine the maximum and minimum data values as well as standard deviations and average values. There are also available features to determine slope, apply linear and quadratic regressions to the data, perform a frequency analysis, smooth data and determine derivatives.

The use of datalogging in education has been hindered by misunderstandings of its appropriate educational role. The most common misconception is that probeware can harm student learning by reducing the amount of exposure to hands-on learning. As with any technology, probeware can be used well or poorly, but with appropriate instructional design, probeware actually increases student learning from inquiry. High quality instruction is not an automatic consequence of using dataloggers. Good instructional strategies and designs are necessary. Instruction that uses dataloggers should still leave it to the student to decide what to measure and how to interpret the results. The role of the probeware is to lessen the drudgery, allow students to focus more on the experiment, and increase the amount and range of experimentation students can undertake. For students to use dataloggers effectively, they all they need is to understand the relationship between input and output. They can learn quickly, for instance, that an increase of temperature at the sensor causes the line to go up on a graph on the display. They do not need to know how the display works to use this representation for exploration and learning.

One important current development has been the use of probeware with iPad and Android tablets. This makes it feasible to extend experiments outside the lab and classroom. Current developments in probeware are also expanding the ways data can get from sensors into computers. "Smart" loggers like the Labdisc use standard serial inputs, USB, and/or Bluetooth connectivity.

Environmental Science Content Covered In This Unit

The lessons in this unit will cover a wide range of interconnected Environmental Science topics including:

- ☆ Greenhouse effect (Greenhouse Effect)
  - Effects on temperature in a closed environment
  - Effects of increased greenhouse gases on environmental temperatures

- ☆ Effects of temperature on behavior (Coping With a Warm Environment & Effects of Temperature on Behavior)
  - Coping strategies for cold temperatures
  - Coping strategies for warm/hot temperatures

- ☆ Climate Conditions (Daily Weather & Water Changes and Circulation)
  - Using longitudinal weather data to explain/predict weather conditions
  - Examine how changes in weather affect ponds/lakes

- ☆ Water Quality (Effects of Turbidity on Aquatic Life)
  - Effects of increased turbidity on growth rate of aquatic organisms

- ☆ Infrared Energy (Herschel Experiment & IR Radiation All Around Us)
  - Prove that infrared energy exists
  - Comparison of visible spectrum and non-visible spectrum temperatures
  - Measurement/Comparison of IR temperatures of objects in the environment

- ☆ Photosynthesis (Photosynthesis and O_2 Production & Photosynthesis & the Water Cycle)
  - Factors affecting O_2 production during photosynthesis
  - Transpiration as part of the photosynthesis process and its results

- ☆ pH (Soil pH)
  - Measurement/Comparison of local soil pH
  - Prediction/Recommendation of successful plant life in local soils

How to…..

Set up the Labdisc from the Labdisc Menu

1. **Turn on** the Labdisc by pressing the On/Off key.
2. **Rotate the Labdisc plastic ring** to expose the sensors. Connect any external sensors that you might be using (pH, Dissolved O2, Conductivity, Thermocouple, External Temperature, Force/Accelerometer, Heart Rate, Current, Voltage or Magnetic Field).
3. **Select Sensors** - Press Scroll key   to open the sensor menu. Press the Select key   to open the Set Up menu   and then choose the Set Sensor icon   using the Select   key again. Select the sensors that you wish to use by pushing the buttons on the perimeter of the Labdisc. Some buttons control more than one sensor. Push the button multiple times to scroll through the available options. When the sensor(s) that you want is/are highlighted push the Escape key   to return to the set up menu. *Note: Some buttons can only activate one sensor at a time because of the external connections needed by the sensors*
4. **Set Sampling Rate** - Press the Escape key   to return to the previous menu and use the scroll key   to move to the Sampling Rate icon   and push the Select key   . Use the Scroll key   to move through the options. Use the Select key   to choose the rate at which you want to select samples. Press the Select key to confirm your choice. Options include manual, 1/second, 10/second, 100/second, 1000/second and 25000/second. The rate of collection by some sensors is limited and so you may not see all of the options for every senso   r. *Note if you choose to sample Manually, skip Step #5.*
5. **Set the Number of Samples** - Press the Escape key   to leave the previous menu and use the scroll key   to move to the Number of Samples icon   and push the Select key   . Use the Scroll key   to choose the number of samples you wish to collect. Options include 10, 100, 1000, 10000. Press the Select key   to confirm your choice.   Press the Escape key   three times (3x) to exit the set up menu
6. **Begin Collecting Data** - When you are ready, press the Select key   to begin the data collection.

Pair your Labdisc with Your Computer via Bluetooth

1. Make sure that Bluetooth is enabled on your computer.

2. Open the Globilab software and *right* click on the Bluetooth icon   in the bottom right corner of the screen. Select Find More Labdiscs and Sensors. The computer will search and find any Bluetooth devices in the area. In the pop up window, select your Labdisc. If there are multiple Labdiscs running in the area, be sure that the number on the back of your Labdisc matches the Labdisc that you select from this list.

3. Press the Scroll key   till you hear a long beep sound and the Labdisc displays " BT PAIRING".

4. In the computer select "Enter the device pairing code" and click Next.

5. In the next dialog box enter "**1234**' as the pairing code and click Next.

6. Wait for the computer to finish the process and announce "Your device is ready to use"

7. Right click the Bluetooth icon on the status bar. Choose the Labdisc you've just paired and click on it.

8. The computer will connect to the Labdisc and turn the Bluetooth icon blue

How to…..

Set up the Labdisc from the Globilab Menu Using a Bluetooth Connection

1. Open the GlobiLab software and turn on the Labdisc by pressing the On/Off key. ⏻

2. If you plan to use a Bluetooth connection between the Labdisc and computer, make sure that your Labdisc has been paired with your computer. (see above) You will only have to do this the first time you use your Labdisc with a computer.

3. Right click on the Bluetooth icon in the bottom right corner of the Globilab screen ⓘ ⑧ 3/127 . Select the Labdisc you are using. Once the Labdisc has been recognized by the software, the icon will turn from grey to blue and you will hear a small chirp.

4. Click on ◎ to configure the Labdisc.

5. Select sensors that you wish to use in the "Logger Setup" window. Different sensors will show for different models of Labdisc, depending on what sensors are available.

   If you are using a Globisens brand external sensor attached to the Universal Adapter port, it will show up in the set up menu after you have attached it.

   If you are using a sensor from another company, you will need to select it from the dropdown menu.
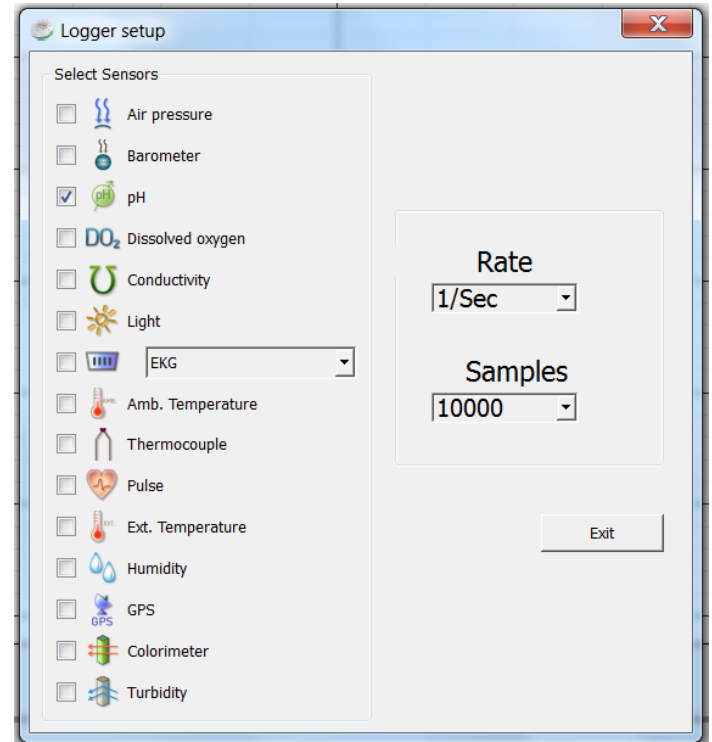
6. Click the dropdown arrow under Rate to select the sample frequency.

7. Click the dropdown arrow under Samples to select the number of samples you wish to collect.

8. Click Exit to complete the set up.

Logger setup

Select Sensors
- ☐ Air pressure
- ☐ Barometer
- ☑ pH
- ☐ DO₂ Dissolved oxygen
- ☐ Conductivity
- ☐ Light
- ☐ EKG
- ☐ Amb. Temperature
- ☐ Thermocouple
- ☐ Pulse
- ☐ Ext. Temperature
- ☐ Humidity
- ☐ GPS
- ☐ Colorimeter
- ☐ Turbidity

Rate
1/Sec

Samples
10000

Exit

How to…..

Download Your Data

1. Start the Globilab software on your computer and connect to the Labdisc to the computer. This can be done using a Bluetooth or a USB connection.

    a. Click on the **Bluetooth** icon in the bottom right corner of the Globilab screen. Select the Labdisc you are using. Once the Labdisc has been recognized by the software, the icon will change from grey to blue. If you have more than one Labdisc paired with your computer, you may have to right click and select the ID number of the Labdisc with which you are trying to connect.

    b. If you prefer a **USB** connection, connect your Labdisc to the computer by plugging the USB plug into the computer and the micro USB plug into the opening on the bottom of the Labdisc (not in the sensor ring). You will hear a beep and see the color change on the USB icon at the lower right corner of the Globilab software when the Labdisc is recognized.

2. Click on the download button to download the last data collection into the Globilab software. If you have collected more than one data set, click the drop down arrow and select the download menu option. This will allow you to select from a list of prior data collections. Save the data collection, by clicking the save icon. Be sure to clearly label your data collection so that you will not confuse it with the other data collections.

Clear the Labdisc Memory

1. Click on the Bluetooth icon in the bottom right corner of the Globilab screen. Select the Labdisc you are using currently. Once the Labdisc has been recognized by the software, the icon will change from grey to blue. If you have more than one Labdisc paired with your computer, you may have to right click and select the ID number of the Labdisc with which you are trying to connect. If you prefer a USB connection follow the previous instruction clicking on the USB icon. You will see the same color change when the Labdisc is recognized.

2. Right click on the numbers to the far right (3/127 in the example above) and select "Delete last" from the pop up menu to remove the most recent data collection from the Labdisc or you can select "Delete all" to remove all data from the Labdisc's memory. *Be sure to save any data you wish to use later **before** clearing the Labdisc's memory.*

How to…..

Use the Globilab Software (PC/Mac)

The Menu/Tool Bar

Open Data Files – this opens graphs showing experiment data previously collected and saved.

Save – this saves data from a current or downloaded experiment.

Activities – this opens pdf files of lesson plans.

Export – this has two options

Export the data in chart form into an Excel .csv file

Save a screen shot of the experiment graph as a .pdf file

Print – Prints a copy of the experiment graph

Zoom – Allows you to enlarge a section of the graph. Use a left click and drag the mouse to make a box over the area that you want to enlarge. You can do this multiple times, zooming in closer and closer on a chosen section. To return to the original size, right click on the graph. The Zoom toggles on and off, so be sure to turn it off before manipulating the graph when it's zoomed in or before selecting other buttons, like the Marker or Annotate buttons.

Marker – this allows you to place markers along a graph line using a left mouse click. The pop up window gives you detailed information about the data at that specific point in time. Hold down the left mouse button to slide the marker along the graph line to see details at different points in time or you can drag them to a different line to see information about other types of data in the same collection.   By double clicking on the marker you can lock it in place. Markers are also used to set the parameters of an area that you want to crop from within the graph. To remove a marker, right click on it and select "yes" when asked if you want to delete the marker. The marker button toggles on and off. To exit marker mode, click the marker button again

6

How to…..

Grid – this turns the background grid on and off.

Annotate – this allows you to add labels to your graph to explain what is happening on the graph. There are two types of annotations – a rectangle and a bubble shape that can be linked to specific places on the graph. You can also add pictures to your annotations by clicking the "add image" button." You can an unlimited number of annotations to a graph. To remove an annotation, right click on it and select "yes" when asked if you want to delete the annotation. The annotation button toggles on and off, so to exit marker mode, just click the annotation button again.

Crop – this allows you to select a specific portion of the graph to be extracted and saved separately. To crop a section of the graph, use the marker button to set a marker at the beginning and the end of the area that you want to save. Then select the crop button. All other data will be removed permanently from the graph.

Statistics – this allows you to quickly see the maximum and minimum values for a specific data collection as well as the average reading, the standard deviation and the number of samples and sampling rate. If you have collected multiple types of data in a single experiment, you'll need to click on the data labels in the upper right hand corner of the graph to select which type of data you want to see in the statistics.

Mathematical Functions – Globilab allows you to apply many different mathematical functions to your data. This drop down menu will allow you to select from:

Linear Regression – is used to display the bets linear line to fit the graph between two markers. A pop up box will display the mathematic formula for the line between the two markers in the Y = aZ + b format.

Quadratic Regression – is used to display the best parabolic line to fit the graph between the two markers. The pop up box will display the mathematic formula for the line between the two markers in the $Y = aX^2 = bX = c$ format.

FFT – is used to split the graphic display to show the original measurements in a time scale in the top window and to show its harmonics, on a frequency scale in the lower window.

How to…..

Smooth – is used to average a graph. Every sample is an average of the 2 before and 2 after samples. It can be useful in case the graph is very noisy

Derivative – is used to measures the sensitivity to change of a quantity in one data source (a function or dependent variable) which is determined by another quantity or another data source (the independent variable). i.e. light as a function of time

Set up – this allows you to select which sensors and set up the desired collection rate and collection size from the computer rather than from the Datahub itself. In order to use the set up button, the Datahub must be connected to the computer/tablet by either a Bluetooth or USB connection and must not be running and experiment.

Run/Stop – this allows you to begin or stop the collection of data. Like the set up button, this button will only work if the Datahub is connected to the computer/tablet by a Bluetooth or USB connection.

Download – this dropdown menu offers two options:

Download the data from the last experiment only

Select and download data from any experiment remaining on the Labdisc

Configuration – this allows you to set up the physical running of the Labdisc including; sound on/off, temperature in Celcius/Farenheit, Bluetooth on/off, GPS enabled/disabled and to set the language used by the Labdisc.

Display Options Menu – This allows you to select the format for data display. It includes:

Line graph – if there is data of more than one type displayed, you can set the scale on the left for different active sensors by *left* clicking on the sensor name in the legend in the upper right hand corner of the screen. A single *right* click on the sensor name will change the line to individual data points. A second *right* click will hide the sensor data from the graph. A third *right* click will return the sensor graph to a line.

How to…..

Bar graph –bar graphs will show data from only one sensor at a time. To change which data is displayed, left click the sensor name in the upper left hand corner of the screen.

Data table –shows data that in a chart format. This can be used to view exact measurements for every collection.   If you have an outlier data point, it can be eliminated or corrected in this format.

Line graph and Data Table – shows both a line graph and a data table simultaneously.

Meters, Data Table and Line Graph – shows sensor data in three formats – a meter, a line graph and a data table. You can change/set the number of meters that are shown from the Meter button. (see below)

Meters – Meters are best used when the Labdisc is connected to the computer during the data collection since they show changes in the data values as are they are happening. There are several different options for meters including;

Full Dial	Half Dial	Vertical Bar	Horizontal Bar	Numeric Readout	Red, Blue & Green Colorimeter Bulb

To change between different meter types or to adjust the range of a meter, left click on the meter to open a pop up window where you can select options. You can select to view 1, 2, 4 or 6 meters by clicking on the meter icons at the bottom of the screen.
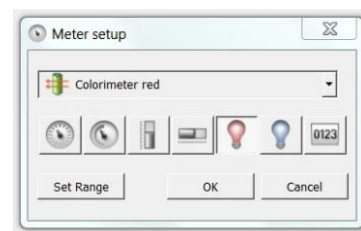
Google Earth Map – this allows you to overlay a Google Earth map of the area where your experiment was conducted with the data from the sensors in that experiment. You must have an Internet connection for this to work properly.

How to.....

Customize the Display Window

Setting the graph title – To customize the graph with the name of your experiment, double click on the graph title to get a pop up window. You can then add the title of your experiment. The default title will be the date and time that the experiment was conducted.
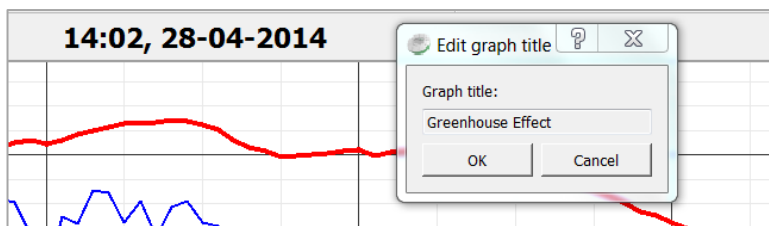
Setting Y axis legend – to set the Y axis for a specific sensor, left click on the sensor name in the upper left hand side of the screen (A) to activate that sensor's reading.

Adjusting the Scale – left click on the Y axis scale to get a pop up window. Type in a minimum number slightly lower than your lowest reading and a maximum number slightly higher that your highest reading. This will give you the greatest detail on your graph (B).

A.
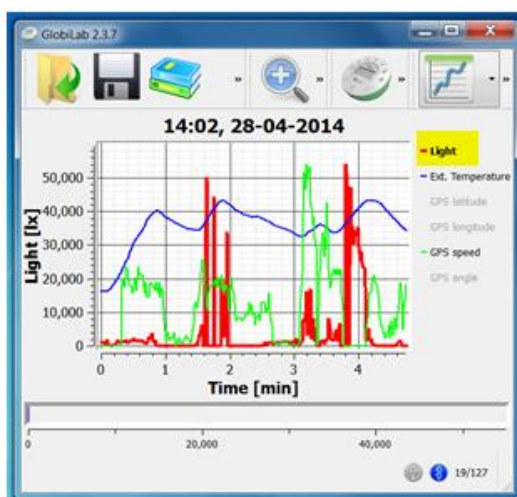
B.
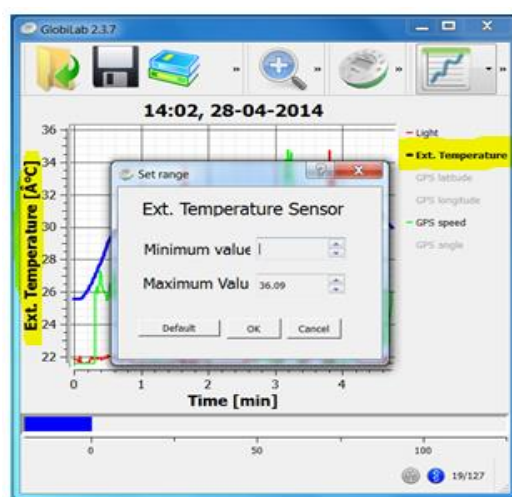
How to…..

Use the Labdisc Enviro Sensors
When using any of the Labdisc Enviro sensors, be sure to rotate the outer ring so that the sensor is exposed to the environment during the experiment unless otherwise noted.

Turbidity Sensor
Calibrate the turbidity sensor by placing a cuvette full of 1000 NTU turbidity standard into the sensor. Press and hold the turbidity key for 3 seconds until a long beep is heard.   To use the sensor, fill the cuvette to a 75% volume with the samples and measure the turbidity, being sure the cuvette is dry outside.   Insert the cuvette into the appropriate space and, keeping the top of the cuvette pointed upwards; rotate the outer protective ring shut over the cuvette.

Colorimeter
Calibrate the colorimeter with the solvent you will use during the experiment. This is important to minimize experimental error of the measurement. To calibrate, fill the cuvette ¾ full with solvent (often distilled water) and place the cuvette in the output. Press and hold the colorimeter button on the Labdisc until you hear a long beep. When finished the calibration, remove the cuvette from the colorimeter. To take a data reading, fill the cuvette ¾ full with solution from the sample. Be sure to ALWAYS hold the upper part of the cuvette to avoid leaving fingerprints on the cuvette. Insert the cuvette into the appropriate space and, keeping the top of the cuvette pointed upwards; rotate the outer protective ring shut over the cuvette.

Ambient Temperature Sensor
No additional set up is needed for the Ambient Temperature sensor. This sensor is best when used for data collections longer than 30 minutes. Since it is an internal sensor, it may take up to 15 minutes to equalize to the environmental temperature.   It is primarily used for long term, environmental temperature measurement.

External Temperature Sensor
Plug the External Temperature sensor into the outlet in the Labdisc and insert the tip (at least 2cm) into the item/area where temperature is being measured. The External Temperature sensor is suitable for taking environmental temperatures as well as the temperature of liquids and loosely packed solids like soil or sand.

GPS (Global Positioning Satellite) Sensor
No additional set up is needed to use the GPS sensor. GPS unit is located behind the housing of the Humidity sensor. It can be used to measure location or speed of movement over a large area. The GPS sensor can also be used to position other collected data onto a Google Earth map, providing accurate information about where the data was collected.

Humidity Sensor
No additional set up is needed for the Humidity sensor. It is used to measure the amount of water vapor in the air. Water vapor is the gaseous state of water and is invisible. The amount of humidity indicates the likelihood of precipitation, dew, or fog.

Infrared Sensor
No additional set up is needed for the IR sensor. It measures the infrared light waves that are part of the non-visible spectrum of light. IR by measured as the heat that is radiated off of objects

Barometric Pressure Sensor
No additional set up is needed for the Barometer. Barometers are used to measure atmospheric pressure. This can be used to make reasonably accurate weather predictions. Typically lower pressures produces precipitation and higher pressures produce clear skies. Rapid changes in barometric pressure are indicative of impending weather changes.

How to…..

pH Sensor

Attach the pH sensor to the input bracket by inserting and turning ¼ turn. The pH meter will measure the H ion activity in a solution. The pH sensor is factory calibrated and under normal conditions does not require any calibration. If you need to calibrate this sensor; insert the Labdisc pH electrode into a 7.0pH buffer and wait for the pH reading to stabilize. Press and hold the pH key for 3 seconds, until you hear a long beep sound and the pH sensor is calibrated and will show a reading between 6.95pH to 7.05pH. To take a pH measurement with the sensor, completely insert the tip into the liquid sample without touching the sides of the container. After each measurement the pH probe should be cleaned with distilled water. Always keep the wash bottle and distilled water close at hand. If you don't have a wash bottle you will need a syringe of at least 10 ml in order to clean the sensor properly.   When not in use, the pH sensor should be stored in the buffer solution.

Disolved O_2 Sensor

Prior to first use, unscrew membrane module at the bottom of the electrode. Rinse the membrane module with distilled water and blot dry. Completely fill the membrane module with dissolved oxygen electrolyte solution for Galvanic DO Probes. Rinse the internal anode/cathode element with distilled water and blot dry. Screw the membrane module onto the end of the electrode being careful not to over tighten. Rinse with distilled water. Attach the Dissolved O_2 sensor to the input bracket by inserting and turning ¼ turn. Use an aquarium pump to bubble air through 100 ml of water in a 150 ml beaker to completely saturate the water with oxygen, stirring gently with the DO sensor. Keep the sensor at a 20° angle to avoid trapping air bubbles in the sensor. After 20 minutes, hold the Labdisc DO2 key down for 3 seconds until you hear a long chirp. The Labdisc should read 8.25 mg/l with is the reading for water saturated with oxygen at room temperature. To use, insert the sensor into the liquid sample and stir slowly and continuously until the value on the Labdisc stays consta

Greenhouse Effect
Introduction

What Is A Greenhouse?

Greenhouses are used extensively by botanists, commercial plant growers, and gardeners. In cool climates, greenhouses are useful for growing plants because they both allow sunlight to enter and prevent heat from escaping. The transparent covering of the greenhouse lets light in to warm the interior as it is absorbed by the material within. The transparent covering also prevents the heat from leaving by reflecting the energy back into the interior and preventing outside winds from carrying it away.

Like a greenhouse, our atmosphere also helps keep heat at the surface of the earth. Most of the sun's energy reaches earth as visible light. About 30% of the sun's visible light is reflected back out into space by clouds, snow and ice-covered land, sea surfaces, and atmospheric dust. The rest is absorbed by things here on Earth. The sun's energy that is absorbed is later emitted as longer-wavelength light called *infrared radiation*. This is also called "heat" radiation, because although we cannot see infrared, we can feel its presence as heat. Gases in our atmosphere, like Methane (CH_4), Carbon Dioxide (CO_2) and Water Vapor H_2O) help absorb this outgoing infrared radiation and trap the heat energy.

The ability of gases to be transparent to incoming visible light from the sun yet opaque to the energy radiated from earth is well known to scientists. This phenomenon is called the

Infrared Radiation light is electromagnetic radiation with longer wavelengths than those of visible light Most of the thermal radiation emitted by objects near room temperature is infrared.

"greenhouse effect" because the gases trap heat the same way that a greenhouse's transparent covering traps heat. Without our atmospheric greenhouse effect, earth's surface temperature would be far below freezing. On the other hand, an increase in atmospheric gases could result in increased trapped heat and rising global temperatures. While the earth's temperature is dependent upon the

greenhouse-like action of the atmosphere, the amount of heating and cooling are strongly influenced by several factors.
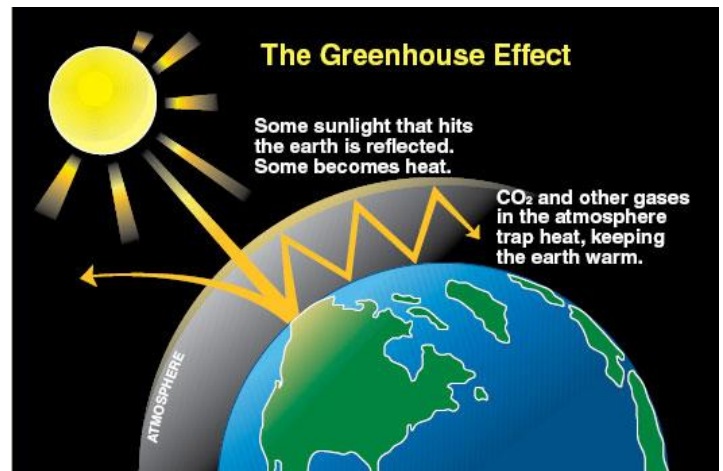
What Factors Influence The Earth's Temperature?

The type of surface that the sun's light hits is important in determining the extent of the greenhouse effect. Forests, grasslands, ocean surfaces, ice caps, deserts, and cities all absorb, reflect, and radiate radiation differently. Sunlight falling on a white glacier surface strongly reflects back into space, resulting in very little increase in surface and atmospheric heat.   Dark soils absorb large amounts of the sun's energy as heat and contribute to significant heating of the surface and lower atmosphere. The amount of clouds also affects greenhouse warming by reducing the amount of solar radiation reaching the earth's surface and by reducing the amount of radiation energy reflected back into space.

Albedo
is a comparison of the amount of light reflected from a surface, compared to the amount of light that fell on it. Albedo is expressed as a percentage and is measured on a scale from 0 for no reflection off a perfectly black surface to 1 for total reflection off a white surface.

Low-Altitude Clouds
are of mostly composed of water droplets since their bases generally lie below 2,000 meters. But, when temperatures are cold, they may also contain ice particles and snow.

High-level clouds
form above 6,000 meters. Since the temperatures are so cold at such high elevations, these clouds are primarily composed of ice crystals. High-level clouds are typically thin and white in appearance, but can appear in a magnificent array of colors when the sun is low on the horizon.

Scientists use the term ***albedo*** to define the percentage of solar energy reflected back by a surface. Understanding local, regional, and global albedo effects is critical to predicting global climate change. The following are some of the factors that influence the earth's albedo.

Clouds: On a hot, sunny day, we usually welcome a big fluffy cumulus cloud passing overhead because we feel cooler immediately. That's because the top of the cloud reflects sunlight back into space before it ever reaches earth. Depending on their altitude and optical properties, clouds either cool or warm the earth. Large, thick, relatively ***low-altitude clouds***, such as cumulus and cumulonimbus, reflect incoming solar radiation and thereby reduce warming of the surface. The whitewash on the roofs of greenhouses can have the same effect on a smaller scale. ***High-altitude clouds***, such as cirrus clouds, absorb longwave radiation reflected from the earth's surface, causing increased warming.

Color and Texture: Just like some clouds reflect solar energy into space, so do light-colored land surfaces. This is called surface albedo and it strongly influences the absorption of sunlight. Snow and ice cover are highly reflective, as are light-colored deserts. Large areas of reflective surfaces can significantly reduce solar warming. Dark-colored land surfaces absorb lots of light and contribute to warming. If global temperatures increase, snow and ice cover may shrink. The exposed darker surfaces underneath may absorb more solar radiation, causing further warming. The idea of global warming is a matter of serious scientific study and there is a lot of disagreement over the cause and effect of this weather phenomenon.

Oceans: From a distance, oceans look much different than land areas - they often appear darker, suggesting that they should be absorbing far more sunlight. But water absorbs energy in a dynamic fashion. Some of the solar energy contacting the surface may be carried away by currents, some may go into producing water vapor, and some may penetrate the surface and be mixed deep into the water column. These factors combine to make the influence of the ocean surface an extremely complex and difficult phenomenon to predict.

Water can also store heat and carry large amounts of heat energy. Oceans are also an important storage site for atmospheric CO_2. Their ability to absorb CO_2 is very much related to ocean temperature. Because of their size and depth, oceans are very important in determining global climate and the future rate of global temperature change.

Forested areas: The interaction between forests and sunlight is also complex. The amount of solar radiation absorbed by forest vegetation depends upon the type and color of vegetation, the time of year, and how well watered and healthy the plants are. Plants provide a dark surface, so you might expect high solar absorption. A significant fraction of the solar radiation is captured by the plants and used to make food through photosynthesis so it does not re-radiate as heat. Some of the energy is dissipated as water evaporates from plant leaves; and some is absorbed and distributed deep within the forest canopy. Like the ocean, predicting how forested areas will contribute to infrared radiation is complicated. The same conditions must be considered when looking at large areas of any habitat (like grasslands/farmlands)

Objectives:

Students will be able to:

1. Identify and explain factors affecting the heat-trapping ability of a greenhouse.
2. Explain the factors important in the atmosphere's heat trapping ability.
3. Describe the influence of albedo on Earth's temperature and give examples of different albedo conditions.
4. Explain how the Greenhouse Effect affects the Earth's climate.
5. Explain human concerns about the Greenhouse Effect and Global Warming

Materials Needed:

- Labdisc Enviro
- External temperature probes
- 1 sheet of white tissue paper
- 1 bag dark soil (garden or potting soil)
- 1 bag white sand or perlite
- Greenhouse kit

Part One – The Greenhouse Effect
Labdisc Set Up

For this experiment you will setup the Labdisc from the Labdisc menu. You will need to make sure that your Labdisc has a completely empty memory before starting. If you're not sure how to do this, follow the instructions in the *How to…* section to clear the logger's memory.

Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Sensor Selection - select both the Ambient Temperature and External Temperature sensors

- Sampling Rate – Select 1/minute

- Number of Samples – select 100

Rotate the Labdisc plastic ring to expose the sensors. Connect the external temperature sensor.

Experiment Procedure

1. Push the Select Key ⏎ to begin collecting data.

2. Place the Labdisc inside the greenhouse with the external temperature sensor, remaining outside and put the greenhouse in a sunny area of the schoolyard. Try to have the cord for the external temperature sensor make as little disruption to the "door" of the greenhouse as possible.

3. Collect data for at least 30 minutes before pushing the Select key ⏎ followed by the Scroll key. ↻

Part Two – Albedo and the Greenhouse Effect

1. After you have collected the data, cover the plastic roof with white tissue paper.

2. ***Before you begin the experiment***, ask students to predict what effect the white roof will have on the temperature in the "greenhouse."

3. Push the Select Key ⏎ to begin collecting data and let the collection continue for at least 30 minutes.

Dark Soil
1. For the next data collection, you will put a layer of dark soil in the bottom of the greenhouse. ***Before beginning the data collection***, predict how dark soil will affect the temperature inside both greenhouses.

2. Push the Select Key ⏎ to begin collecting data and let the collection continue for at least 30 minutes.

White Sand
1. For the next data collection, you will put a layer of white sand in the bottom of the greenhouse. ***Before beginning the data collection***, predict how the white sand surface will affect the temperature inside both greenhouses.

2. Push the Select Key ⏎ to begin collecting data and let the collection continue for at least 30 minutes.

Downloading Your Data
See the *How to…* section for instructions if you are not familiar with how to download your data.

Data Analysis
Greenhouse Effect

1. Open the data from the first greenhouse by clicking on the open file icon. 	Make sure you know the file name that you used to save your data. Select the file name and click Open.

2. Double click on the graph title at the top of the page and change it to Greenhouse Effect.

3. Click on the Ambient Temperature label on the upper right hand side of the screen to set the Y axis scale to Ambient Temperature.

4. Click on the Statistics button 	to see the maximum, minimum and average temperatures in the greenhouse.

5. Select the Label (Annotate) button 	and a pop up window will come up. Add text telling the Maximum, Minimum and Average temperature readings from inside the greenhouse. Click OK to close the window.

6. Select the Marker button 	and put a marker on *highest* point on the ambient temperature line. A pop up window will tell you the length of time into your data collection and the temperature at this point in time.

7. Select the Label (Annotate) button 	and a pop up window will come up. Add text telling the time and the temperature reading. Click OK to close the window.

8. Select the Marker button 	and put a marker on *lowest* point on the ambient temperature line. A pop up window will tell you the length of time into your data collection and the temperature at this point in time.

9. Select the Label (Annotate) button 	and a pop up window will come up. Add text telling the time and the temperature reading. Click OK to close the window. Be sure to save your work after adding the labels.

10. Click on the External Temperature label on the upper right hand side of the screen to set the Y axis scale to External Temperature

11. Repeat steps 4 thru 9 for the External Temperature data. Be sure to save your work after adding the labels.

12. Open the data file from the clear vs. white roofed greenhouse and repeat steps #4 through 9.

13. Open the data file for the data collected on the dark soil and repeat steps #4 through 9.

14. Open the data file for the data collected on the white sand and repeat steps #4 through 9.

15. Print out the graphs so that you can compare them side by side.

Questions and Observations

1. Compare and contrast the temperatures that you saw;

   a. Inside the "greenhouse"

   b. In the outside world

2. How is the data similar? How is it different?   Discuss the results and propose some possible explanations.

3. Relate the factors affecting the model greenhouses to the factors affecting the "global greenhouse." Which factors are the same? Which are different?

4. Compare and contrast the temperatures that you saw;

   a. Inside the clear "greenhouse"

   b. Inside the white roofed "greenhouse"

5. How is the data similar? How is it different?   Discuss the results and propose some possible explanations.

6. How is the data similar from one ground type to another? How is it different? Why do you think this is?

7. After discussing their findings, ask students to sketch and explain how to set up a model greenhouse with the absolutely coolest possible temperatures. Where on Earth could you do this?

8. Now ask them to sketch and explain a greenhouse designed to generate the maximum possible heat. Where might such a condition really exist?

9. How is the earth's atmosphere similar to a greenhouse?

10. What factors influence the function of a greenhouse?

11. What is albedo and how is it related to understanding global climate change?

12. What are the limitations in comparing the Earth's Atmosphere to a greenhouse?

Coping with a Warm Environment
Introduction

Perspiration

If you live in a warm environment, you know that your body sweats to cool down. Most people sweat in hot weather. If you exercise and produce more body heat than usual, you will sweat even more. Sweating is one way that humans and some other mammals cope with a warm or hot environment.

Sweating allows the body to regulate its temperature. Sweating causes a decrease in core temperature through evaporative cooling at the skin surface. As high energy molecules evaporate from the skin, releasing energy absorbed from the body, the skin and superficial vessels decrease in temperature. Cooled blood then returns to the body's core and counteracts rising core temperatures.

There are two situations in which the nerves will stimulate the sweat glands, causing perspiration: during physical heat and during emotional stress. In general, emotionally induced sweating is restricted to palms, soles, armpits, and sometimes the forehead, while physical heat-induced sweating occurs throughout the body.

People have an average of two to four million sweat glands. But how much sweat is released by each gland is determined by many factors, including gender, genetics, environmental conditions, age or fitness level, with fitness level and weight as major factors. The greater an individual's weight the faster the sweat rate will increase because the body must exert more energy to function and there is more body mass to cool down. Additionally, individuals who are extremely fit will start sweating earlier and easier. Individuals who are physically fit find that the body becomes more efficient at regulating the body's temperature and sweat glands adapt along with the body's other systems.

Thermoregulation
The ability of an organism to keep its body temperature within a given temperature range even when the surrounding temperatures are very different.

In humans, sweating is primarily a means of **thermoregulation**. Adults sweat as much as 2-4 liters per hour or 10-14 liters per day. Children sweat far less prior to puberty. Evaporation of sweat from the skin surface has a cooling and so in hot weather, or when the individual's muscles heat up due to exertion, more sweat is produced.

Animals with few sweat glands, such as dogs, accomplish similar temperature regulation by panting. This allows water to evaporate from the moist lining of the mouth and nose. Monkeys, apes and horses have armpits that sweat like those of humans. Although sweating is found in a wide variety of mammals, very few produce large amounts of sweat in order for cooling purposes.

Objectives:

Students will be able to:

1. Explain how perspiration helps individuals in hot weather situations.
2. Describe factors that my limit or enhance the effectiveness of evaporative cooling.

Materials Needed:
- Labdisc Enviro
- External temperature sensor
- Small piece of cotton cloth (6 cm^2)
- Rubber band
- Water
- Small Electric Fan
- Clear plastic bag (large enough for Labdisc and your hand)

Labdisc Set Up

For this experiment we will setup the Labdisc from the Globilab menu. Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Select the External Temperature sensor

- Select a Rate of 1/second

- Select 1,0000 samples

Experiment Procedure
Part One – Evaporative Cooling

1. Push the Start button 🏃 to begin your data collection.

2. Soak a piece of thin cloth in lukewarm water. Squeeze out the excess moisture and wrap the cloth around the last 3 cm of the External Temperature probe. Secure with a rubber band.

3. Slowly wave the senor in the air and observe and record any temperature changes.

4. Blow on the sensor from a distance of 20 centimeters. Observe and record any temperature changes.

5. Push the Stop button to end this data collection.

Labdisc Set Up
Part Two - Sweat Production

1. Using the procedure in Part One, select the External Temperature and the Humidity sensors.

Experiment Procedure

1. Remove the cloth from the end of the External Temperature Sensor.

2. Holding the Labdisc in your hand, place it and the External Temperature sensor inside a clear plastic bag. Seal the bag around your wrist with the rubber band or with tape.

3. Push the Start button 🏃 to begin your data collection.

4. Let the data collection run for 10 minutes before pushing the Stop button. 🛑
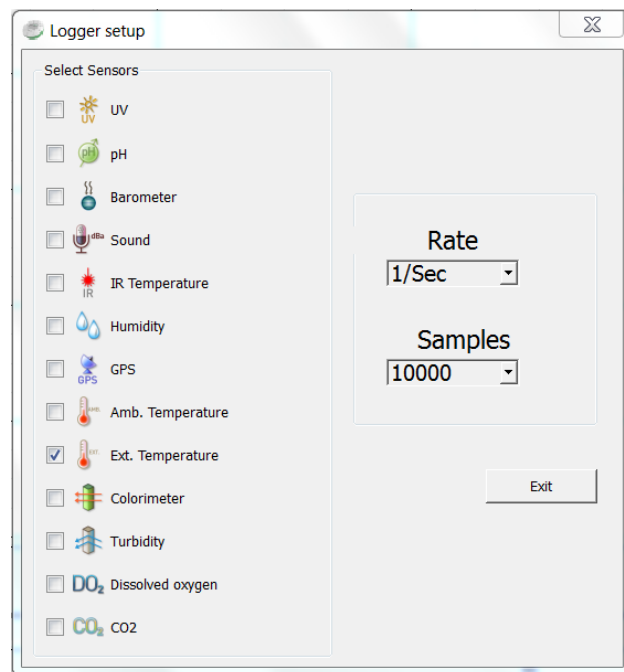
Downloading Your Data

Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis – Part One

1. Open the Evaporative Cooling data by clicking on the open file icon.   Make sure you know the file name that you used to save your data. Select the file name and click Open.

2. Press the Statistics Button and make note of the maximum and minimum temperature values. Be sure to label these points on your graph.

3. Select the Marker button and put a marker on the line at the beginning of the experiment.   A pop up window will give you the exact temperature at this point in time.

4. Select the Label (Annotate) button and a pop up window will come up. Add text describing the conditions at this point and the exact temperature. Click OK to close the window.

5. Using your mouse, slide the marker along the line to the point where you were waving the sensor. Using the method in #4, add a label with condition and temperature.

6. Repeat steps #3 and #4 at the point where you blew on the sensor. Save your work after adding labels.

7. Print out your graph using the Printer button.

Questions and Observations - Part One

1. What happened to the temperature as the water in the cloth evaporated?

2. Which of the conditions that you tested produced the greatest level of cooling? Why did this happen?

3. Predict what would happen if you'd done this with cold or ice water? (Ask the teacher if you can test your theory.)

Data Analysis – Part Two

1. Open the Sweat Production data by clicking on the open file icon.   Make sure you know the file name that you used to save your data. Select the file name and click Open.

2. Press the Statistics Button and make note of the maximum and minimum temperature values. Be sure to label these points on your graph.

3. Select the Marker button and click to a marker on Maximum temperature on your graph line.   A pop up window will give you the exact temperature at this point in time.   Click again to put a marker at the Minimum temperature point on your graph line.

4. Select the Label (Annotate) button and a pop up window will come up. Label the Maximum and Minimum temperature points. Include the temperature reading at those points in your label. Click OK to close the window.

5. In the upper right side of the screen, click on the humidity line to set the y axis to humidity.

6. Repeat steps #2 through #4 for the humidity graph. Be sure to save your work after you've added the labels.

7. Print out your graph using the Printer button.

Questions and Observations - Part Two

1. How are the temperature and humidity lines the same? How are the different?

2. Why didn't both lines hit their maximum point at the same time?

3. Think about how your hand felt during the experiment. How do the graph results reflect what you were feeling?

4. Where did the humidity come from?

5. Why didn't your hand get cooler from the evaporation of sweat?

6. What could you have done to help cool your hand?

The Effects Temperature on Respiration

Introduction

Endothermic
"warm blooded" creatures with a constant, internally maintained body temperature.

Exothermic
"cold blooded" creatures whose body temperature is affected/determined by their surroundings.

Alveoli
a small hollow cavity found in the lungs of mammals. An exchange of oxygen and carbon dioxide during respiration occurs in the alveoli.

Capillaries
the smallest of a body's blood vessels. An exchange of water oxygen, carbon dioxide, nutrients and other substances occurs across capillary membranes.

Epithelium
a type of body tissue that allows for diffusion of substances from one side of a membrane to another.

Gills
a respiratory organ found in many aquatic organisms that is capable is extracting dissolved oxygen from water

Operculum
the protective flap of tissue covering a fish's gills

Endothermic vs. Exothermic Body Temperatures

Each kind of living thing survives best within a certain range of temperatures. The body temperature of mammals and **endothermic** animals remains the same no matter what the environmental temperatures are. This is not the case with **exothermic** animals like fish, reptiles or amphibians. Their internal body temperature changes as the temperatures around them change. Temperature influences breathing rate and the activity level of exothermic animals. It also affects feeding and reproductive behaviors.

Fish remove oxygen from water just as human lungs extract oxygen from air. The oxygen content of air is about 20 times as great as highly aerated water. This means that aquatic organisms like fish spend about 20 times as much of their energy breathing than do air breathing organisms.

Gills work on the same principle as lungs. In the lungs, there are small sacs called **alveoli** that are approximately 70% **capillaries**. These capillaries carry deoxygenated blood from the body back to the lungs. After oxygen passes across the alveoli's membrane into the blood and carbon dioxide passes across the alveoli's membrane into the lungs, the capillaries take the newly oxygenated blood back to the body.

Much like lungs, gills have small rows and columns of specialized cells grouped together called the **epithelium**. In the fish, deoxygenated blood is carried to the epithelium via arteries, arterioles and capillaries. As water is forced across the epithelium membranes, dissolved oxygen in the water is absorbed into the blood, while the carbon dioxide is moves across the epithelium membranes back into the water.
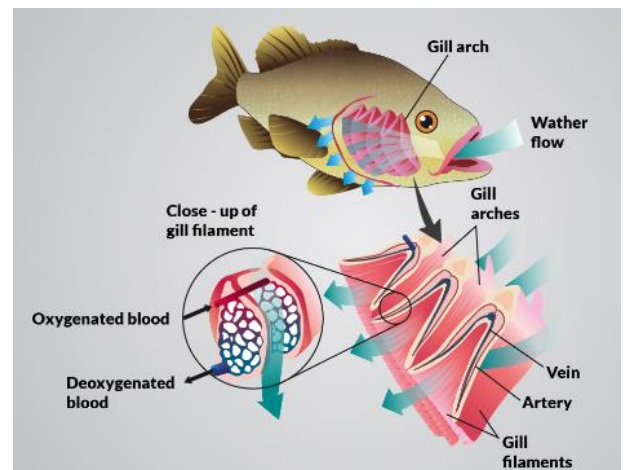
A fish inhales water. It does not drink water. The "yawning" movements pull water into the mouth and then the fish closes its mouth. The mouth cavity contracts, forcing water across the **gills** and out the **operculum**. This coordinated movement of the mouth and operculum brings in oxygen rich water to the gills, where the oxygen is extracted. The oxygen depleted water is then expelled through the operculum. Most fish have 4 gills on each side, consisting of a main bar-like structure that has numerous branches as that of a tree, and those branches consisting of even smaller branch-like structures. This arrangement allows for a very large surface area when the gills are immersed in water.

The gills need a very large surface area due to the fish's oxygen demands. Air is approximately 21% oxygen or about 210,000 parts per million. Water, however, only has about 4-8 parts per
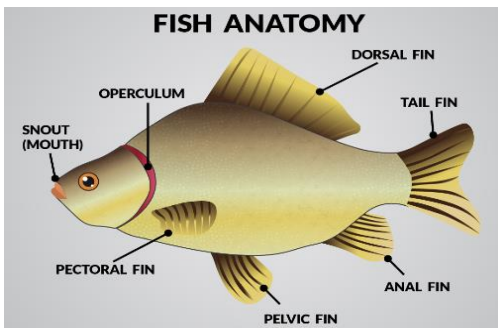
million of dissolved oxygen that the gills can extract. Because of this, if the fish did not have a large gill surface area to absorb as much oxygen as it can, it would suffocate.

Exothermic animals also tend to have a lower metabolism than their endothermic counterparts. This makes it possible for them to survive in environments with low amounts of available oxygen. The oxygen requirements of fish change with the temperature of the water. As temperatures decrease, the fish's metabolism is lowered or decreases and so less oxygen is needed. As temperatures rise, so does the fish's metabolism and its need for. Consider also that as the water becomes warmer, it also holds less dissolved oxygen so the fish's respiration rate must increase to accommodate both of these conditions.

Objectives:

Students will be able to:

1. Define the terms endothermic and exothermic
2. Predict and describe how environmental temperatures affect the respiration rate of an exothermic and an endothermic organism.
3. Predict and describe how exercise will affect the respiration rate of an air breathing organism.

Materials Needed:

- Labdisc Enviro
- External Temperature Sensor
- Aquarium
- 3 one-liter glass jars
- 3 Goldfish
- Dip Net
- Ice
- 100 watt clip on lamp
- Clear bowl large enough to hold the jar and ice
- Air stone
- Aquarium Pump & tubing (from Turbidity Lesson)
- Observation worksheet

Set Up Your Aquarium

1. Get your aquarium or fish bowl ready by filling it with tap water two days before you get your fish.
2. Label the Jars A, B and C and fill them with water also. Leave the lids off and let them sit for 2 days to let the water reach room temperature and to let any chlorine in the water evaporate.
3. After the water has "cured," add the three fish to the aquarium and give them at least 24 hours to acclimate before beginning the experiment. When adding the fish to the new tank, you may want to float the bag that they came in from the pet store in the aquarium for about 30 minutes to let the water temperatures equalize.
4. Use the Aquarium pump with plastic tubing and air stone to ensure that there is adequate oxygen in the tank for your fish.

Set up the Labdisc from the Globilab Menu

For this experiment we will setup the Labdisc from the Globilab menu. Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Select the External Temperature sensor

- Select Manual

- Select 10 samples

Experiment Procedure

Fish are living creatures and must be treated with respect. Be sure to not leave them in the cold or warmed conditions beyond the limits of the experiment or to leave them there for extended periods of time.
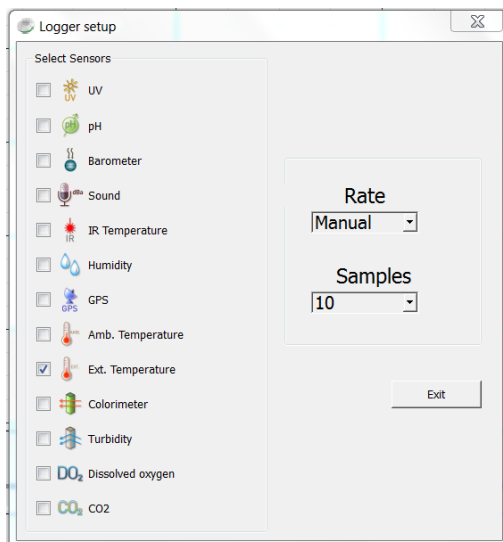
1. Put the lids on the three jars and shake them to make sure that there is plenty of oxygen in the water for the fish to breath. Remove the lids and put one fish in each jar. Give them at least 3 minutes to become used to the jar.

2. Press the Start button 🏃 to begin the data collection.

3. With a digital camera, Smart phone, iPad or Android tablet, take a photo of fish A.

4. Place the external temperature sensor in Jar A. When the read out on the Labdisc holds steady, push the Scroll key ⮐ to record the first measurement.

5. Observe the operculum of the fish. Watch them open and close as the fish pulls water over the gills to get the oxygen it needs to survive.

6. Count the number of times that the operculum opens and close in 15 seconds. Multiply this number by 4 to get the fish's respiration rate in one minute.

7. Repeat this a second time and calculate the average respiration rate for fish A and record the average respiration rater on your data sheet.

8. Carefully put the fish A back into the aquarium and observe its behavior. For one minute, count the number of turns or changes in direction that the fish makes and record this number on the data sheet.

9. Use the dip net to gently return the fish to Jar A.

Cooling

1. Place Jar B in the bowl. Put a few ice cubes and tap water into the bowl. Use enough to cover at least ¾ of the jar.

2. With a digital camera, Smart phone, iPad or Android tablet, take a photo of fish B in the cool water bath.

3. Put the temperature sensor into Jar B. When the water temperature has dropped 3 degrees Celsius, push the Scroll

24

key ⮐ to record the second measurement and begin your observations. Count the number of times that the operculum opens and close in 15 seconds. Multiply this number by 4 to get the fish's respiration rate in one

4. Repeat this a second time and calculate the average respiration rate for fish B and record the average respiration rate on your data sheet.

5. Remove Jar B from the cool water bath and add ice to the water bath.

6.   Carefully put the fish B back into the aquarium and observe its behavior.   Be careful to put only the fish and not any of the cold water from Jar B. For one minute, count the number of turns or changes in direction that the fish makes and record this number on the data sheet.

7. Place Jar C into the ice water bath and insert the external temperate probe.

Jar C

8. With a digital camera, Smart phone, iPad or Android tablet, take a photo of fish C in the ice water bath.

9. When the water temperature has dropped 6 degrees Celsius, push the Scroll key ↺ to record the third measurement and begin your observations.

10. Count the number of times that the operculum opens and close in 15 seconds. Multiply this number by 4 to get the fish's respiration rate in one minute.

11. Repeat this a second time and calculate the average respiration rate for fish C and record the average respiration rate on your data sheet.

12. Carefully put the fish C back into the aquarium and observe its behavior.   Be careful to put only the fish and not any of the cold water from Jar C. For one minute, count the number of turns or changes in direction that the fish makes and record this number on the data sheet.

Warming

1. Place Jar A approximately 15 cm from the lamp and turn the lamp on. Place the temperature sensor into Jar A.

2. With a digital camera, Smart phone, iPad or Android tablet, take a photo of fish A in front of the lamp.

3. When the water temperature has increased by 3 degrees Celsius, push the Scroll key ⮐ to record the fourth measurement and begin your observations. Count the number of times that the operculum opens and close in 15 seconds. Multiply this number by 4 to get the fish's respiration rate in one minute.

4. Repeat this a second time and calculate the average respiration rate for fish A and record the average respiration rate on your data sheet

5. Move Jar A away from the lamp.

6. Carefully put the fish A back into the aquarium and observe its behavior.   Be careful to put only the fish and not any of the warm water from Jar A. For one minute, count the number of turns or changes in direction that the fish makes and record this number on the data sheet.

7. Place Jar B approximately 10 cm from the lamp and turn the lamp on.

8. With a digital camera, Smart phone, iPad or Android tablet, take a photo of fish B closer to the lamp.

9. Put the temperature sensor into Jar B. When the water temperature has increased by 6 degrees Celsius, push the Scroll key ⏎ to record the fifth measurement and begin your observations. Count the number of times that the operculum opens and close in 15 seconds. Multiply this number by 4 to get the fish's respiration rate in one minute.

10. Repeat this a second time and calculate the average respiration rate for fish B and record the average respiration rate on your data sheet

11. Move Jar B away from the lamp.

12. Carefully put the fish B back into the aquarium and observe its behavior.   Be careful to put only the fish and not any of the warm water from Jar B. For one minute, count the number of turns or changes in direction that the fish makes and record this number on the data sheet.

13. Return the fish from Jars A and C to the aquarium.

Air Breathing Comparison

1. With the external temperature sensor lying on the table, push the Scroll key ⏎ to record the air temperature in your classroom.

2. Without telling the, carefully observe one of your classmates and count the number of times that they breath during a 15 second period. Multiply this number by 4 to get the respiration rate for a minute.

3. Repeat a second time and calculate and record the average on your data sheet.

4. Next ask the same classmate if you may record their respiration rate and repeat step #2 and 3.

5. With a digital camera, Smart phone, iPad or Android tablet, take a your classmate looking at the camera and not looking at the camera

6. Have your classmate job in place for two minutes and repeat steps #2 and 3. With a digital camera, Smart phone, iPad or Android tablet, take a photo your classmate while they are exercising.

Downloading Your Data

Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis

1. Open the data from the by clicking on the open file icon.   Make sure you know the file name that you used to save your data. Select the file name and click Open.

2. Right click on the temperature legend on the right side of the screen to set the graph to individual data points instead of a line.

3. Select the Marker button and put a marker on first data point (keep in mind that your first data point may show up at the 0 marker and show as Sample 0). A pop up window will tell you the exact temperature.

4. Select the Label (Annotate) button ![Abc] and a pop up window will come up. Add text describing the experiment conditions and recording the temperature reading. From your data sheet, add information about the fish's respiration rate and behavior. Insert the photo of the fish from this data collection. Click OK to close the window.

5. Using your mouse, slide the marker over to the next data point (-5°C). Using the method in #4, add a label with information about temperature, fish respiration and behavior.

6. Repeat steps #5 and #4 for the remaining data points (-10°C, +5°C & +10°C).

7. Repeat steps #5 and #4 for the three human observations (unaware, aware and after exercise)

8. Print out the graph and attach it to your data sheet.

Questions and Observations

1. Which of the fish had the slowest respiration? Which had the highest?

2. Which fish was the most active? Which was the least active?

3. Explain why you think the different temperatures produced the behaviors that you observed?

4. What do you think would happen if the temperature dropped another 10°? Another 20°?

5. What about if the temperature was higher?

6. Which of the three human observations had the lowest respiration rate? Which had the highest?

7. Explain why the human respiration rates increased or decreased when they did.

Extensions

1. Design and share an experiment that would test how another factor might affect respiration. Things to consider include: size of the fish, amount of light, increased activity, etc.

Effects of Temperature on Respiration Rate

Fish Respiration Rate

	Room Temperature	5° Cooler	15° Cooler	5° Warmer	10° Warmer
Water Temperature:					
Fish Respiration Rate:					
Fish Activity Level:					
Observations:					

Human Respiration Rate

	Unaware of Observation	Aware of Observation	After Exercise
Room Temperature:			
Human Respiration Rate:			

Conclusions:

28

Daily Weather Data

Vocabulary

Atmosphere
The layer of gases surrounding a planet

Precipitation
Liquid or solid water vapor which falls from clouds. May include snow, sleet, hail or rain

Climate
Long term weather patterns within a region

Troposphere
The lowest layer of the Earth's atmosphere

Stratosphere The middle layer of the Earth's atmosphere

Humidity
The amount of water vapor in the air

Water vapor
The invisible gaseous state of water

Barometric Pressure
The force exerted by the atmosphere on the Earth's surface.

Meteorologist
Scientist who studies weather

Weather Reports

Weather is the state of the **atmosphere** around us. It can be hot or cold, wet or dry, calm or stormy, clear or cloudy. Weather generally refers to day-to-day temperature and **precipitation** activity, whereas **climate** is the term for the average atmospheric conditions over longer periods of time. Most weather phenomena occur in the **troposphere**, just below the **stratosphere**. When used without qualification, "weather", is understood to mean the weather of Earth.

Different weather reports contain different amounts of information. The simplest and shortest weather report contains only one piece of information, the present temperature. More detailed weather reports contain information about precipitation, relative **humidity**, **barometric pressure**, and more.

Often a weather report tells you the highest and lowest temperatures for the past day. The day's **lowest temperature** usually occurs just after sunrise. The day's highest temperature is usually reached during early to mid-afternoon. The may also give you the average temperature for the day. The average daily temperature lies halfway between the highest temperature and the lowest temperature.

Most weather reports give the amount of precipitation, if any fell during the past day. They also tell you the totals for the current month and the current year. Reports also indicate how much the monthly and annual precipitation totals are above or below normal (the long-term average).

Weather Forecasts

People are usually most interested in what the weather will be tomorrow or in the next few days. **Meteorologists** make both short-term (up to one week) and long-term (a month, a season, or a year) forecasts of the weather for. Long-term forecasts are sometimes called outlooks. Long-range outlooks are different from short-term forecasts in that they predict departures of temperature and precipitation from long-term averages (e.g., colder or warmer than normal, wetter or drier than normal).

Many years ago, the only way of predicting the weather was to use local experiences. The next day's weather was often predicted based on the previous day's weather. As you can imagine, the success of such forecasting was not much better than making a random guess.

Once the national weather service began to gather weather observations from weather stations located over large areas of the country, simultaneous weather observations allowed meteorologists to plot weather maps and follow weather systems as they moved from place to place, greatly improving the accuracy of weather forecasts. Through the 20th century, meteorologists developed even better tools for observing and predicting weather.

The science of weather forecasting is still developing. Weather prediction will never be perfect. Small changes in the weather in one place can cause much larger changes in weather elsewhere. The effects are small at first, but they become much greater. It's very difficult for predict these interactions. Although forecasts will never be perfect, they will continue to improve in the years ahead. Through research, meteorologists learn more and more about the details of how weather in the Earth system works.

Objectives:

Students will…
1. Record Temperature, Barometric Pressure, Relative Humidity and Precipitation over a 5 day period.
2. Compare measurements from
    a. Several days at the same school over an extended period
    b. Different times of year at the same location.
    c. Different schools in different topography.
3. Interpret data to explain the type of weather conditions associated with the data they have collected.

Materials Needed:

- Labdisc Enviro
- Rain Gauge
- Vented Protective Housing for Labdisc
- Weather Data Recording sheets

Labdisc Set Up

For this experiment you will setup the Labdisc from the Labdisc menu. You will need to make sure that your Labdisc has a completely empty memory before starting.   If you're not sure how to do this, follow the instructions in the *How to…* section to clear the logger's memory.

Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Sensor Selection - select the Ambient Temperature, Humidity, Barometric Pressure and GPS .

- Sampling Rate – Select 1/minute

- Number of Samples – select 10,000

Rotate the Labdisc plastic ring to expose the sensors. Connect the external temperature sensor. Press the select key to begin collecting data.

Experiment Procedure
Data Collection
1. Select a place in your school yard that is shaded from the sun and at least 1 meter from any buildings. The protective box should be placed on a stand at least 60 cm tall (like a picnic table or an overturned trash can or a pole). You want to be sure that heat from the ground or buildings doesn't interfere with your measurements.

2. Attach your rain gauge to the protective box as shown here.

3. Allow the Labdisc to collect data for one week. You should check and empty your rain gauge daily and make a note of the amount of precipitation collected. Save this information, you will use it at the end of the activity. Be sure to do this at the same time each day – starting 24 hours after you set up your weather logging station.

4. At this time, also start recording the daily weather conditions. Pick several times during the day to circle the current weather conditions on the Weather Data worksheet to circle.   You ca do this as few as 3-5 times or you can do this every hour, depending on what other activity is going on in your classroom. Make sure to record the time of any changes in weather like starting to rain, becoming clear/overcast. Also be sure to check and record the information from your rain gauge daily. Collect this data at the same time every day.

5. After one week, collect the Labdisc from the protected box and stop the data collection by pressing the SELECT KEY ⏎ followed by the SCROLL KEY. ⟳

Downloading Your Data

Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis

1. Select the Magnifying button 🔍 and use your mouse/cursor to drag a small box around the area at the 1 hour mark of data collecting along the temperature reading to zoom in on the temperature line.

2. Select the Marker button 📈 and put a marker on temperature line at the first hour of data collection. A pop up window will tell you the length of time into your data collection and the temperature at this point in time.

3. Select the Label (Annotate) button [Abc▼] and a pop up window will come up. Add text telling the time and the temperature reading. Click OK to close the window.

4. Repeat Steps 7-9 for the barometer and air pressure readings at the first hour.

5. Repeat Steps 7-9 for the other times in your collection that your teacher assigns. This might be every hour, every 6 hours or every 12 hours.

6. Use the Label/Annotate button [Abc▼] to add a label at the 24, 48, 72, 96 and 120 hour mark (1 day, 2 days, etc.) with the amount of precipitation that was collected in the 24 hour period prior.

7. Use the information on your graph to complete the Daily Weather Data form.

Questions and Observations

Temperature

1. Is there any pattern in your temperature measurements?

2. At what time(s) of day so you see the highest temperatures? The lowest? What is happening at these times of day?

3. Are there any situations where this pattern changes? What weather conditions were happening at that point in time?

4. What differences do you think you would see in the temperature readings if you did this experiment again in a week? A month? Six months?

Humidity

1. Is there any pattern in your humidity readings?

2. When did you see the highest humidity? The lowest?

3. Do changes in humidity happen at the same time with changes in temperature? What kind of relationship between temperature and humidity can you observe?

4. What differences do you think you would see in the temperature readings if you did this experiment again in a week? A month? Six months?

Barometric Pressure

1. Is there any pattern in your pressure readings?

2. When did you see the highest barometric pressure? The lowest?

3. What was the weather like on the days when you had the highest barometric pressure? What was it like on the days with the lowest barometric pressure?

4. Do changes in temperature or humidity happen at the same time with changes in barometric pressure? What kind of relationship between these conditions can you observe?

5. What differences do you think you would see in the temperature readings if you did this experiment again in a week? A month? Six months?

Precipitation

1. Did any precipitation fall during your data collection?

2. What happened to the temperature during that time?

3. What happened to the humidity during that time?

4. What happened to the barometric pressure during that time?

Application

1. Based on your observations and your data, describe what the weather data would look like on:

   a. A sunny day in March

   b. A rainy day in July

   c. A cloudy day in January

2. Describe what you think the weather would be like with the following conditions:

   a. Temperature 18°C – Humidity 20% - Barometric Pressure 102.2kPa

   b. Temperature 30°C – Humidity 97% - Barometric Pressure 16kPa

   c. Temperature 26°C – Humidity 98% - Barometric Pressure 20.6kPA

3. Many old sayings have a basis in fact. Use what you've learned to predict what will happen to the weather conditions that you've just measured by the following sayings:

   a. *A ring around the Moon, brings rain upon you soon.*

   b. *When high clouds and low clouds do not march together, prepare for a blow and a change in weather.*

   c. *Red Sky in morning, sailors take warning. Red Sky at night, sailors delight.*

d. *Catchy drawer and sticky door, coming rain will pour and pour.*

e. *Flowers smell best just before a rain.*

Extensions: The Next Step

1. Repeat this experiment again in three months. And again in six months. Compare your data. What is the same about your data? What is different? Why do you think this is?

2. Share your information with students from another school in another area. Try to compare data from the same or very similar dates. How is your data the same? How is it different? Why do you think this is? Using their data, predict what the weather conditions were like during that time period.

Temperature: Humidity: Barometric Pressure: Precipitation: Weather Conditions:	Temperature: Humidity: Barometric Pressure: Precipitation: Weather Conditions:	Temperature: Humidity: Barometric Pressure: Precipitation: Weather Conditions:
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Water Changes & Circulation
Introduction

About Water Temperatures

Water has two unique characteristics: it is a very poor conductor of heat and it has a great capacity to hold energy. In other words, it takes a lot of energy to raise the temperature of water, but once the temperature is raised, the heat energy dissipates very slowly.

How much do Water Temperatures Change?

When sunlight strikes the water's surface, it heats the top layers the most quickly. Sunlight is transmitted by the water enough to heat lower levels a little bit. In the ocean, most of the light energy is absorbed in the top 50 cm. At 2 meters depth, 98% of the energy has been absorbed and transformed into heat.

Water has a high capacity to hold on to heat, so seasonal changes in ocean temperatures lag about 2 months behind land temperatures. This means that in temperate climates, the ocean is much warmer for swimming in the fall than in the spring. The temperature lag is even greater in deeper layers of larger lakes and in oceans and can stretch to as long as 5 months.

Thermocline
a thin but distinct layer in a large body of fluid (e.g. water, such as an ocean or lake, or air, such as an atmosphere) in which temperature changes more rapidly with depth than it does in the layers above or below.

Heat is transferred to lower levels of large bodies of water by circulation within the body of water. Water circulation is caused by the movement of water molecules between areas of different densities. The water near the surface and warmed by the Sun is less dense than water near the bottom, because density of water changes as the temperature of the water changes. Water circulation happens as the solar-heated water of the surface moves down into cooler lower layers, helping to heat the lower levels. The lower the temperature of water, the higher the density of that water—until around 4°C. Water reaches its maximum density at 4°C.

Water below 4°C is actually lighter than water at 4°C because the water molecules are beginning to form into ice crystals. During the phase change from liquid into ice, water molecules begin to take on a crystalline structure which is less dense than liquid water. This crystalline structure (ice) floats to the surface.

Temperature stratification
water of different temperatures forms distinct layers with litter movement between the layers. These layers are normally arranged according to density, with the least dense water masses sitting

Thermoclines

If the surface layers of a body of water are not disturbed by wind or tides, layers of water with different temperatures can exist without mixing because different densities. When the upper water layers of a body of water are warmed by the sun, they may become separated from the deeper, cooler water by a transition zone known as a **thermocline**. In the upper layer the temperature is roughly the same as the surface water. In the thermocline, the temperature decreases rapidly from the upper layer temperature to the colder deeper water temperature.
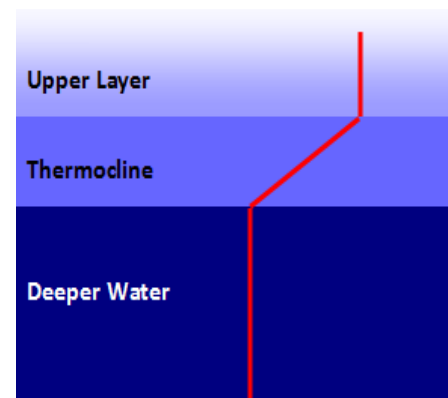
above the more dense layers.

Primary production
the synthesis of organic compounds from carbon dioxide. It principally occurs through the process of photosynthesis, which uses light as its source of energy.

The temperature within upper layer and the deeper water layer stays relatively consistent throughout the layer. In a thermocline, the temperature decreases rapidly with small increases in depth. This phenomenon linking temperature change with depth is called **temperature stratification**. Temperature stratification occurs in most bodies of water from small ponds to oceans, but thermoclines are primarily found in the larger bodies of water.

Temperature stratification can create barriers to nutrient mixing between layers and can affect the **primary production** in an area by limiting photosynthesis. Almost no exchange of water or solutes takes place across an established thermocline. For example, if rich river sediment is flowing into an ocean bay, this sediment will flow across the top of the thermocline and not move into deeper currents that might carry it elsewhere.

Water Temperatures and Aquatic Life
Water temperatures in lakes during summer months are not uniform from top to bottom. Three distinct layers develop: The top layer stays warm. The middle layer drops dramatically; sometimes by as much as 7 to 8° C degrees. The bottom layer is the coldest.

Since light does not penetrate to the bottom, photosynthesis is limited to the top layer. Because of the warmer waters and more plentiful food supply, almost all creatures spend the summer months in the upper layer. During spring and fall the lake temperature is more uniform. Fish and other animals are found throughout the layers of the lake.

Even in cold climates, most lakes are large enough so that they don't freeze solid. During the winter months some creatures hibernate in the bottom mud. Some fish continue to feed, but less actively. A layer of ice can develop on the top of lakes during winter. The ice blocks out sunlight and can prevent photosynthesis. Without photosynthesis, oxygen levels drop and some plants and animals may die. This is called "winterkill."

Objectives:
Students will be able to:
1. Measure water temperatures at different depths in a pond.
2. Explain how water temperatures affect circulation in the pond.
3. Measure water and weather conditions over an extended period
4. Correlate water temperature change during Day/Night in comparison with e temperature changes

Materials Needed:
- Labdisc Envio
- External Temperature Sensor
- Wooden meter stick
- Tape
- Protective Box from the Weather Data activity

Before the Activity

1. Tape the cord of the external temperature sensor to the meter stick, leaving 5 cm of the sensor tip extending beyond the end of the meter stick and the plug portion of the cord loose. Be sure to put the sensor tip at the beginning end of the meter stick (i.e. where the reading is 0) and make sure that you can still read the numbers on the meter stick.

Labdisc Set Up Labdisc Set Up

For this experiment you will setup the Labdisc from the Labdisc menu. You will need to make sure that your Labdisc has a completely empty memory before starting.   If you're not sure how to do this, follow the instructions in the *How to…* section to clear the logger's memory.

Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Sensor Selection - select the External Temperature sensor

- Sampling Rate – Select Manual

- Number of Samples – Skip this step

Rotate the Labdisc plastic ring to expose the sensors. Connect the external temperature sensor. Press the select key to begin collecting data. ⏎

Experiment Procedure
Part One – Temperatures at Different Depths

1. Before you begin, make predictions as to what part of the pond you think will have the warmest water. The coolest? What factors do you think will influence water temperature?
2. One student will hold the Labdisc and be responsible for pushing the Scroll key⏎ to record each measurement. Another student will hold the measuring stick with the temperature sensor and be responsible for depth control.
3. If you can, complete this activity from a dock that extends out into the pond. Start by holding the meter stick so that just the tip of the sensor is in the water. When the temperature reading is holding constant, push the Select key ⏎ to record the first data point.
4. Holding the meter stick perpendicular the water, lower it until it is submerged 5cm in the water (use the numbers on the meter stick to help you measure this accurately. Repeat at 10 cm, 15 cm and every 5 cm until you can no longer lower the meter stick.
5. Push the Select key followed by the Scroll key to end the data collection.

Downloading Your Data

Follow the instructions in the *How to…* section for how to download your data if you need assistance.

Data Analysis

1. Open the data from the temperature by depth experiment by clicking on the open file icon. 📁 Select the file name and click Open.

2. Right click on the graph label for External Temperature on the upper right side of the graph to change graph from a line to individual data collection points.

3. Click on the zoom button 🔍 and using your mouse drag a box as close as possible around your data points, being sure to include all of them.

4. Click on the marker button 📉 and set a marker on the data collection point from the first data collection at the water's surface. The pop up window will give you the temperature at that collection point. Make sure that you are reading the data for the proper point. Keep in mind that the first collection point will come up as Sample = 0 (not 1).

5. Select the Label (Annotate) button **Abc** and a pop up window will come up. Add text telling the depth and the temperature reading. Click OK to close the window. Use your mouse to position the label close to the first point.

6. Using your mouse, slide the marker to the 5 CM recording. Using the method in #5, add a label with depth and temperature.

7. Repeat steps #4 and 5, at each depth where you recorded the temperature. Be sure to save your work after you've added the labels.

Questions and Observations
1. At what depth did you find:
    a. the greatest temperature?
    b. the lowest temperature?
2. Calculate the incremental temperature difference for each time you moved the temperature sensor to a deeper level. At what depth did you find the greatest change? Where did you see the least change? Why do you think this is?
3. Predict what you think would happen to the temperature if you continued taking the temperature at greater and greater depths.

Part Two – Environmental Conditions and Water Temperatures
1. Set up the Labdisc using the same steps as for Part One except:
    a. select both Ambient and External Temperature sensors.
    b. select 1/minute for the sampling rate.
    c. select 10000 samples.

2. Place the protective box on the ground as close to the end of the water as it is safe to do so and place the Labdisc in the box.
3. Plug the External Temperature sensor in by pulling the cord through one of the lower slits in the protective box. (keep the cord attached to the meter stick).
4. Make sure that the box is closed tightly.
5. Extend the External Temperature sensor into the water from the shoreline so that it is at a depth of approximately 5 CM.
6. Push the Select key ⏎ to start the data collection and let it run for 24 hours.
7. Push the Select key ⏎ followed by the Scroll key ⎙ to stop the data collection.

Downloading Your Data
Follow the instructions from the *How to…* section to download your data if you need assistance.

Questions and Observations
1. Were you able to observe any patterns in the water temperature data?
2. Were you able to observe any patterns in the environmental temperature data?
3. What was the relationship between environmental temperature and water temperature?
4. How would this affect organisms living in the pond?

Extensions
1. Think of some ways that you might be able to collect data from other parts of the pond. Design a device or an experiment to allow you to this. Share your ideas with the class.

The Effects of Turbidity on Aquatic Life

Introduction

What Is Turbidity?

Turbidity is essentially a measurement of how cloudy or clear the water is or how easily light can be transmitted through it. The relative clarity of water: the greater the turbidity, the murkier the water. Turbidity increases as a result of suspended solids in the water that reduce the transmission of light. Suspended solids are varied, ranging from clay, silt and plankton, to industrial wastes and sewage. As sediments and other suspended solids increase in the water, the amount of light that can pass through the water decreases. Thus, the cloudier the water, the greater the turbidity. As algae, sediments, or solid wastes increase in the water, so does turbidity.

With higher levels of turbidity, water loses its ability to support a diversity of aquatic organisms. Water becomes warmer as suspended particles absorb heat from the sunlight which causes oxygen levels to become lower because warm water is capable of holding less oxygen than cooler water.

Turbidity affects organisms that are directly dependent on light, like aquatic plants, because it limits their ability to carry out photosynthesis. This, in turn, affects other organisms that depend on these plants for food and oxygen. In turbid water, photosynthesis decreases because less light penetrates the water which results in even further drops in oxygen levels. The combination of warmer water, less light and oxygen depletion makes it impossible for some forms of aquatic life to thrive or survive.

JTU

Jackson Turbidity Units

inverse measure of the length of a column of water needed to completely obscure a candle flame viewed through it. The taller the column of water, the clear (less turbid) it was. This unit of measure is no longer used.

Suspended solids affect aquatic life in other ways as well. Suspended solids can clog fish gills, reduce growth rates, decrease resistance to disease and prevent egg and larval development. Particles of silt, clay and organic materials settle to the bottom, especially in areas of a river or stream that are slow moving. These settled particles can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae. Material that settles into the spaces between rocks makes these microhabitats unsuitable for larvae and aquatic insects living there.

Scientists often consider turbidity of the water in connection with other factors to get a better understanding of its causes and consequences. For example, high levels of turbidity can identify problems with shoreline erosion, or sewage processing facilities not functioning properly.

Measuring Turbidity

The unit historically used in to measure turbidity was **JTU** (Jackson Turbidity Units), which was measured with the Jackson candle turbidimeter. This unit is no longer in standard use. Turbidity is measured in **NTU**: Nephelometric Turbidity Units. The instrument used for measuring it is called nephelometer or turbidimeter, which measures the intensity of light scattered at 90 degrees as a beam of light passes through a water sample. If there are lots of small particles scattering the source beam, more light reaches the detector than if there are few.

NTU

Nephelometric Turbidity Units

Measures the intensity of light that is scattered by particulates in a water sample at 90°

How much light is reflected by particulates is dependent upon properties of the particles like their shape, color, and reflectivity. For this reason (and the reason that heavier particles settle quickly and do not contribute to a turbidity reading), a correlation between turbidity and the

total amount of suspended solids is somewhat unique for each location or situation. Very low turbidity readings indicate an absence of planktonic life in a system; high turbidity readings can indicate water with too much suspended matter (and potentially too little dissolved oxygen) to support aquatic life. Turbidity can be useful as an indicator of the effects of runoff from construction, agricultural practices, logging activity, discharges, and other sources.

Brine Shrimp

Brine shrimp are crustaceans that make up the genus *Artemia*. Their closest relatives include fairy shrimp, triops and water fleas. More distant relatives include crabs, lobsters and shrimp. Brine shrimp populations are found worldwide in inland saltwater lakes, but not in oceans. Brine shrimp are able to avoid living near many predators like fish, because they are able to live in waters with very high salinity (up to 250g/L!)

Exoskeleton
A hard protective structure on the outside of an organism's body that offers protection and support. Animals with an exoskeleton do not have bones.

The eggs of brine shrimp are actually embryos within thin shells called cysts. As long as the eggs are kept dry, the embryos within them remain dormant. Once placed in salt water, they become active. After approximately 22 hours in room temperature salt water, the eggs open and the embryos slowly emerge.

As they grow and develop, brine shrimp go through a series of 14 to 17 different stages. Each stage is separated from the next by a molt. Molting involves growing a new larger **exoskeleton** and shedding the old one. At maturity, they will grow to be 10 to 20 mm long. When the water is warm, food is plentiful, and oxygen levels are high, brine shrimp can develop to adulthood in as little as 8 days.

Nauplii
Newly hatched brine shrimp larvae.

When conditions are good, mature females release developing embryos or free-swimming **nauplii** into the water. When conditions are favorable, brine shrimp can produce four or more generations per year. But when temperatures drop and food is scarce, the females release dormant cysts. Inside the cysts, the embryos are arrested in development. The surrounding shell protects them from the elements. When conditions improve, the embryo resumes development, and the life cycle continues. Brine shrimp cysts can remain viable for up to 25 years. Brine shrimp cysts have been found in Great Salt Lake geologic core samples up to 600,000 years old!

Brine shrimp have a segmented body which is attached to broad leaf-like appendages. The body usually consists of 19 segments, the first 11 of which have pairs of appendages, the next two which are often fused together carry the reproductive organs, and the last segments lead to the tail. Brine shrimp come in many colors. From white to pink to green, the different colors are probably an effect of diet and environmental conditions. Brine shrimp are used in the laboratory for testing the toxicity of chemicals. Brine shrimp cysts are packaged and sold as Sea-Monkeys.

Objectives:

Students will be able to:

1. Describe the visual appearance of water with high turbidity
2. Explain the consequences for aquatic creatures in water with high levels of turbidity
3. Suggest ways to help reduce/prevent excessive turbidity.

Materials Needed:

- Labdisc Enviro
- Cuvette
- 800 ml beaker
- Water
- Brine shrimp eggs with brine mix
- Magnifying glass
- Soil
- Aquarium pump with splitter
- Plastic aquarium tubing
- Baker's yeast
- Medicine dropper/Pipette
- Small flashlight
- Petri dish

Prepare Your Aquariums

1. At least 2 days before you begin the experiment, make two saltwater containers for your shrimp.

2. Rinse the beakers well and fill half way with tap water. Label them Tank A and Tank B.

3. Let the water sit 24 to allow any chlorine to evaporate. Then add the brine & shrimp mix to the water in each tank, reserving a small quantity of the eggs for use in Step 1 of the experiment.

4. Attach the plastic tubing to the aquarium pump and put the end in the water. Turn on the pump to keep the aquarium aerated. ***Do not*** to use an air stone for aeration because the young brine shrimp will stick to the small bubbles and die—just use the air hose so you have bigger bubbles.

5. Add 60ml of dirt to Tank B (do not use potting soil). If you can still see through the tank, add more dirt; 15 ml at a time. Add soil until the water is cloudy. Several times a day, *gently* stir the water in Tank B to keep the soil suspended in the water.

Experiment Procedure

1. Using the magnifying glass, examine the brine shrimp eggs that you saved during the experiment set up. Draw a picture of what you see.

2. Put the flashlight against the side of Tank A near the bottom to attract the shrimp. Take a sample from the water in the cuvette from near the surface. You will use this water in the next part of the experiment. Remove the flashlight.

3. Gently stir the water in Tank A to spread out the brine shrimp and use the medicine dropper to take a sample of the water from a depth of at least 5 cm.   Put this in the petri dish.

4. Use the magnifying glass to examine them. Count how many shrimp you see. Draw a picture of they look like. Return the shrimp to Tank A.

5. Repeat Steps #3, 4 & 5 with Tank B using a second cuvette for the water sample. You will use this water during the next part of the experiment.

6. After taking your water sample, prepare food for the shrimp by mixing 2ml baker's yeast with a little salt water.   Use a medicine dropper to add *2-4 drops* of this solution to both Tank A and Tank B. Be sure not to over feed them. Store the unused mixture in the refrigerator.

7. Take samples from each tank using the same procedure on Days 4, 5 and 6.

Labdisc Set Up

For this experiment you will setup the Labdisc from the Labdisc menu. You will need to make sure that your Labdisc has a completely empty memory before starting.   If you're not sure how to do this, follow the instructions in the *How to…* section to clear the logger's memory.

Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Sensor Selection - select both the Turbidity sensors

- Sampling Rate – Select Manual

- Number of Samples – Skip this step

Checking the Turbidity

1. Rotate the Labdisc plastic ring to expose the turbidity sensor. Be sure the cuvettes are dry on the outside before you put them into the sensor slot.

2. First calibrate the turbidity sensor by introducing a cuvette full of drinking water into the sensor slot. Press and hold the turbidity button for 3 seconds until a long beep is heard.

3. Place the cuvette with the water from Tank A into the opening for the Turbidity Sensor with cap of the cuvette is pointing straight up. Be sure to have the cap end of the cuvette away from the center of the Labdisc.

4. Press the Scroll key to record the turbidity reading from Tank A.

5. Repeat Step #2 & 3 with the cuvette with the water from Tank B.

6. Test samples from each tank using the same procedure on Days 4, 5 and 6.

Downloading Your Data

Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis

1. Open the data by clicking on the open file icon.   Make sure you remember the file name that you use to save your data. Select the file name and click Open.

2. Press the Display selection button and choose a Bar Graph format

3. Press the Statistics Button and make note of the Maximum and Minimum turbidity readings.

4. Left click on the scale along the Y axis. Reset the Maximum and Minimum values to be 10 greater or less than the maximum and minimum values recorded in Step 2.

5. Select the Label (Annotate) button ![Abc] and click directly above the first reading on the graph. A pop up window will come up. Add text identifying which tank, the day of the experiment and the turbidity reading. Click OK to close the window.

6. Repeat steps #5 for each turbidity reading that you took. Be sure to save your work after you've added the labels.

7. Print out your graph using the Printer button.

8. Draw a picture of what the brine shrimp looked like at that point above each label.

Questions and Observations

1. Is there a difference in the population density between the two tanks?

2. Is there a difference in the physical appearance of the brine shrimp in the two tanks?

3. Is this difference greater or lesser with each successive test/observation?

4. Develop a summary statement about how you believe turbidity affected the growth and development of your shrimp.

Extensions

1. Test the growth of aquatic plants in cloudy and clear water.

2. Check to see if turbidity affects the temperature of the water over a period of 2 weeks.

3. Design an experiment to see how turbidity might affect minnows in a pond.

4. Collect different water samples from around your neighborhood. Compare the turbidity reading with the amount of aquatic life you see in those areas.

How Do We Know Infrared Light Exists?
The Herschel Infrared Experiment

Vocabulary

Infrared
The portion of the spectrum with non-visible wavelengths slightly longer than visible red light.

Reflection
A change in the direction of a wave so that it returns to where it came from. With light, the angle between incoming light and the reflecting surface will be the same as the angel between the surface and the reflected. This is like a mirror or a still body of water.

Refraction
A change in the direction of a wave due to a change in its transmission medium.

Absorption
The way in which the energy of a photon is taken up by matter.

Transmission
The property of a substance to permit the passage of light.

What is Infrared Light

Infrared (IR) light has a wavelength longer than that of visible light; between 700nm and 1 mm. It is called infrared because its wavelengths are longer than those that we see as the color red. Infrared waves are invisible to people but can be detected by the presence of heat. Earth's surface and the clouds absorb both visible and invisible radiation from the sun and reflect much of that energy as **infrared** back to atmosphere. Substances in the atmosphere, like cloud droplets, water vapor, carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, and chlorofluorocarbons, absorb this infrared, and re-radiate it in all directions including back to Earth. This is known as the greenhouse effect and it keeps the atmosphere and Earth's surface much warmer than if the infrared absorbers not there.

Infrared radiation was discovered in 1800 by astronomer William Herschel, who discovered a type of invisible radiation in the light spectrum beyond red light, by noticing its effect upon a thermometer. Slightly more than half of the total energy from the Sun was eventually found to arrive on Earth in the form of infrared.

He found that the non-visible light just below the visible red light on the spectrum had a temperature higher than that of any visible light. Herschel performed additional experiments on what he called "calorific rays" (derived from the Latin word for *heat*) beyond the red portion of the spectrum. He found that they were **reflected, refracted, absorbed** and **transmitted** in a manner similar to visible light. Herschel's experiment was important because it marked the first time that someone demonstrated that there were types of light that we cannot see with our eyes.

Infrared light is used in industrial, scientific, and medical applications. Night-vision devices using active near-infrared illumination allow people or animals to be observed without the observer being detected. Infrared thermal-imaging cameras are used to detect heat loss in insulated systems, to observe changing blood flow in the skin, and to detect overheating of electrical apparatus. Medical infrared technology is used for the non-invasive analysis of body tissues and fluids. Infrared satellites are routinely used to measure ocean temperatures, providing an early warning for El Nino events that usually impact climates worldwide. Airborne and space-based cameras also use infrared light to study vegetation patterns and to study the distribution of rocks, minerals and soil. In archaeology, thermal infrared imaging has been used to discover hundreds of miles of ancient roads and footpaths, providing valuable information about vanished civilizations.

Infrared astronomy uses sensor-equipped telescopes to penetrate the far reaches of space. The universe contains vast amounts of dust, and one way to look into the hearts of dusty galaxies is with the penetrating eyes of infrared telescopes. Our universe is also expanding as a result of the Big Bang, and the visible light emitted by very distant objects has been red-shifted into the infrared portion of the electromagnetic spectrum.

Objectives:

Students will be able to:
1. Perform a version of the 1800 experiment conducted by William Herschel to prove the existence of infrared radiation/light.
2. Describe the temperature differences in the different parts of the visible and non-visible spectrum.
3. Explain why their results offer proof of existence for something that they cannot see (IR light/radiation)

Materials Needed:
- Labdisc Enviro
- External Temperature Probe
- 4" long equilateral glass prism with stand
- White paper
- Black tempera paint (WATER based paint!)

Experiment Set Up

Preparing the Temperature Sensor
1. Dip the tip of the external temperature probe into black tempera paint to a depth of 3 cm and allow to dry

Labdisc Set Up

For this experiment we will setup the Labdisc from the Labdisc menu. Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Sensor Selection - select External Temperature sensor 🌡️

- Sampling Rate – Manual

- Number of Samples – Skip this step

Rotate the Labdisc plastic ring to expose the sensors. Connect the external temperature sensor. Press the select key to begin collecting data. ⏎

Experiment Procedure

**Note: this experiment needs to be done outside on a *sunny* day. Clouds or hazy skies will limit your results.*

1. Ask students what colors they consider to be "hot;" what colors they think are "cold;" what colors are "cool." Ask the why they feel this way. There is no right/wrong answer.

2. Place the prism in a bright sunny area facing the sun and rotate the prism until you have the widest array of colors (spectrum) that you can get projected into a white piece of paper/poster board.

3. Start your data collection by pressing the select key. Push the temperature sensor button to set the display to show the external temperature readings during your data collection.

4. Insert the external temperature probe into the box through the slit that you cut along the long side of the box. Place the temperature probe so that the tip is in the **blue** portion of the spectrum. Hold the sensor in the portion of the spectrum until the readout stops changing and holds constant. Press the SCROLL key ⟲ to take the first reading.
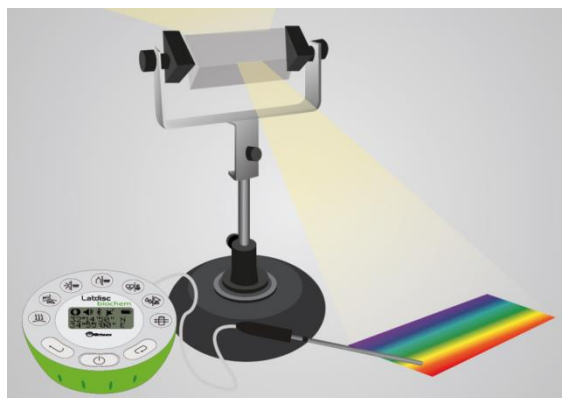
5. Move the sensor along the slit so that the tip moves into the **yellow** portion of the spectrum. Maintain the sensor in the yellow area until the readout becomes steady. Press the SCROLL key ⊘ to take the second reading.

6. Move the sensor along the slit until it is ___*just outside* the spectrum___ at the **red** end. Keep it there until the readout stays steady. Press the SCROLL key ⊘ to take the third reading.

7. Stop the data collection by pushing the Select key ⌄ followed by the Scroll key. ⊘

8. Clean the External Temperature sensor with soap & water. GENTLY use a scrubby sponge if necessary. Try not to get the place where the cord joins to the metal tip wet.

Downloading Your Data
Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis
1. Click on the graph label for Ambient Temperature on the upper right side of the graph to set the Y axis scale for Ambient Temperature. This will show you the temperature of the surrounding environment. Click on the statistics button at the top 🔢 to get the Ambient Temperature during your collection period. Make a note of the average Ambient Temperature on a piece of paper.

2. Click on the graph label for External Temperature on the upper right side of the graph to set the Y axis scale for External Temperature. This will show the temperature readings that you took within the color spectrum. Click on the statistics button at the top 🔢 to get the Ambient Temperature during your collection period.

3. Select the Label (Annotate) button **Abc** ▽ and a pop up window will come up. Add text indicating the Ambient Temperature and the average temperature reading from step #1. Click OK to close the window. Drag the label toward the upper right hand corner of the graph, where there is no other data.

4. Set the graph to line by selecting the 📈 line graph button. Then right click on the external temperature label in the legend in the upper right hand corner to change graph from a line to individual data collection points.

5. Right click on the label for the Y axis to set the range. Set a maximum that is slightly higher than the maximum reading from the statistic read out and a minimum slight lower that the minimum reading from the statistics read out. Hit OK.

6. Click on the marker button 📈 and set a marker on the data collection point from the **blue** portion of the spectrum. The pop up window will give you the temperature at that collection point. Make sure that you are reading the data for the proper point. Keep in mind that the first collection point will come up as Sample = 0 (not 1).

7. Select the Label (Annotate) button **Abc** ▽ and a pop up window will come up. Add text indicating the Ambient Temperature and the average temperature reading from step #2. Click OK to close the window. Drag the label toward the upper right hand corner of the graph, where there is no other data for the sample that you took in the **blue** part of the color spectrum. Label the color and the temperature within the blue light.

8. Repeat step #6 & 7 for the sample that you took from the **yellow** part of the color spectrum and for the sample that you took just **outside of the red** part of the color spectrum. Be sure to save your work.

1. Compare and contrast the temperatures that you saw;

    a. In the blue

    b. In the yellow

    c. Just outside the red

    d. In the environment

2. Calculate the temperature differences between the temperatures measured in the spectrum and the ambient temperature.

	Blue	Yellow	Just Beyond Red
$T_{spectrum}$			
$T_{ambient}$			
Difference $(T_{spectrum} - T_{shade})$			

3. Calculate the temperature differences between each part of the spectrum.

$T_{Yellow} - T_{Blue}$	$T_{JustBeyondRed} - T_{Yellow}$	$T_{JustBeyondRed} - T_{Blue}$

4. What did you notice about your temperature readings? Do you see any trends?
5. Where was the highest temperature? What do you think exists beyond the red part of the spectrum?

Teacher Notes

The temperatures of the colors should increase from the blue to red part of the spectrum. The highest temperature should be just beyond the red portion of the visible light spectrum. This is the infrared region of the spectrum. Herschel's experiment was important not only because it led to the discovery of infrared light, but also because it was the first time that it was shown that there were forms of light that we cannot see with our eyes. As we now know, there are many other types of electromagnetic radiation ("light") that the human eye cannot see (including X-rays, ultraviolet rays and radio waves).

You can also have the students measure the temperature of other areas of the spectrum like the area just before the visible blue (ultraviolet). Run the experiment during different times of the day; the temperature differences between the colors may change, but the *relative* comparisons will remain valid. The differences between the temperatures of the colors of the spectrum vary with the width of the spectrum, which depends on time of day, and the distance from the prism. But the trend of temperature increasing from blue to infrared will still appear.

Herschel's experiment was important not only because it led to the discovery of infrared light, but also because it was the first time that someone showed that there were forms of light that we cannot see with our eyes. As we now know, there are many other types of light that we cannot see and visible colors are only a very small part of the entire range of light which we call the electromagnetic spectrum.

Infrared Radiation All Around Us
Introduction

Vocabulary

Near-infrared
the part of the infrared spectrum that is closest to visible light

Far-infrared
the part of the infrared spectrum that is closer to the microwave region.

Mid-infrared is the region between these two.

Heat or Thermal Radiation
is the radiation produced by the motion of atoms and molecules in an object

Absolute Zero
is the temperature at which all atomic and molecular motion ceases
- 459.67° Fahrenheit
- 273.15° Celsius
  0° Kelvin

Infrared Radiation

Infrared radiation lies between the visible and microwave portions of the electromagnetic spectrum. Infrared waves have wavelengths longer than visible light and shorter than microwaves. Infrared is broken into three categories: ***near, mid and far-infrared***.

Infrared radiation is just as important to the Earth's weather and climate as sunlight is. This is because, for all of the sunlight that the Earth absorbs, an equal amount of IR radiation must travel from the Earth back to outer space. If this was not the case, there would be global warming or global cooling. Much like the way that the temperature of a pot of water on a stove is tied to an imbalance between the rate at which the pot receives energy from the stove versus the rate at which the pot loses energy to its surroundings, global warming or global cooling is caused by an imbalance between absorbed sunlight and emitted infrared radiation.

The primary source of infrared radiation is ***heat or thermal radiation***. This is the radiation produced by the motion of atoms and molecules in an object. The higher the temperature, the more the atoms and molecules move and the more infrared radiation they produce. Any object which has a temperature i.e. anything above ***absolute zero*** radiates in the infrared.

Everything emits infrared radiation.   But even though everything emits infrared energy, we usually don't notice it because it is often weak, and we can't see infrared light like you can sunlight. It takes a very hot object for us to feel infrared energy, like a hot stove, a fire, or a brick wall heated by the sun. Even objects that we think of as being very cold, such as an ice cube, emit infrared. When an object is not quite hot enough to radiate visible light, it will emit most of its energy in the infrared. The warmer the object, the more infrared radiation it emits.

Infrared Radiation in the Atmosphere

When an IR sensor is directed at a clear sky, it will almost always indicate a temperature below the air temperature at ground level. This is because the IR sensor is measuring IR radiation originating from high in the atmosphere, where temperatures are colder.

If the humidity of the air is very dry, then the IR sensor will typically read temperatures well below 0 deg. F, sometimes below -25 deg. F. However if the air is humid, it will read much warmer temperatures, closer to 30 or 40 deg. F, sometimes higher. While the temperature of the overlying air mass has some effect, the response of the IR sensor to humidity changes will be found to be much greater than can be explained by air temperature changes.

There are two reasons why a more humid air mass gives a higher temperature reading. Both are related to the fact that the atmosphere is more opaque (less transparent) to IR radiation. Less of the cold outer

space is seen by the thermometer, and IR emission comes from a lower altitude in the atmosphere, which is almost always warmer than higher altitudes.   If you point the IR sensor at a cloud, which is very opaque and does not allow for the transfer of much IR radiation, it will measure the approximate temperature of the cloud.

If it is a low altitude cloud, the temperature reading may approach that of the air temperature around you; perhaps 65°F for the cloud when the air temperature around you is 75°F. Higher altitude clouds will register a much colder temperature because they exist at altitudes where the temperature is much cooler.

How is This Help Prove of the Greenhouse Effect?

Greenhouse theory says that Earth-bound infrared radiation warms the temperature of the Earth's surface above what it would be if greenhouse components of the atmosphere did not exist. The IR thermometer actually measures warming of the sky-viewing side of the thermocouple in response to how strong the downward IR emission is from the sky.

Low clouds and high humidity air have the strongest greenhouse effect. A very dry, clear atmosphere has the weakest greenhouse effect.   Thus, the IR sensor measures exactly what greenhouse gas theory predicts: a temperature change in response to various intensities of downward IR emission from the sky.

This is direct evidence of the Earth's greenhouse effect: *downward infrared emissions by the sky influence the surface temperature of the Earth. The greater the intensity of that downward emission, the warmer the surface temperature*.   Finally, you don't have to wait for a change in humidity or for clouds to appear to do this experiment. If the sky is clear, just point the IR thermometer straight up, note the temperature, then slowly scan down toward the horizon. The indicated temperature will slowly increase because the IR thermometer is seeing more atmospheres, and thus more greenhouse gases, along a slant path than it sees pointing straight up.

Does the Greenhouse Effect Violate the 2nd Law of Thermodynamics?

2nd Law of Thermodynamics states that energy must flow from areas of higher temperature to areas of lower temperature.

Greenhouse warming of the Earth's surface is believed by some people to be physically impossible. They claim it would violate the ***2nd Law of Thermodynamics***.   The reason for this apparent violation is that the greenhouse gases in the middle and upper *colder* layers of the atmosphere make the Earth's surface WARMER, which would suggest energy flow from colder to warmer temperatures, which would seem to violate the 2nd Law. But the greenhouse effect is similar to putting a lid on a pot of boiling water. Even though the lid is colder than the water, its presence actually makes the water warmer. The flow of IR radiation between two objects is always two-way, with the total net flow being from warmer to colder temperatures.   So, the 2nd Law is not really violated because it's the net flow of energy which must be from warmer to colder temperatures, which is indeed the case in both the greenhouse effect, and adding a lid to the pot of water on the stove.

Objectives:

Students will be able to:

1. Predict which items will have higher IR readings and explain why
2. Interpret IR data to prove/disprove their hypothesis

Materials Needed:
- Labdisc Enviro

Labdisc Set Up

For this experiment you will setup the Labdisc from the Labdisc menu. Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Sensor Selection - select IR sensor ※

- Sampling Rate – Manual

- Number of Samples – Skip this option

Pre Activity Discussion

Discuss with students why some objects outside might feel warmer than others. Include in your discussion about temperature differences in the sun/shade and on a sunny/cloudy day. Ask them to predict items in the school yard that they think would feel warmer than others. Ask them to predict items in the schoolyard that they believe will feel cooler than others. Ask what makes them believe this?

Experiment Procedure

1. Start your data collection by pushing the SCROLL key ⟲. If the LED readout is not showing the IR temperature reading, push the IR section button again while the Labdisc is running.

2. Point the IR sensor on the Labdisc into a clear, not cloudy area of the sky and hold it steady until the digital reading stabilizes. Push the SCROLL key ⟲ to record your measurement.

3. Point the IR sensor at a cloud in the sky and hold it steady until the digital reading stabilizes. Push the SCROLL key ⟲ to record your measurement.

4. Point the IR sensor at the ground at your feet and hold it steady until the digital reading stabilizes. Push the SCROLL key ⟲ to record your measurement. Say

5. Point the IR sensor at ten other items in the school year and record a measurement. Make sure that five of these items are abiotic (non-living) and five are living. Be sure to hold the Labdisc steady until the readout stabilizes before recording your data.

6. With your smart phone, tablet or a digital camera, take a photo of each area where you took an IR reading.

Downloading Your Data

Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis

1. Set the graph type to bar graph using the display button 📊

2. Select the Label (Annotate) button [Abc] and a pop up window will come up. Add text labeling what item was sampled and the IR temperature reading. Add a photo of the item. Click OK to close the window and drag the label to just above the bar for that reading.

3. Repeat Step #2 for each item that you recorded the IR temperature. Be sure to save your work after you've added the labels.

Questions and Observations

1. Compare and contrast the IR temperatures that you saw;

    a. from a clear sky

    b. from a cloud

    c. from the ground

    d. from different parts of buildings

    e. from different non-living objects

    f. from different living objects

2. How are your measurements similar? How are they different?   Discuss the results and propose some possible explanations. What do the different IR emissions of objects and ground depend on?

3. Why did a clear sky show a lower temperature than a cloudy sky?

4. Sometimes the air temperature is warmer on a cloudy day than a clear day in the winter. Why does this happen?

Photosynthesis and Oxygen Production
Introduction

Photosynthesis
process used by plants to convert light energy into chemical energy and storing it by manufacturing sugars

Cell Wall
rigid structure enclosing plant cells. Made of cellulose, cell walls help keep call shape and protect the internal parts of the cell.

Chloroplast
structure within a plant cell where chlorophyll is found.

Vacuole
storage structure found in both plant and animal cells

Organelle
specialized part of a cell with a specific function. An organelle serves a cell much the way that an organ serves an organism

Stroma
area of fluid found within the chloroplast where starch/sugar is stored.

Thylakoid
specialized area in the chloroplast that holds chlorophyll molecules

Chlorophyll
green photo-pigment found in chloroplasts

Introduction

What do all plant cells have in common? The big thing that connects plants is photosynthesis. **Photosynthesis** is the process that allows plants to take energy from the Sun and create sugars. Plants have **cell walls** made from **cellulose** and organelles like **chloroplasts** and **vacuoles**.

Plants are able to turn sunlight into energy but not directly. Plants are able to store energy in some chemical bonds that can be used later. Before we get into details, we'll explain that there are two processes on Earth: Photosynthesis and Respiration. Photosynthesis stores the energy and respiration releases that energy. It all starts with the Sun.

Not all of the Sun's light makes it to the Earth's surface. As light passes through the Earth's atmosphere it is reflected and scattered. But the small percentage of light that does make it to the Earth's surface is enough for the plants of the world to survive and go through the process of **photosynthesis**. Light is actually energy, electromagnetic energy to be exact. That energy is used by green plants to make and store energy in the form of sugar molecules. Plants don't use all of the light that reaches them. Chlorophyll looks green because it absorbs red and blue light, making these colors unavailable to be seen by our eyes. It is the green light which is NOT absorbed that finally reaches our eyes, making chlorophyll appear green.

However, it is the energy from the absorbed red and blue light that is used to do photosynthesis. The green light we can see is not/cannot be absorbed by the plant, and thus cannot be used to do **photosynthesis**. The actual **photosynthesis** process occurs in the **chloroplast**. Chloroplasts are the food producers of the plant cell. Within this **organelle** is the chlorophyll that captures the light from the Sun. Two membranes surround each chloroplast. The **stroma** is an area inside the chloroplast where chemical reactions occur and starches/sugars are made. The **thylakoids** have **chlorophyll** molecules on their surface.

Chlorophyll is the magic compound that can grab that sunlight and start the whole process. Chlorophyll can also be found in many microorganisms and even some prokaryotic cells. However, as far as plants are concerned, the chlorophyll is found in the chloroplasts. The other big molecules are water (H_2O), carbon dioxide (CO_2), oxygen (O_2) and glucose ($C_6H_{12}O_6$). Carbon dioxide and water combine with light to create oxygen and glucose. That glucose is used in various forms by every creature on the planet. The oxygen produced by plant cells is important since all animal cells require oxygen to survive.
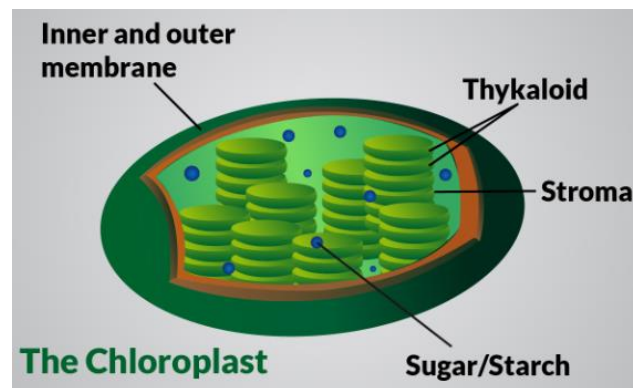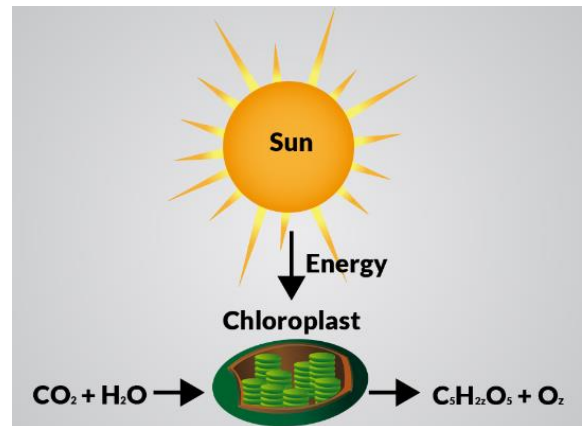
Stomata
leaf pore used for gas exchange

Light-independent Reaction
the first stage of photosynthesis where light energy is converted into ATP and NADPH

ATP
Adenosine triphosphate is one of the end products of photosynthesis, and used in many cellular processes. ATP transports chemical energy within cells for metabolism.

Calvin Cycle
Collective name for the three parts of the light-independent photosynthesis reaction: carbon fixation, reduction reactions, and ribulose 1, 5-bisphosphate (RuBP) regeneration.

Carbon Fixation
The process by which inorganic carbon (CO_2) is converted to organic compounds by living organisms.

The word **photosynthesis** means "building from light." The sun is the single most abundant source of energy at the surface of the earth, and living things long ago figured out how to harness that energy. What green plants and other organisms do it pretty remarkable, but it's pretty easy to summarize. They take a very low-energy compound like water, and then use the energy of sunlight to kick the low-energy electrons in water up to a much higher energy level. This is very similar to the way in which solar panels produce electricity from sunlight - except that plants don't make electrical current. Instead, they use those high energy electrons to build energy-rich sugar molecules from carbon dioxide. These sugars can then be stored to provide energy for just about any activity the cell needs.

Photosynthesis takes place primarily in plant leaves, and little to none occurs in stems and other plant parts. The upper and lower epidermal cells do not have chloroplasts, and so photosynthesis does not occur there. They serve primarily as protection for the rest of the leaf. The **stomata** are holes which occur primarily in the lower epidermis and are for air exchange: they let CO_2 in and O_2 out. The vascular bundles or veins in a leaf are part of the plant's transportation system, moving water and nutrients around the plant as needed. The mesophyll cells have chloroplasts and this is where photosynthesis occurs.

The chemical reaction involved in photosynthesis is:
$6CO_2$ + $6H_2O$ (+ light energy) → $C_6H_{12}O_6$ + $6O_2$. The oxygen by-product of photosynthesis is the source of the O_2 we breathe. There are two parts to photosynthesis. They are called the **light reaction** and the **dark reaction.**

Light and Dark Reactions
Photosynthesis doesn't happen all at one time. The process of photosynthesis is divided into two main parts. The first part is called the **light-dependent reaction**. This reaction happens when the light energy is captured and pushed into a chemical called ATP. The second part of the process happens when the ATP is used to make glucose (the **Calvin Cycle**). That second part is called the **light-independent reaction**.

The **light reaction** happens in the thylakoid membrane and converts light energy to chemical energy. This chemical reaction must, therefore, take place in the light. Chlorophyll and other pigments are involved in the light reaction. Each of these differently-colored pigments absorbs a slightly different color of light and passes its energy to the central chlorophyll molecule to do photosynthesis. The energy harvested via the light reaction is stored by forming a chemical called **ATP (adenosine triphosphate)**, a compound used by cells for energy storage.

The light-independent reaction takes place in the stroma within the chloroplast, and converts CO_2 to sugar. The light-independent reaction involves a cycle called the **Calvin cycle** in which CO_2 and energy from ATP are used to form sugar. The light-independent Calvin cycle uses the energy from electronically excited carriers to convert CO_2 and H_2O into organic compounds that can be used by the organism (and by animals that feed on it). This set of reactions is also called **carbon fixation.** Despite its name, the dark reactions

In aquatic environments dissolved oxygen is vital to the creatures that live there. The availability of oxygen depends on the rate of photosynthesis, which is greatly determined by the intensity of light. Because so much of the Earth's surface is covered with water, this aquatic photosynthesis is very important.

Everything we eat can be traced to photosynthesis. Energy resources like coal, oil, and natural gas are the result of photosynthesis, too. Over millions of years, the decayed bodies of plants and animals, all dependent upon photosynthesis, have given rise to deposits of fossil fuels throughout the earth. And, finally, photosynthetic organisms dominate the earth. They shape the composition of the atmosphere (that's where the oxygen we breathe comes from), form whole ecosystems, and produce both the energy and the mass upon which food chains depends. Without photosynthesis, life on Earth would not be possible.

Objectives
Students will:
1. Compare photosynthesis of aquatic plants in multiple environments.
2. Use a measure of dissolved O_2 in the water to prove that photosynthesis has occurred.
3. Describe how the O_2 produced by photosynthesis impacts humans and the atmosphere.
4. Describe how the CO_2 used by photosynthesis impacts humans and the atmosphere.

Materials
- Labdisc Enviro
- Dissolved O2 sensor
- 4 aquatic plants of the same species and similar size (*Elodea densa* works well)
- 3 glass containers with airtight lids
- Water
- 100 watt clip on lamp
- Small wooden or cardboard box (roughly 30 cm x 30 cm and at least 15 cm tall)
- Flat lid from a Styrofoam cooler
- Packing tape

Part One – In the Lab
Before starting, have students make a prediction about how they think light intensity will affect the rate of photosynthesis. Have them explain how/why a measure of dissolved Oxygen can be used to measure this.

Labdisc Set Up
For this experiment we will setup the Labdisc from the Globilab menu. Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Select the Dissolved O_2 sensor
- Select Manual
- Select 100 samples
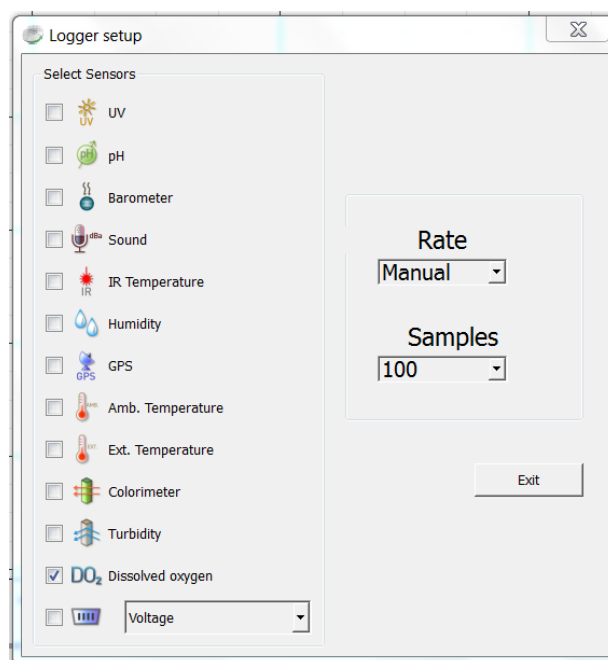
Procedure

1. Fill the glass jars with 250 mil of water at room temperature.

2. Measure the dissolved oxygen in one of them. Press ![run icon] to start your data collection. Slowly stir the water with the DO sensor until the read out on the Labdisc remains steady. Push the Select key ![select key] to record the value.

3. Completely submerge a plant in each container and close the lid tightly.

4. Place one container 15 cm from the light; the second container 20 cm from the light and the third container in a dark closet/cupboard. Leave them there for 10 minutes.

5. After 10 minutes, take the container from the cupboard and shake it several times. Remove the lid and use the dissolved oxygen sensor to measure the dissolved oxygen by stirring gently until the readout on the Labdisc remains steady. Push the Select Key ![select key] to record the value.

6. Repeat Step #5 with the 15 cm jar and then the 20 cm jar.

7. With fresh tap water, replace the 250 ml of water in the jar from the dark closet and place it into the light at a distance of 25 cm from the light.

8. Replace the water from the jar that had been 15 cm from the light with 250 ml of new water and submerge the remaining plant in it. Place this jar 30 cm from the light.

9. Wait 10 minutes and repeat Step #5 with these two jars starting with the jar closer to the light.

Downloading Your Data

Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis

1. From the Display Type dropdown menu, select the Line Graph. ![line graph icon] In the legend on the upper right hand side, right click on Dissolved Oxygen so that the display shows individual data points.

2. Click on the Annotation button ![Abc icon] and add labels describing the conditions of each sample (i.e. dark, 15 cm)

3. Click on the Marker button ![marker icon] and then on the mark from your first reading. The pop up box will give you an exact reading. Add this information to your label.

Questions & Observations

1. What was the control in your experiment?
2. How did the jar with only water compare to your other results? What about the jar with a plant that was kept in the darkness? Why did this happen?
3. Which conditions produced the greatest amount of photosynthesis? How do you know?
4. What happened to the Dissolved Oxygen levels as you moved the jars further and further from the light source? Why?
5. What information would you need to calculate the actual amount of oxygen produced in each sample? Use that data to complete the chart below

Plain Water	Darkness	15 cm from light	20 cm from light	25 cm from light	30 cm from light

Extension

1. What other factors, besides light intensity might affect the rate of photosynthesis? Design an experiment to test this.
2. How could the amount of Dissolved Oxygen in water affect aquatic life?

Part Two – Dissolved Oxygen in a Pond

Labdisc Set Up

For this experiment you will setup the Labdisc from the Labdisc menu. Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Sensor Selection – Select the Dissolved O_2 **DO₂** and light ☼ sensors

- Sampling Rate – Select 1/minute

- Number of Samples – select 1,000

Rotate the Labdisc plastic ring to expose the sensors. Connect the Dissolved O_2 sensor. Press the select key to begin collecting data. ⏎

Procedure

1. Set the box close enough to the edge of the pond that the DO_2 sensor can reach to the water.

2. Tape the DO_2 sensor to the end of the cooler lid so that approximately 5 CM extends below the bottom of the cooler lid. Dissolved Oxygen

3. Attach the DO_2 sensor to the Labdisc. Place the Labdisc in the box and float the cooler lid in the pond so that the sensor is immersed in the water.

4. Push the Select ⏎ key to begin your data collection.

5. Allow the collection to run for 24 hours and then collect the Labdisc and push the Select key ⏎ followed by the Scroll key ⏮ to stop the data collection.

Downloading Your Data

Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis

1. From the Display Type dropdown menu, select the Line Graph and Table format.

2. Click on the Statistics button to discover the maximum and minimum light values for your data.

3. Use the Marker button to place a marker on the line representing the light data. Slide it along the line until you find where the Maximum and Minimum values occurred.

4. Use the table portion of the read out to calculate the time of day that this value occurred. (Hint: Remember 60 seconds in a minute and 60 minutes in an hour). You can determine your exact

5. Click on the Annotation button and add labels indicating the maximum and minimum values and at what time they occurred.

6. Click on the colored line for the Dissolved O_2 sensor in the upper right hand corner of the screen.

7. Repeat steps #2 through 5 for Dissolved O_2.

Questions and Observations

1. At what time of day did you observe the highest light levels? The lowest?
2. At what time of day did you observe the highest concentration of Dissolved O_2?
3. Where does the O_2 come from?
4. Describe the relationship between light and Dissolved O_2. What makes this happen?
5. How does photosynthesis affect aquatic life?
6. What could happen if the photosynthesis decreased greatly?
7. How might an increase in photosynthesis affect aquatic life?
8. Could there be such a thing as too much aquatic plant life? What conditions might that cause?

Photosynthesis and the Water Cycle
Introduction

Vocabulary

Evaporation
Vaporization of a liquid into a gas.

Precipitation
Any condensation of atmospheric water vapor that falls to Earth due to gravity. Examples include rain, sleet and snow.

Transpiration
The transfer of water from plants to the atmosphere

Stomata
A pore or opening found on a leaf's surface. It is used to control gas exchange (O^2 and CO^2).

Cuticle
a waxy film found on the surface of leaves and plant shoots which offers protection

Movement of Water in the Atmosphere

Evapotranspiration is the sum of **evaporation** from the land surface plus transpiration from plants. **Precipitation** is the source of most water in an environment.

Transpiration is the evaporation of water into the atmosphere from the leaves and stems of plants. Plants absorb water through their roots which can come from deep in the soil. Some plants may have roots that grow as far down as 20 meters. Plants bring the water up from the soil to deliver nutrients to their leaves. This pumping is driven by the evaporation of water through small pores called stomata, which are found on the undersides of leaves. As water evaporates from the surface of the leaves, more water (with nutrients) is pulled from the soil into the roots and the plant to replace it.
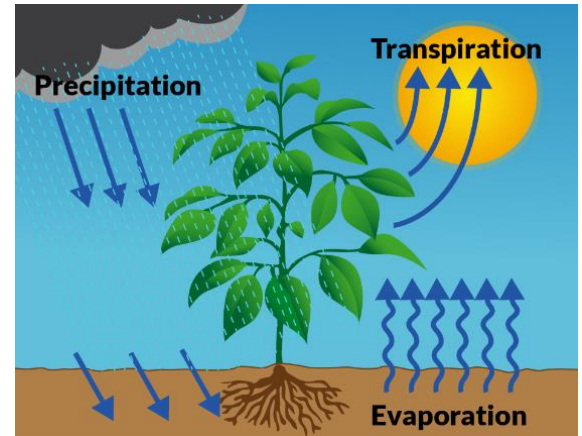
Leaf surfaces have small openings which are called **stomata**. In most plants stomata are more numerous on the undersides of the foliage. The stomata are able to open and close. Transpiration occurs through the stomata. The opening of the stomata allows the plants to take in CO_2 from the air which is used during photosynthesis. Transpiration also cools plants, changes water pressure within the cells, and allows the plant to carry minerals and other nutrients and water from roots to the main body of the plant.

Rate of Transpiration

Plants regulate the rate of transpiration by controlling how far the stomata are opened. Factors like humidity, temperature, wind and light all affect the rate that transpiration occurs. The amount of water in the soil and soil temperature can also influence the stomata opening, and thus transpiration rate.

Transpiration accounts for approximately 10% of all evaporating water. The amount of water lost by a plant also depends on its size and the amount of water absorbed at the roots. Transpiration accounts for most of the water loss by a plant, but some direct evaporation also takes place through the **cuticle** of the leaves and young stems. Transpiration serves to cool plants as the escaping water vapor carries away heat energy.

During a growing season, a leaf will transpire many times more water than its own weight. Desert plants have specially adapted structures, such as thick cuticles, reduced leaf areas, sunken stomata and hairs to reduce transpiration and conserve water. In many cacti photosynthesis occurs in thick, fleshy stems, rather than leaves, so the surface area of the plant is very low, reducing water loss to transpiration.

Atmospheric factors that affect the rates of transpiration include:

Number of leaves	More leaves means more surface area and more stomata for gaseous exchange. This will result in greater water loss.
Size of the leaf	A leaf with a bigger surface area will transpire faster than a leaf with a smaller surface area.
Plant Cuticle	A waxy cuticle reduces evaporation from the plant surface except via the stomata. A reflective cuticle will reduce solar heating and temperature rise of the leaf which reduces evaporation.
Number of stomata	More stomata will provide more pores for transpiration.
Light supply	The stomata open for photosynthesis. Bright light usually encourages the stomata to open which increases transpiration.
Temperature	Higher temperatures will increase the rate of transpiration. Because it causes the stomata to open, while colder temperatures will cause them to close.
Relative humidity	Lower humidity increases the rate of transpiration. It is easier for water to evaporate into dryer air than more humid air.
Wind	Stronger winds/breezes will increase the rate of transpiration.
Water supply	Stress caused by a reduced water supply from the soil may result in the stomata closing which reduces the rate of transpiration.
Soil Moisture	When soil is extremely dry, plants may begin **sensce**, which will reduce the amount of transpiration.

Sensce
Premature aging of a plant which can cause leaf wilting or loss

Objectives:

Students will be able to:

1. Describe two ways that water returns to the atmosphere from earth
2. Explain how decreased CO_2 and humidity are indicators of photosynthesis occurring
3. Explain why different conditions caused changes in CO_2 and humidity levels.

Materials Needed:
Labdisc Enviro

- CO_2 sensor
- Potted plant (10-15 cm diameter pot)
- Large clear plastic bag (large enough to completely contain the plant and the Labdisc)

Labdisc Set Up
For this experiment we will setup the Labdisc from the Globilab menu. Use the directions in the *How To....* section if you need assistance in setting up the Labdisc.

- Connect the CO2 sensor to the Labdisc Enviro universal input (the most left sensor).

- If you are using the CO2 or the first time, connect the Labdisc to its AC/DC adapter and allow the CO2 sensor to run for 24 hours, to reach calibration.

- Select the CO2 and Humidity sensors

- Select a sample rate of 1/second

- Select 1,000 samples
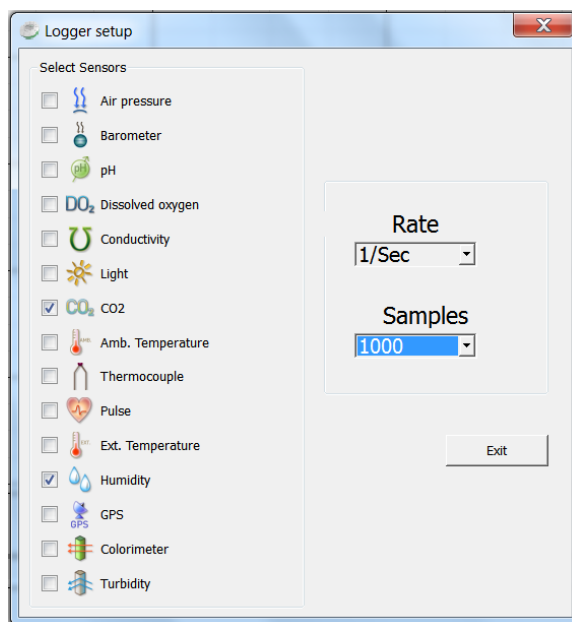
Pre-Activity Discussion
We saw in the photosynthesis activity that Oxygen is produced by plants during photosynthesis. This activity will explore two other parts of the photosynthesis process – CO_2 consumption and transpiration.

1. What do you think will happen to the humidity and CO2 levels in a closed system with a plant? Why?

2. What do you think will happen to the humidity levels in a closed system with a plant? Why?

3. How could environmental conditions have an effect on CO_2 and humidity?

Procedure
1. Make sure the Labdisc is connected to the computer via a Bluetooth connection.

2. Press the Start button 🏃 measure the humidity and the CO_2 in the classroom environment.

3. Make sure that the soil in the pot is damp/moist but not wet.

4. When your first data collection is complete, place the plant and the Labdisc inside the bag and seal the bag.

5. Place the bag in a dark closet/cupboard and push the Start button to begin the second data collection.

6. When the second data collection is complete, move the plant and the Labdisc to a place in the classroom that is not in direct sunlight. Press the Start button 🏃 to being the third data collection.

7. When the third data collection is complete, move the bag to a sunny area, near a window. If necessary, put the bag and the Labdisc outside in the sun. Press the Start button 🏃 to begin the fourth collection.

Downloading Your Data
Follow the instructions from the *How to…* section to download your data sets.

Data Analysis

9. Open the data from the Environment collection by clicking on the open file icon. 📂 Select the file name and click Open.

10. Click on the CO_2 label at the upper right side of the screen. Select the Statistics button. 🖩 Make a note of the maximum and minimum CO_2 readings and click OK to close the window.

11. Select the Marker button 📈 and put a marker on CO_2 line at the minimum CO_2 reading. A pop up window will tell you the length of time into your data collection and the temperature at this point in time.

12. Select the Label (Annotate) button ⬇Abc and a pop up window will come up. Add text telling the time and the temperature reading. Click OK to close the window.

13. Using your mouse, slide the marker along the ambient temperature line to the maximum CO_2 reading. Using the method in #4, add a label with time and temperature. Be sure to save your work after adding labels.

14. Click on the Humidity label at the upper right side of the screen. Select the Statistics button. 🖩 Make a note of the maximum and minimum humidity readings and click OK to close the window.

15. Repeat Steps #3 through #5 for the humidity data.

16. Repeat the entire process (Steps #1-#7) for each of the remaining three data collections

17. Print out the graphs so that you can compare them side by side.

Questions and Observations
1. Compare and contrast the CO_2 levels that you saw;

    a. In the environment before you started

    b. When the plant was in the dark

    c. When the plant was in indirect light

    d. When the plant was in direct sunlight

2. Compare and contrast the humidity levels that you saw;

    a. In the environment before you started

    b. When the plant was in the dark

    c. When the plant was in indirect light

    d. When the plant was in direct sunlight

3. Under what conditions was the greatest amount of CO_2 consumed? What conditions produced the greatest change in humidity? Discuss the results and propose some possible explanations.

4. How does the data that you observed in this activity indicate that photosynthesis is occurring?

Extension

An apple tree has 200,000 leaves. Each of the leaves has a surface area of 20 cm^2. The lower surface area of each leaf contains 25,000 stomata per cm^2. In a single summer, each leaf loses about 86 mL of water through transpiration.

1. What is the total leaf surface area of the tree?
2. How many stomata are on the lower surface of each leaf?
3. If the stomata are only on the underside of the leaves, how many stomata are on the tree?
4. How much water is transpired by the entire tree in a single summer?

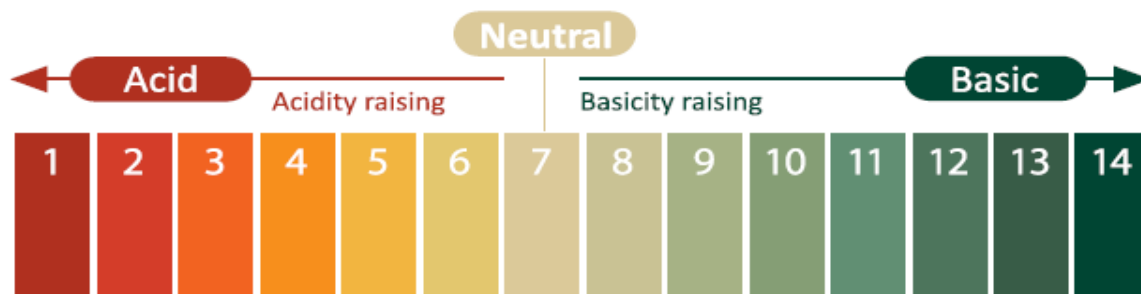# Soil pH
Introduction

Acids and Bases Are Everywhere

Every liquid you see will probably be either *acidic* or *basic (alkaline)*. Water (H$_2$O) can be both an acid and a base, depending on how you look at it. It can be considered an acid in some *reactions* and a base in others.

Most of the time, the positive and negative ions in distilled water are in equal amounts and cancel each other out. Most water you drink from the tap has other ions in it. Those special ions in solution make something acidic or basic. In your body you have compounds called amino acids. The name tells you those are acids. In fruits there is something called citric acid. That's an acid too. Vinegar? Acid. But what about baking soda? When you dissolve it in water, it becomes basic.

So what makes something an acid or a base? A chemist named Svante Arrhenius came up with a way to define acids and bases in 1887. He saw that when you put molecules into water, sometimes they break down and release a hydrogen (H$^+$) ion. At other times, you find the release of a hydroxide (OH$^-$) ion.

When a hydrogen ion is released, the solution becomes acidic. When a hydroxide ion is released, the solution becomes basic. Those two special ions determine whether you are looking at an acid or a base.

Scientists use something called the *pH scale* to measure how acidic or basic a liquid is. Although there may be many types of ions in a solution, pH focuses on concentrations of hydrogen ions (H$^+$) and hydroxide ions (OH$^-$). The scale measures values from 0 to 14. The pH of distilled water is 7 (right in the middle). Acids are found between 0 and 7. Bases are from 7 to 14. Most of the liquids you find every day have a pH near 7. They are either just below or just above pH 7. There are very strong acids with pH values below 1, such as battery acid. Bases with pH values near 14 include drain cleaner and sodium hydroxide (NaOH). Those chemicals are very dangerous.

Soil pH and Plants

Soil may also be *acidic* or *basic*. Generally, soils in moist climates tend to be acid and those in dry climates are alkaline. A soil with a pH lower than 7.0 is considered an acidic soil and one with a pH higher than 7.0 is alkaline. Very acidic soil has a pH of 3 to 5. A soil with a pH of 8 to 10 is mildly basic or alkaline according to chemists but is considered very alkaline for growing plants. Most plants don't grow well in soils with a pH greater than 8. The soil must be adjusted to suit the plants which will occupy that area if it is not already within that plants requirement range for it to be successful

In a forest of conifers, like pines or firs, the soil will be acidic and very likely sandy. Other plants, like those that grow in the grasslands, prefer an alkaline soil. Some plants are natural pH indicators. Hydrangeas, for example have blue blossoms in soil with a pH of 5.0 to 5.6, the pH of typical rainfall. They bloom pink in soil that has a pH of 6.0 or higher. To make hydrangeas bloom a more distinct shade of blue, you can add aluminum sulfate to make the soil more acidic. You can make them bloom pinker by reducing the soil's acidity by adding lime.

Why should we be concerned about soil pH? Plant nutrients have to be dissolved in water for plants to absorb them. Solubility of minerals is related to pH. Manganese and iron are essential plant nutrients but at a pH of 5 and below they are very soluble and can be phytotoxic. Aluminum, nonessential for plant growth but prevalent in clay soils, is very soluble at pH of 4 and is very toxic to many plants. By using lime we can raise the pH of soil and by using elemental sulfur make the soil more acidic. There are some natural methods, like sphagnum peat or oak leaves that will also help acidify soil.

Optimal Soil pH Levels of Common Fruits and Vegetables

Plant	Optimal pH	Plant	Optimal pH	Plant	Optimal pH
Annona	6.5 to 7.6	Ginger	5.5 to 7.5	Rambutan	4.5 to 6.5
Artichoke	5.6 to 6.6	Gourds	5.0 to 6.0	Raspberry	6.0 to 6.5
Avocado	6.0 to 7.0	Guava	4.0 to 8.2	Rutabaga	5.0 to 7.0
Basil	5.5 to 6.5	Jackfruit	5.5 to 7.0	Shallots	5.0 to 7.0
Beans	6.0 to 7.0	Lemongrass	5.5 to 7.5	Spinach	5.0 to 7.0
Beet	5.6 to 6.6	Lettuce	6.5 to 7.0	Squash	6.0 to 7.0
Broccoli	6.0 to 7.0	Lychee	5.5 to 7.5	Strawberries	6.0 to 7.0
Cabbage	5.6 to 6.6	Mushrooms	7.0 to 8.0	Spearmint	5.5 to 7.5
Cantaloupe	6.0 to 7.0	Okra	6.0 to 8.0	Spiny Chayote	5.5 to 7.5
Carrot	5.0 to 6.0	Onions	6.2 to 6.8	Sweet Potato	5.0 to 7.0
Cauliflower	6.0 to 7.0	Parsley	6.0 to 8.0	Swiss Chard	6.0 to 7.0
Celery	6.0 to 7.0	Parsnip	5.0 to 7.0	Tamarind	4.5 to 8.0
Chard	6.0 to 7.0	Peas	5.6 to 6.6	Taro	6.0 to 6.8
Chili Pepper	5.0 to 6.0	Peanuts	5.0 to 6.0	Thyme	5.5 to 7.0
Chives	5.0 to 6.0	Peppermint	6.0 to 7.5	Tobacco	5.0 to 7.0
Chrysanthemum	6.5 to 6.7	Peppers	6.0 to 8.0	Turnip	5.0 to 7.0
Cucumber	5.0 to 6.0	Pomelo	5.6 to 6.5	Water Chestnut	5.5 to 6.0
Dragonfruit	5.3 to 7.6	Potato	5.8 to 6.5	Yams	6.0 to 8.0
Eggplant	5.0 to 6.0	Pumpkin	5.0 to 7.0	Yucca	5.5 to 7.5
Garlic	5.0 to 6.0	Radish	6.0 to 7.0	Zucchini	6.0 to 7.0

Objectives:

Students will…

1. Explain the difference between acidic and alkaline.
2. Measure the pH of different soil samples and identify them as acidic, alkaline or neutral
3. Explain why soil pH is important for gardening and food production.
4. Give examples of different plant types that grow in acidic and alkaline soils and discuss how soil pH might affect crop selection.

Materials Needed:

- Labdisc Enviro
- pH Sensor
- Soil samples from several different areas
- 4 to 8 oz Jars with lids (1 for each sample)
- Distilled Water
- Large syringe or wash bottle (for cleaning the pH sensor)

Labdisc Set Up

For this experiment we will setup the Labdisc from the Globilab menu. Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

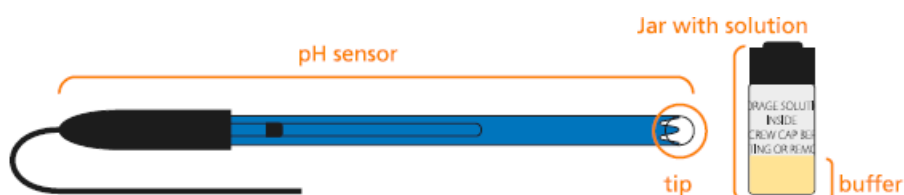- Select the pH sensor

- Select Manual

- Select 10 samples

The pH sensor is very sensitive and requires certain treatment. Please consider that:

a. After each measurement, the pH probe should be rinsed thoroughly with distilled water. If you don't have a wash bottle, you will need a 10 ml or larger syringe to use to clean the sensor

b. After each time the sensor is washed, dry the tip lightly with absorbent paper. Be sure to not touch the transparent ball at the tip of the sensor.

c. When the sensor is not being used, store it in the buffering solution. Make sure that the sensor is cleaned thoroughly before storing it.
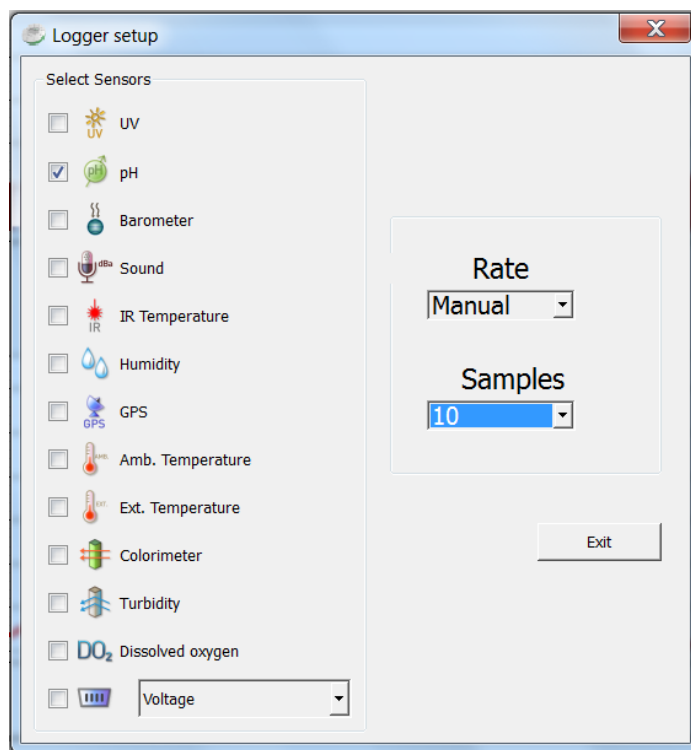
Experiment Procedure

1. Collect a soil sample from several different areas in your neighborhood/schoolyard. With a digital camera or a smart phone, take a picture of the area where you have collected the sample. Write a brief description of the area and include information like the amount and type of plants growing there, what type of human or animal action happens there and the condition of the area.

2. Fill each jar with equal parts of soil and water.

3. Put the cover on the jars and shape vigorously to mix the soil and the water thoroughly.

4. Let the soil settle for 5 minutes

5. Remove the sensor from the buffer solution and carefully clean it with distilled water and dry gently with a paper towel. Be sure to not touch the round bulb at the end of the sensor.

6. Rotate the Labdisc plastic ring to expose the sensors and attach the pH sensor

7. Click on the display icon and select the Bar Graph

8. Click the Run icon on the Globilab software to start the data collection.

9. Slowly put the end of the sensor into the first sample without touching the sides of the jar or the soil in the bottom of the jar. Slowly stir the solution until the readout stabilizes.

10. Push the SCROLL button to collect a data reading.

11. Before you take a measurement from the second sample, clean the electrode again with distilled water and dry gently with a paper towel.

12. Repeat steps 10 and 11 for each of the soil samples.

13. Once you have finished, click the Stop button to end the data collection.

14. Carefully clean the sensor with distilled water and return to the buffer solution for storage.

Downloading Your Data
Follow the instructions from the *How to…* section to download your data sets.

Data Analysis

1. Observe the graph of your data collection.

2. Use the text button to add labels to identify the soil samples and list the pH reading from each different sample. Add a photo of the area where the soil sample was collected. Be sure to save your experiment data.

Questions and Observations

1. What were the pH levels of the soil samples that you tested? Were they acidic or alkaline?

2. Think about the areas where you collected the soil. Now that you know the pH of the soil, what impact do you believe that it has on what plants grow there?

3. Look at the list of common food plants and the pH that they should be grown in. Why does soil pH matter to farmers?

4. If you were a farmer with slightly acidic soil, what are three plants that you might consider growing? If you were a farmer with highly acidic soil, what crops could you grow? What about if your soil was slightly alkaline/basic? What crops could you grow?

5. What do you think would happen to a farmer whose soil had a pH of 3?

Carbon Dioxide in the Classroom

Introduction

Vocabulary

Chemical Compound
a pure chemical substance consisting of two or more different elements that can be separated into simpler substances by chemical reactions
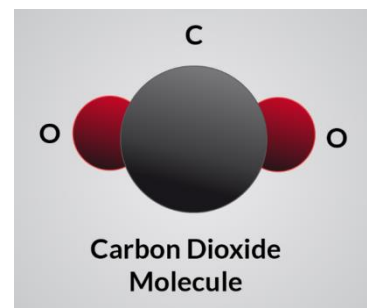
Greenhouse Gas
is a gas in the atmosphere that absorbs and emits infrared radiation (heat). Without greenhouse gases, the Earth's surface would average about 33 °C colder.

Carbon Dioxide

Carbon dioxide is a **chemical compound** composed on one carbon atom (C) and two oxygen atoms (O_2). Its chemical formula is CO_2.

Carbon Dioxide Molecule

It accounts for only 0.035% of the total mass of the atmosphere but it essential for our survival.   Since the early days of the Earth, CO_2 has been emitted from volcanoes, from decaying plants and animals, from forest fires and from animal respiration. This natural CO_2 has kept the temperature on Earth in a range suitable for life.

CO_2 is a **greenhouse gas** which traps heat in the atmosphere. Without it and other greenhouse gases, the Earth would be a frozen world. But humans have burned so much fossil fuel that there is about 30% more carbon dioxide in the air today than there was 150 years ago. According to data from ice cores in the Arctic and Antarctic, the Earth's atmosphere has not held this much carbon for at least 420,000 years. Increased greenhouse gases like CO_2 in our atmosphere are helping the Earth to become warmer.

But Where Does It Come From?

A vital part of all the food chains in any ecosystem are the decomposers. Lacking the chlorophyll necessary for photosynthesis, organisms like fungi and bacterial get their energy by breaking down dead plant and animal material. In the process, large amounts of CO_2 are produced. Decomposition occurs constantly on the floor of a forest, at the bottom of the ocean, on the ground of a prairie and in the mud of a marsh and is a normal and necessary process. When humans upset the balance in these communities, for example by cutting down trees, decomposition happens at an even faster rate, adding even more CO_2 to the atmosphere (not to mention removing trees which help to reduce existing CO_2)

CO_2 is also emitted into the atmosphere by human activity. Scientists have determined the concentration of CO_2 in the atmosphere from past times through analysis of ice cores taken in Antarctica and Greenland. Today, scientists determine the CO2 concentration directly from the air. Over the last 200 years, atmospheric CO_2 concentration has increased noticeably, mostly due to the activities of increasing human population. The largest contribution of CO_2 comes from the burning of fossil fuels in for heating/cooling, automobiles and industrial processes. CO_2 is also added to the atmosphere, both indirectly and directly by deforestation and changes in land use patterns. CO_2 is expected to account for about 50% of the increase in the Earth's average global temperature caused by human activity.
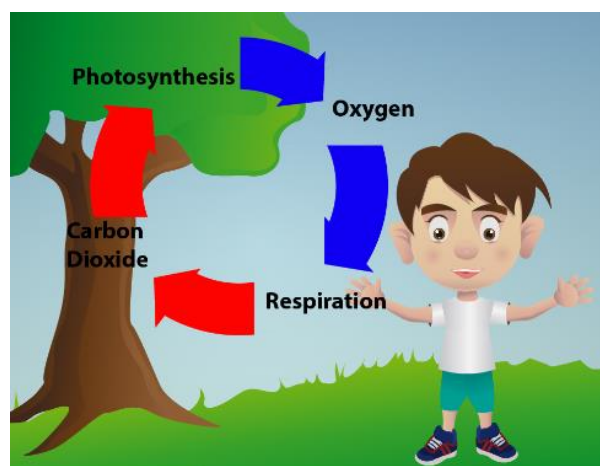
CO_2 is removed from the atmosphere by photosynthesis and by the oceans absorbing it. It is not well known how long CO_2 can linger in the atmosphere because there are so many processes that produce and remove CO_2. From 650,000 years ago until the industrial revolution the concentration of CO_2 never rose above 280ppm, in the atmosphere. Since then the level of CO_2 in the atmosphere has grown gradually over time. The CO_2 concentration in 2013, was 393ppm, and has been increasing at an average global rate of 1.9ppm per year.

The carbon dioxide data from Mauna Loa, Hawaii is the longest record of direct measurement of CO_2 in the atmosphere. Data collection there was started by C. David Keeling of the Scripps Institution of Oceanography in March of 1958 at a facility of the National Oceanic and Atmospheric Administration. The NOAA started its own CO_2 measurements in May of 1974, and has run in parallel with the data collected by Scripps since that time

How Does This Relate to Public Health?
High levels of CO_2 in the air can result in higher amounts dissolved in the ocean. His can cause the ocean waters to become more acidic and cause harm to aquatic ecosystems. Studies have shown that some marine species like conchs, clams, and sea urchins struggle to grow new shells or suffer from shell deterioration when exposed to elevated levels of carbon dioxide. Other species with protective shells like crustaceans, temperate urchins, mussels, and coralline red algae can create heavier shells under elevated CO_2 conditions. Many of these species hold promise to treat human illness, as well as provide incentive for numerous recreational activities.

Increased levels of CO_2 contribute to earlier pollen seasons, which can cause problems for people with allergies. Higher CO_2 levels also contribute to higher evaporation rates, which may threaten global water supplies. A 2006 study found that current levels of severe drought worldwide (3%) could be as high as 30% by 2100.

Objectives:
Students will be able to:

1. Relate changes in CO_2 in the classroom to actions/activities that have occurred there.
2. Describe factors that can affect CO_2 levels
3. Explain how the burning of fossil fuels affects CO_2 levels
4. Explain why increased CO_2 is problematic

Materials Needed:
- Labdisc Enviro
- CO_2 sensor
- Potted plants
- Candles (1/student)
- Matches or Lighter

Labdisc Set Up

For this experiment we will setup the Labdisc from the Globilab menu. Use the directions in the *How To….* section if you need assistance in setting up the Labdisc.

- Connect the CO2 sensor to the Labdisc Enviro universal input (the most left sensor).

- If you are using the CO2 or the first time, connect the Labdisc to its AC/DC adapter and allow the CO2 sensor to run for 24 hours, to reach calibration.

  - Select the Ambient Temperature, Humidity and CO_2 sensors

  - Select 1/minute

  - Select 10,000 samples
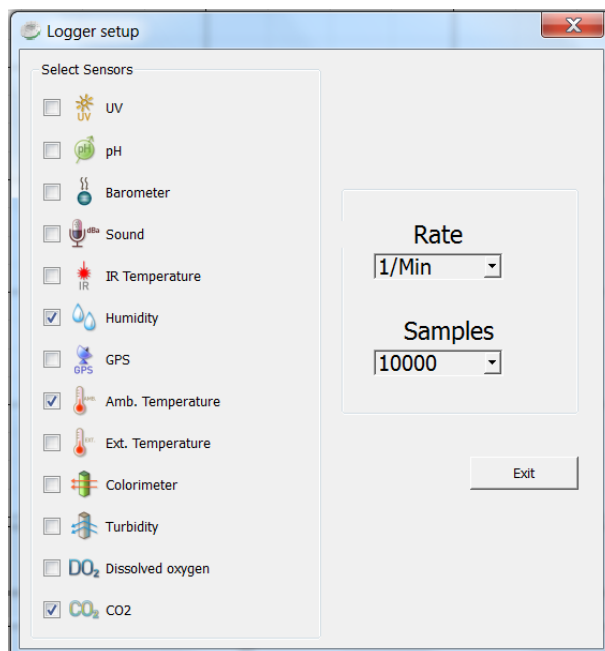
Experiment Procedure

Part One - Baseline Data

1. Place the Labdisc in the back of the classroom in an area that will not interfere with daily classroom activities. Make sure that there is air circulation around the CO_2 sensor.

2. Press the Select key ⏎ to start the data collection. Make notes of times when key events/things that might affect CO_2 levels occur. These include things like:

   a. When the first person enters the classroom in the morning

   b. When did the class arrive in the morning

   c. How many people are in the classroom

   d. When doors or windows are opened

   e. When did the class leave the room

   f. When did the last person leave the room

   g. What is the weather like outside

3. Allow the data collection to run for a week.

Downloading Your Data

Follow the instructions from the *How to…* section to download your data if you need assistance.

Data Analysis

1. Open the data by clicking on the open file icon. Make sure you know the file name that you used to save your data. Select the file name and click Open.
2. Click on the CO_2 label in the upper right hand corner of the screen to set the Y axis of the graph to CO_2.
3. Press the Statistics Button and make note of the maximum and minimum CO_2 values. Be sure to label these points on your graph.
4. Select the Marker button and put a marker on the CO_2 line at the first place where there is a noticeable change.   A pop up window will tell you the length of time into your data collection and the CO2 level at this point in time. Using your notes, try to correlate the time with what was happening in the classroom
5. Select the Label (Annotate) button **Abc** and a pop up window will come up. Add text telling the time and the CO_2 reading and what was happening at that time. Click OK to close the window.
6. Using your mouse, slide the marker along the CO_2 graph line to the next noticeable change. Using the method in #4, add a label with time, CO_2 level and classroom activity.
7. Repeat steps #3 and #4 every place that there is a noticeable change in the CO_2 levels. Be sure to save your work after you've added the labels.
8. Print out your graph using the Printer button.

Questions and Observations

1. Compare the rise and fall of the CO_2 graph to the temperature and humidity graphs. Do you see any correlation between temperature and humidity and CO2?
2. What kind of activities/events in the room increased the CO_2 level? What made the CO_2 level go down?

Part Two – Learning More

1. Place the Labdisc in the back of the classroom in an area that will not interfere with daily classroom activities. Make sure that there is air circulation around the CO_2 sensor.
2. Press the Select key to start the data collection.
3. Try adding the following activities to the classroom during the second week of collection.
   a. have all the students jog in place for 2 minutes (make note of the day/time)
   b. make note of a time when students are reading or doing an assignment and no one is talking
   c. have everyone sing a song together
   d. open all the windows in the classroom
   e. think of other things that you can do that might make an impact on CO_2 levels

Download Your Data

1. Use the method in Part One to download your data. Be sure to clearly label the data so you will not confuse it with the first data set.

Data Analysis

1. Press the Statistics Button and make note of the maximum and minimum CO_2 values. Be sure to label these points on your graph.
2. Use the methods from Part One to label where key events from Part Two happened. Include information about what was happening, when it happened and what the CO_2 level was.
3. Print out your graph using the Printer button.

Questions and Observations

1. Compare two graphs. What kind of changes in CO_2 levels did that activities that you added create?
2. How easily can you identify the places where you did activity that was out of the regular classroom routine?

Part Three – The Effects of Plants on Classroom CO_2

1. Ask each student to bring a potted plant to school and place them on the window sill
2. Place the Labdisc in the back of the classroom in an area that will not interfere with daily classroom activities. Make sure that there is air circulation around the CO_2 sensor.
3. Press the Select key to start the data collection.
4. Continue to make notes of times when key events/things that might affect CO_2 levels occur. Include:
   a. When the first person enters the classroom in the morning
   b. When did the class arrive in the morning
   c. How many people are in the classroom
   d. When doors or windows are opened
   e. When did the class leave the room
   f. When did the last person leave the room
   g. What is the weather like outside
5. Allow the data collection to run for a week. Do not add any special activities (like singing or exercise) until the 4th day.

Download Your Data

1. Use the method in Part One to download your data. Be sure to clearly label the data so you will not confuse it with the other data sets.

Data Analysis

1. Press the Statistics Button and make note of the maximum and minimum CO_2 values. Be sure to label these points on your graph.
2. Use the methods from Part One to label where key events happened. Include information about what was happening, when it happened and what the CO_2 level was.
3. Print out your graph using the Printer button.

Questions and Observations

1. Compare graphs from the two CO_2 graphs. Describe any differences that you can see from having plants in the classroom?
2. Using what you've just learned, explain why deforestation could contribute to global warming.

Part Four – Burning Fossil Fuels

This next section should be done with adult supervision since it involves open flame. Run this part of the experiment on two different days – first with plants in the room and then on another day without plants in the room.

1. Place the Labdisc in the back of the classroom in an area that will not interfere with daily classroom activities. Make sure that there is air circulation around the CO_2 sensor.
2. Press the Select key to start the data collection.
3. Let students each light a candle for 15 minutes in the classroom.
4. Allow the data collection to continue for at 60 minutes after the candles have been extinguished

Download Your Data

1. Because you are downloading two data collections, select the dropdown arrow next to the download button to choose the Selective Download button (small clock next to download arrow). Select the most recent data collection, download it and label it clearly.
2. Repeat and select the second most recent data collection, download it and label it clearly.

Data Analysis

1. Press the Statistics Button and make note of the maximum and minimum CO_2 values. Be sure to label these points on your graph.
2. Use the methods from Part One to label where key events happened. Include:
    a. When candles were lit
    b. When candles were extinguished.
3. Print out your graphs using the Printer button.

Questions and Observations

Compare the two graphs.
1. What was happening at the point where the CO_2 level is the highest?
2. Where was it the lowest?
3. What effect did plants have on the CO_2 levels…
    a. While the candles were burning?
    b. Immediately after the candles were extinguished?
    c. 5 minutes after the candles were extinguished?
    d. 15 minutes after the candles were extinguished?
    e. 30 minutes after the candles were extinguished?
4. What are some activities that emit CO2 into the Earth's atmosphere?
5. How is CO_2 related to temperatures on Earth?

Decomposers and the Carbon Cycle

Introduction

Vocabulary

Biosphere
The sum total of all life-forms on Earth and the interaction between those life forms.

Hydrocarbons
Molecules composed of only hydrogen and carbon atoms.

Fossil Fuel
A fuel formed over millions of years, from the remains of plants and animals that is burned to produce energy.

Photosynthesis:
Chemical process by which plants use sunlight to manufacture their own food by converting carbon dioxide and water to carbohydrates, releasing oxygen as a by-product

The Carbon Cycle

Carbon (C) is the basis of life on Earth. Scientists say that 99.9% of all organisms on Earth are carbon based life-forms. Whether the carbon is in the form of a sugar or carbon dioxide gas, All of those organisms need carbon to survive. The Earth only has a fixed amount of carbon and so carbon must be continuously cycled and reused.

Since a continual supply of carbon is essential for all living organisms, the carbon cycle is the name given to the different processes that move carbon from one to another. Carbon recycling takes place within Earth's **biosphere** and between living things and the nonliving environment. The complete cycle is made up of "sources" that put carbon back into the environment and "sinks" that absorb and store carbon
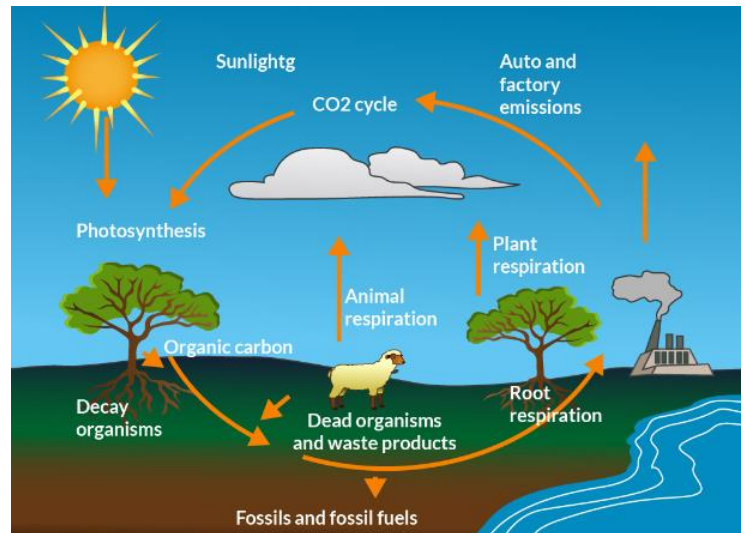
Earth's biosphere can be thought of as a sealed container into which nothing new is ever added except the energy from the Sun. Since new matter is not created, it is essential that living things be able to reuse the existing matter over and over. The carbon cycle is just one of several recycling processes, but it may be the most important process since carbon is a basic building block of life.

Since almost all living things contain the element carbon, it is one of the most abundant elements on Earth. The total amount of carbon on Earth, whether we are able to measure it accurately or not, always remains the same, although the carbon regularly changes its form.

Carbon is found in great quantities in Earth's crust, its surface waters, the atmosphere, and the mass of green plants. It is also found in many different chemical combinations, including carbon dioxide (CO_2), calcium carbonate ($CaCO_3$) and sugar ($C_6H_{12}O_6$), as well as in a huge variety of organic compounds like **hydrocarbons** (**fossil fuels** like coal, petroleum, and natural gas).

Start With Plants

Plants use a process called **photosynthesis** to utilize the Sun's energy to create sugars ($C_6H_{12}O_6$) and O_2 using carbon dioxide from the atmosphere and water. Any organism that is not capable of photosynthesis, uses the oxygen. Through the various food chains, all living organisms use the sugars and starches created by plants.

Animals Eat The Plants

Animals are the non-photosynthetic creatures of the planet. Since they are not able to create their own food, they eat plants or other animals. The sugars and starches they eat are broken

down by a process of metabolism. The results are energy for the creature and water, and carbon dioxide molecules which are returned to the environment. Plants reuse the CO_2 in the photosynthetic process and the cycle begins again.

STEP ONE		STEP TWO		STEP THREE
Plants use carbon (CO_2) from the air, water and energy from sunlight	→	Animals eat plants (sugar for energy) and breath in O_2 and breath out CO_2	→	Plants use CO_2 for photosynthesis Animals and plants die and decompose and carbon is returned to the soil

Decomposers
organisms that live in the soil and water, that feed on the rotting remains of plants and animals, which help return carbon dioxide to the atmosphere by respiration.

Decomposition
The breakdown of complex molecules into simple nutrients that can be reutilized by living organisms.
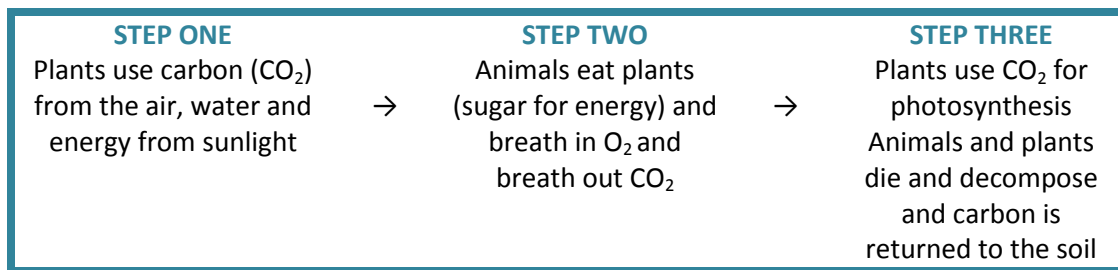
Who Eats The Animals?

There are also **decomposers** involved in the carbon cycle. Decomposers, like microbes and fungi, play an important role in the carbon cycle. They break down the remains of dead plants and animals and, in doing so, release carbon dioxide through respiration. Decomposers play a key role in the carbon cycle and help break down, remove, and recycle what might be called nature's garbage.

One decomposer that plays an important role in the world is yeast. Yeast cells obtain their energy by changing sugar into CO_2 and alcohol. This process is known as fermentation. Yeast is used to produce alcoholic beverages from sugars found in materials like molasses and grains. It is widely used in baking because the CO_2 that it produces causes dough to rise. CO_2 is also used in fire extinguishers because it is heavier than air, will not burn and will not support combustion. The CO_2 replaces the O_2 around the fire and puts out the flame.

Materials

- Labdisc Enviro
- CO_2 sensor
- Sugar
- Baker's Yeast
- Water
- Small drinking glass
- Matches & wooden splint
- Clear plastic box with tight fitting lid – big enough to hold the class and the CO_2 sensor

Objectives:

Students will be able to:

1. Explain the role of decomposers in the carbon cycle.
2. Measure the production of CO_2 by a decomposer.
3. Describe problems that would occur in a world without decomposers

Labdisc Set Up

For this experiment we will setup the Labdisc from the Globilab menu. Use the directions in the *How To....* section if you need assistance in setting up the Labdisc.

- Connect the CO2 sensor to the Labdisc Enviro universal input (the most left sensor).

- If you are using the CO2 or the first time, connect the Labdisc to its AC/DC adapter and allow the CO2 sensor to run for 24 hours, to reach calibration.

  - Select the CO_2 sensor

  - Select 1/minute

  - Select 10,000 samples
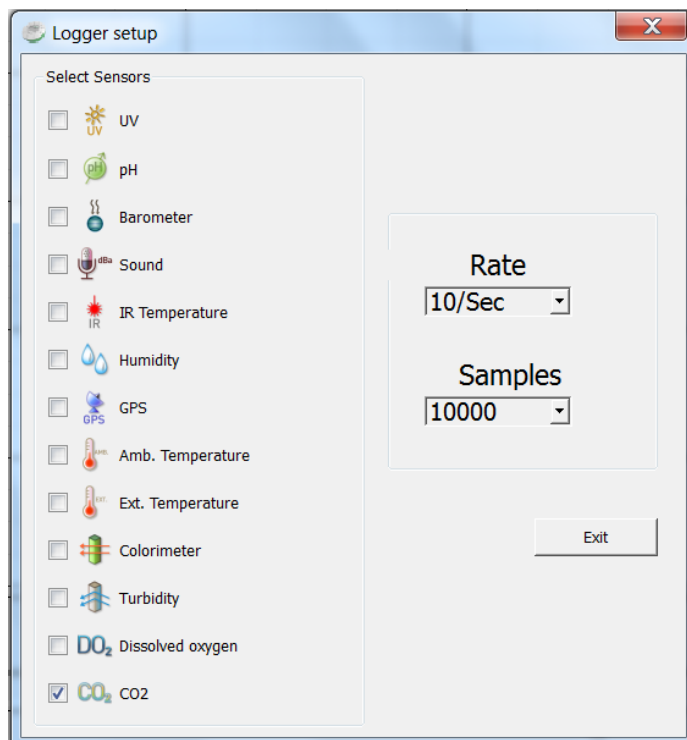
Experiment Procedure

1. Place the CO_2 sensor into the plastic box. You may have to make a small cut in the rim of the box for the cable so that the lid can seal tightly.
2. Fill the drinking glass about ¼ full with warm water.
3. Add 1 packet (about 15ml) of dried yeast and 15 ml of sugar to the water and stir.
4. Place the glass into the box, press the Select key ⏎ to start the data collection and close the lid of the box tightly.
5. Allow the data collection to run for several hours.
6. Open the box and remove the CO_2 sensor. Set the CO_2 sensor aside. Leave your data collection running.
7. Pick up the glass and swirl the liquid in it. Put your ear near the glass. What do you hear? Reseal the box let sit for 10 minutes
8. ***This step should be done by the teacher or an adult.*** Light the splint and remove the lid from the box. Lower the splint into the box and observe what happens.
9. Next exhale onto the CO_2 sensor. Allow the sensor to run until you see that the CO2 level has returned to where it was prior to the experiment.
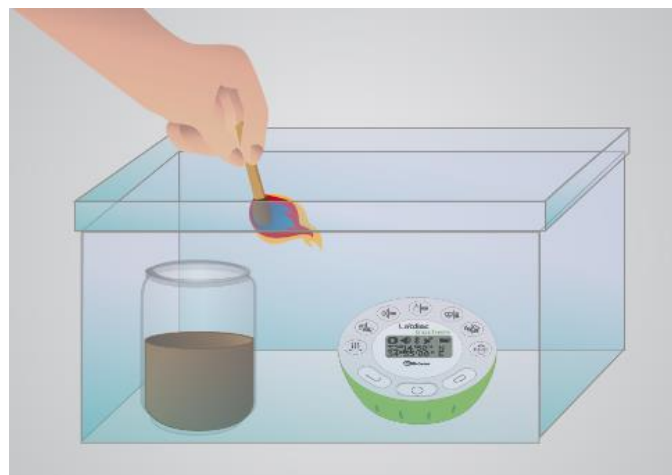
Downloading Your Data

Follow the instructions from the *How to...* section to download your data if you need assistance.

Data Analysis

1. Open the data by clicking on the open file icon. Make sure you know the file name that you used to save your data. Select the file name and click Open.

2. Press the Statistics Button and make note of the maximum and minimum CO_2 values. Be sure to label these points on your graph. Include what was happening at the time of the reading.

3. Select the Marker button and put a marker on the CO_2 line where your experiment started. This will give you a baseline reading of the CO2 level in the box and in the atmosphere.

4. Select the Label (Annotate) button and click above where you've placed the marker. A pop up window will come up. Add text telling the time and the CO_2 reading. Click OK to close the window.

5. Using your mouse, slide the marker along the CO_2 graph line to the highest point, just before you removed the CO2 sensor from the box. Using the method in #4, add a label with time, CO_2 level and what was happening.

6. Slide the marker along the CO_2 graph line to the point where you removed the CO2 sensor from the box. Using the method in #4, add a label with time, CO_2 level and what happened here.

7. Repeat steps #3 and #4 at the point where you exhaled onto the CO2 sensor and at the point where the CO2 level returned to that of the classroom. Be sure to save your work after you've added the labels.

8. Print out your graph using the Printer button.

Questions and Observations

1. When you listened to the glass, what did you hear? What made that noise?
2. Look at your graph of the CO_2 level. Describe what you see. Where did the CO_2 come from?
3. What happed to your graph at the point where you exhaled on the CO_2 sensor? Where did that CO_2 come from? What happed to the graph line in the first minute after you exhaled on the CO_2 sensor? In the third minute? The fifth minute? Why did the CO_2 level change the way that it did? About 4% of the air that you exhale is CO_2, yet only about 0.04% of the air we breathe is CO_2. Where did the CO_2 you measured come from?
4. What are some activities that emit CO_2 into the Earth's atmosphere?
5. How is CO_2 related to temperatures on Earth?