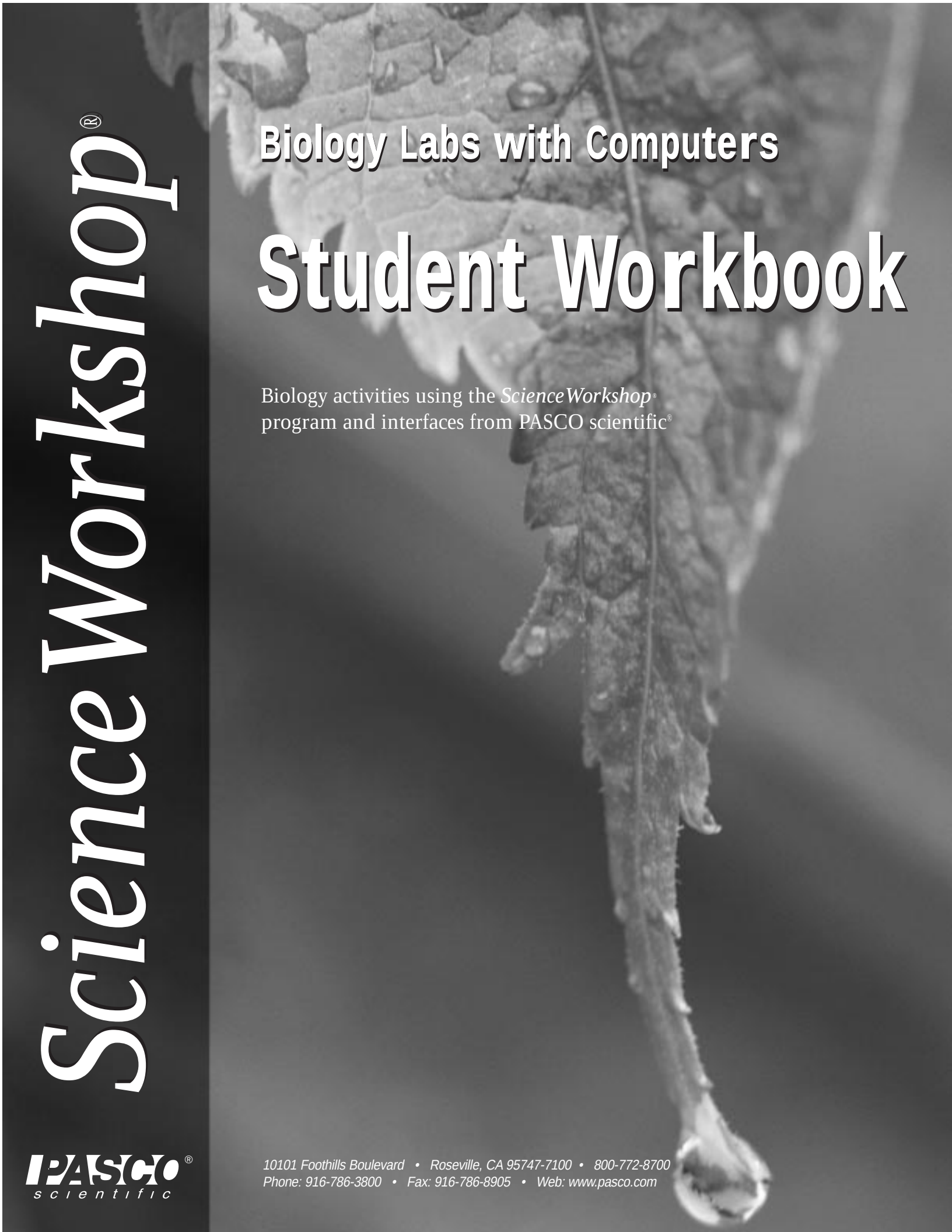


ScienceWorkshop®

Biology Labs with Computers

Student Workbook

Biology activities using the *ScienceWorkshop*® program and interfaces from PASCO scientific®

PASCO® scientific

10101 Foothills Boulevard • Roseville, CA 95747-7100 • 800-772-8700
Phone: 916-786-3800 • Fax: 916-786-8905 • Web: www.pasco.com

Copyright Information

Published by
PASCO scientific
10101 Foothills Boulevard
Roseville, CA 95747-7100
Phone: (916) 786-3800
FAX (916) 786-8905

Biology Labs with Computers Student Workbook
***PASCO* Catalog Number CI-7031B**
PASCO Part Number 012-06635B.
Printed in the United States of America.

Cover designed by Christy Leuzinger.

Edited by David A. Griffith.

Contents

Preface

I. Overview of Biology Labs with Computers Student Workbook (CI-7031)

This manual has eighteen activities in the following areas: biochemistry, cell biology, physiology, and environment. Most of the activities can be done with the sensors that are included in the Biology Bundle: heart rate, pH, pressure, respiration rate, or temperature.

Each activity has the following parts:

Equipment List	Procedure
Purpose (What Do You Think?)	Analyzing the Data
Background	Lab Report
Safety Reminders	

Equipment List

The list includes PASCO equipment (in **bold** font), other equipment, chemicals and consumables, and quantities.

Purpose (What Do You Think?)

The purpose includes a question for you to answer in the Lab Report section.

Background

This section provides information about the concepts in the activity.

Safety Reminders

General safety reminders include following instructions for using the equipment, taking precautions when handling glassware or chemicals, and wearing protective gear (e.g., splash shield or goggles, gloves, and an apron).

Procedure

The procedure is a *basic outline* of how to get started, how to set up equipment, and how to use *DataStudio* or *ScienceWorkshop* to record data. The procedure has four sections:

- Set up the interface.
- Open the *DataStudio* or *ScienceWorkshop* file.
- Set up the equipment.
- Do the experiment (record the data).

Analyzing the Data

This section outlines methods and makes suggestions for using built-in analysis tools in the software to analyze the data.

Lab Report

The Lab Report section is where you can record their your and answer the questions.

II. Safety Reminders

PASCO scientific assumes no responsibility or liability for use of the equipment, materials, or descriptions in this book.

- Take safety precautions to protect yourself during all activities in the lab, and especially during the lab activities in this manual.
- It is not possible to include every safety precaution or warning! Please use extra care when setting up and using equipment, glassware, and especially chemicals.
- In those activities where you use chemicals, be sure to wear protective gear such as a lab coat or apron, gloves, and protective goggles or a splash shield to protect your eyes and face.

SAFETY REMINDERS

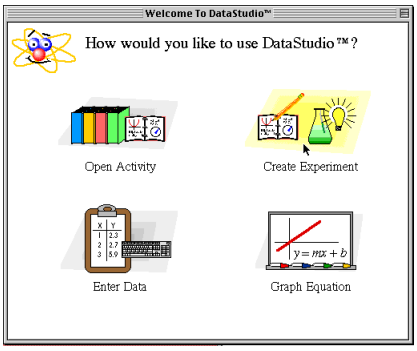
- Wear protective gear.
- Follow directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

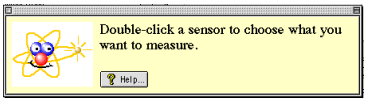
Remember, if you have any questions about safety or about using the equipment, ASK!

Quick Reference Guide for *DataStudio*

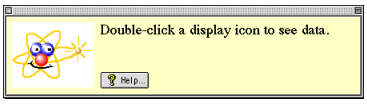
Create an Experiment



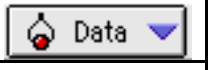
(1) Double-click a sensor.



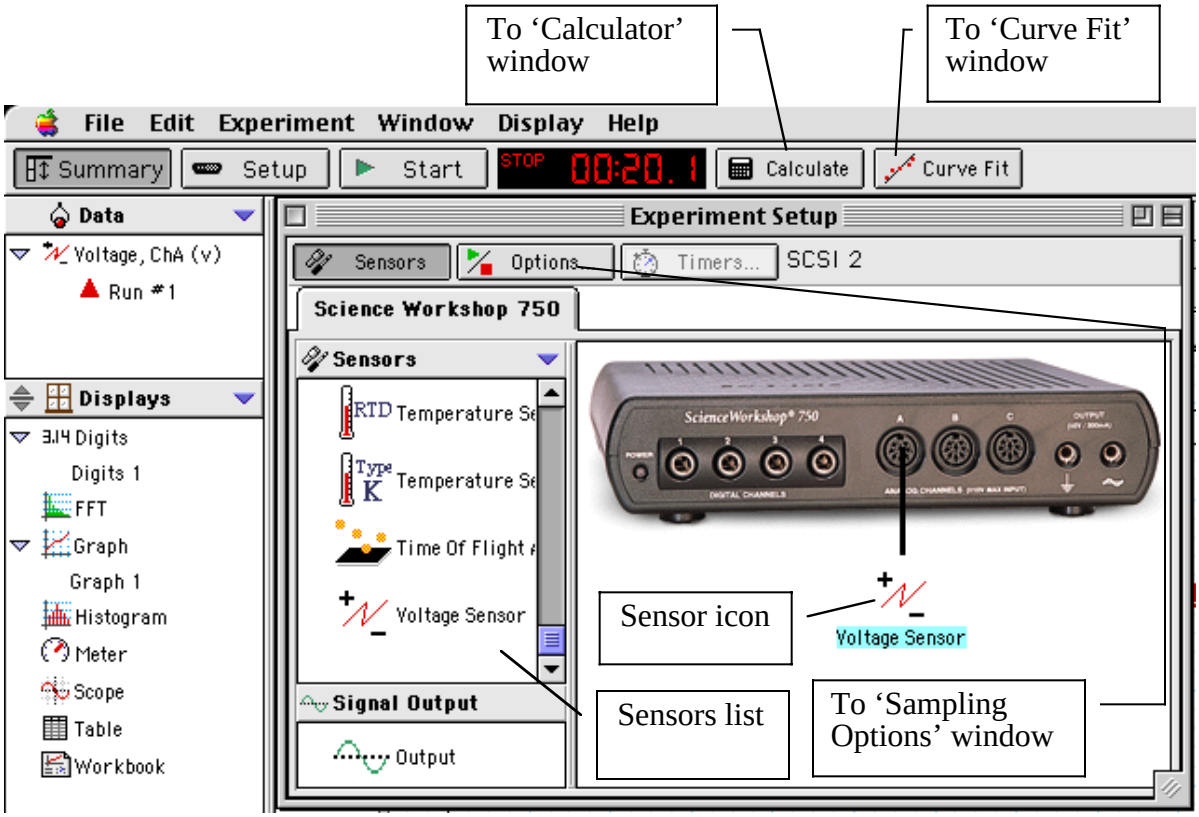
(2) Double-click a display.



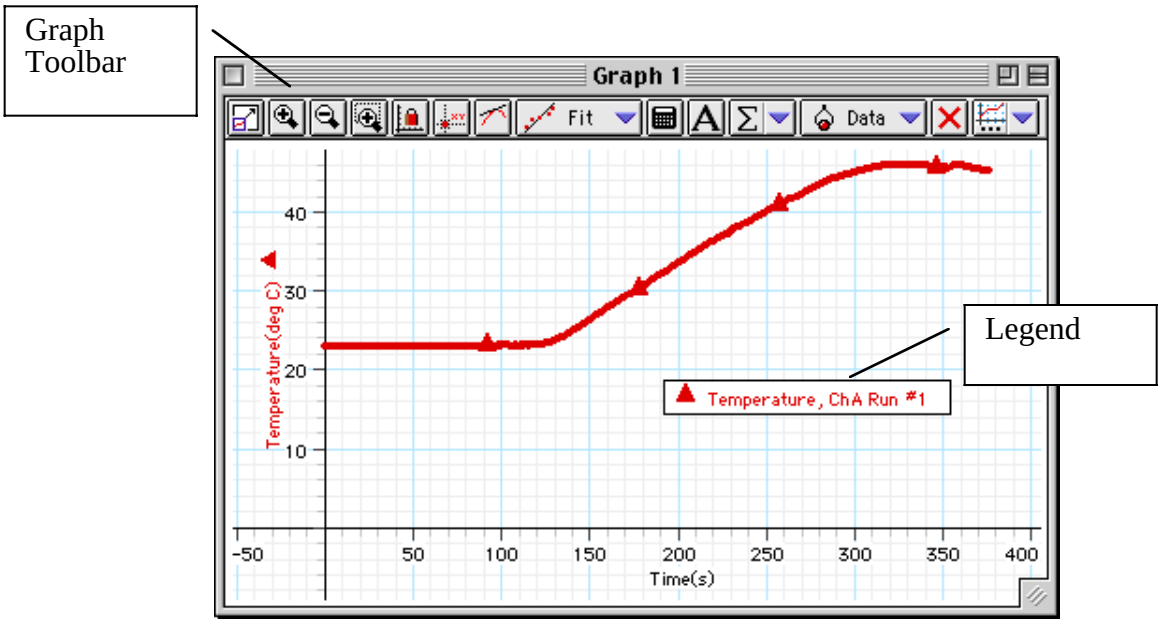
What You Want To Do	How You Do It	Button
Start recording data	Click the 'Start' button or select 'Start Data' on the Experiment menu (or on the keyboard press CTRL - R (Windows) or Command - R (Mac))	
Stop recording (or monitoring) data	Click the 'Stop' button or select 'Stop Data' on the Experiment menu (or on the keyboard press CTRL - . (period) (Win) or Command - . (Mac))	
Start monitoring data	Select 'Monitor Data' on the Experiment menu (or on the keyboard press CTRL - M (Win) or Command - M (Mac))	**none**

On the Graph Display	In the Graph Toolbar	Button
Re-scale the data so it fills the Graph display window	Click the 'Scale to Fit' button.	
Pinpoint the x- and y-coordinate values on the Graph display	Click the 'Smart Tool' button. The coordinates appear next to the 'Smart Tool'.	
'Zoom In' or 'Zoom Out'	Click the 'Zoom In' or 'Zoom Out' buttons.	
Magnify a selected portion of the plotted data	Click the 'Zoom Select' button and drag across the data section be to magnified.	
Create a Calculation	Click the 'Calculate' button	
Add a text note to the Graph	Click the 'Note' button.	
Select from the Statistics menu	Click the Statistics menu button	
Add or remove a data run	Click the 'Add/Remove Data' menu button	
Delete something	Click the 'Delete' button	
Select Graph settings	Click the 'Settings' menu button	

Experiment Setup Window



Graph Display



Instructions – Using the Interface and *DataStudio*

There are several features that make *DataStudio* a unique and powerful teaching tool for science and math. Section #1 covers the mechanics of the interface. Section #2 covers setting up an experiment with the software. Section #3 covers data analysis in more detail.

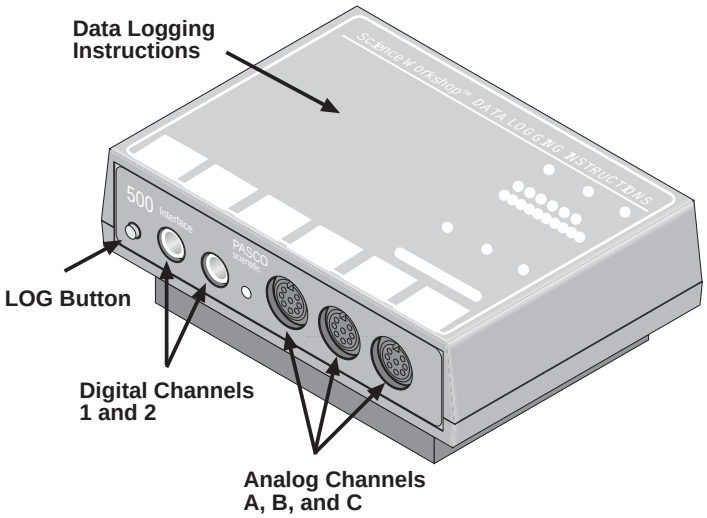
Hint: Working at a computer with *DataStudio* up and running while reading these instructions will bring a "hands-on" experience to the user and enhance the learning process.

Section # 1: ScienceWorkshop 500 Interface

Data Logging with the *ScienceWorkshop* 500 Interface Box

If you want to disconnect the interface box and use it for data logging, be sure to install four AA batteries in the bottom of the interface.

After you have set up an experiment in *DataStudio*, click the 'Logging' button in the Experiment Setup window in the software. Follow the instructions about saving your experiment. Disconnect the interface from the computer and the power supply. (Make sure that the switch on the back of the interface is in the ON position.)



After you have disconnected for logging, use the **LOG button** when you want to record data. Press the Log button once to begin data collection, and press it a second time to end that data run. Repeat this sequence to collect more sets of data points that will be called RUN #2, RUN #3, etc

Caution: In the remote data logging mode, the ON switch at the back of the box must remain on at all times. Loss of power will result in loss of data.

After you have collected data, reconnect the interface to the computer and the power supply.

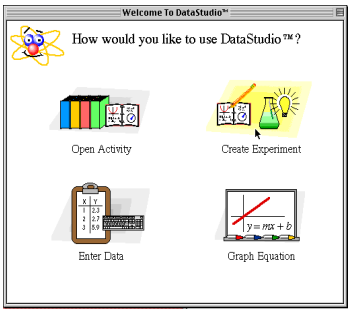
Click the 'Connect' button in the Experiment Setup window in the software. Your data will download automatically.

The **green LED (light-emitting diode)** on the front of the interface box indicates the mode of the interface box. A green light indicates that the power is ON. When you disconnect the interface for remote data logging the light will flash slowly when in the sleep mode and rapidly when you are collecting data. (Refer to the label on the top of the interface for details).
The **Analog Channels** allow up to three analog sensors to be plugged into the *500* interface. You can plug in an analog sensor's DIN plug in only one way. The Starter Bundle includes three analog sensors: Light, Temperature, and Voltage.
The **Digital Channels** allow one or two digital sensors to be plugged into the *500* interface. The Photogate and Motion Sensor are examples of digital sensors. The Starter Bundle does not include a digital sensor.

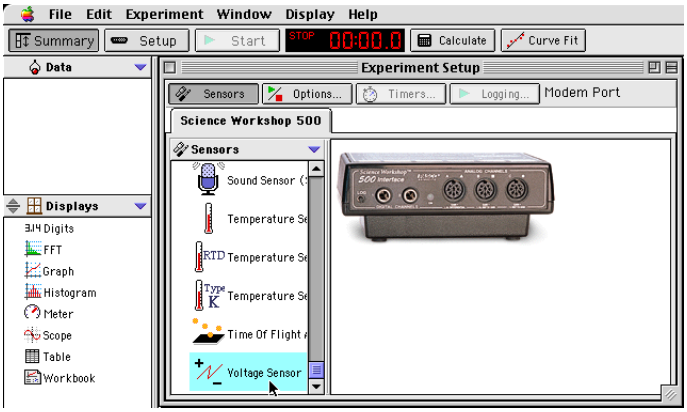
Section #2: Setting Up Your Own Experiment in DataStudio

The Summary List and the Setup Window

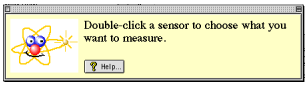
Start *DataStudio*. In the 'Welcome to DataStudio™' window, click 'Create Experiment'.



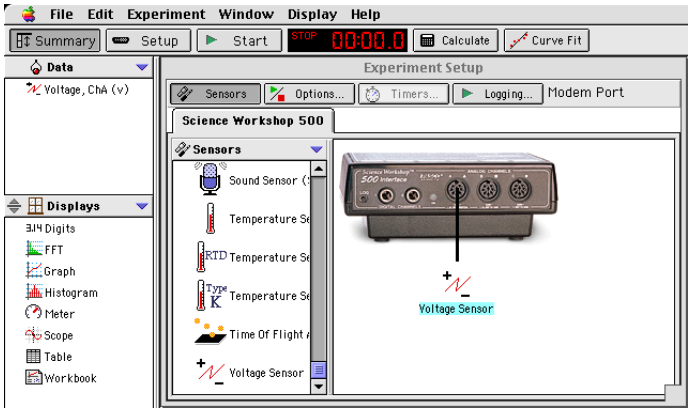
The first step to becoming proficient with *DataStudio* is to understand the Summary List and the Experiment Setup window. The Summary List shows runs of data (under 'Data') and the available displays (under 'Displays'). The Experiment Setup window shows the list of sensors (under 'Sensors') and the interface that is connected.



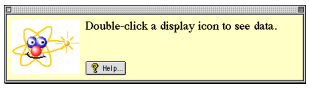
Select a sensor. The sensors are listed by name. Scroll through the list to find the 'Voltage Sensor', and then double-click the sensor to select it.



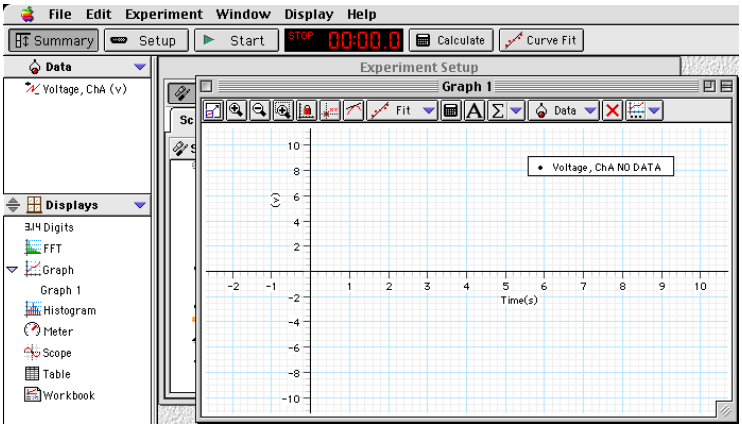
The Voltage Sensor icon appears below Channel A of the interface, and 'Voltage, ChA (v)' appears in the Data list.



Now, select a display. Double-click 'Graph' in the Displays list.



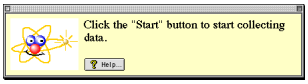
Graph 1 opens, and 'Graph 1' appears in the Displays list. Also, 'Voltage, ChA NO DATA' appears in the Graph's legend.



Finally, click the 'Start' button (

) to begin recording data.

When you are finished, click 'Stop'.



The Menu Bar

The **menu bar** at the top of the Experiment Setup window is very similar to menus bars found in Macintosh® and Windows® programs.

- Use the **File** menu to make a new activity, open an activity, save an activity, save an activity with a specific filename or in a specific location, import data, export data, select options (for saving *to* or opening *from* a particular directory), setup the page for printing, print, or quit.
- Use the **Edit** menu to undo, cut, copy, paste, delete, or select all.
- Use the **Experiment** menu to control the data collection, delete the last data run, disconnect for data logging or re-connect after data logging, set sampling options, open a new empty data table, or add a display.
- Use the **Window** menu to close, minimize, or maximize a window, to tile or cascade windows, or to select a window so it 'pops-to-the-top'.
- Use the **Display** menu to export data or a picture of a display or to activate any of the buttons in a display's toolbar.
- Use the **Help** menu to open the online help files, see the most recent help message, turn on or turn off the tips and confirmation windows, or change the license key.

Features of the Experiment Setup Window

In addition to the Sensors list, the Experiment Setup window has a button to open the 'Sampling Options' window (

), a button to open the 'Timers' window (

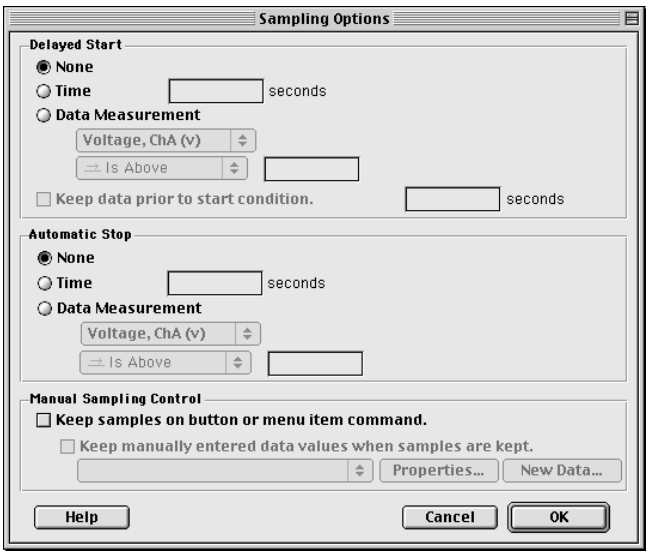
) (for use with Photogates), and a 'Logging' button (

) for use when you disconnect the interface for data logging.

Note: After you click the 'Logging' button, a 'Connect' button (

) appears. If you disconnect for data logging and then re-connect after collecting data, click the 'Connect' button after you re-connect the interface to the computer and power supply.

Use the 'Sampling Options' window to set a 'Delayed Start', an 'Automatic Stop' or to set the 'Manual Sampling Control'.

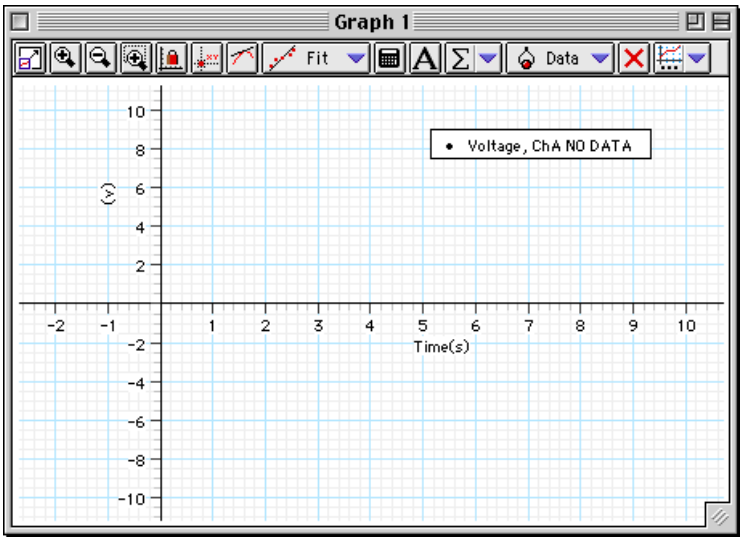


Section #3: Data Analysis

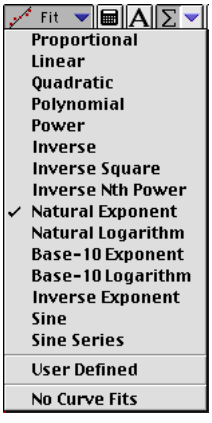
DataStudio offers several ways to analyze data:

- Use the built-in analysis tools in the Graph display toolbar
- Use the 'Calculator' to create calculations based on your measured data or on a range of numbers that you select.
- Use the 'Curve Fit' to compare your data to mathematical models.

In the **Graph display toolbar**, the built-in analysis tools include the 'Smart Tool' button (), the 'Slope Tool' button (), the 'Fit' menu button (), the 'Calculate' button (), and the 'Statistics' menu button ().

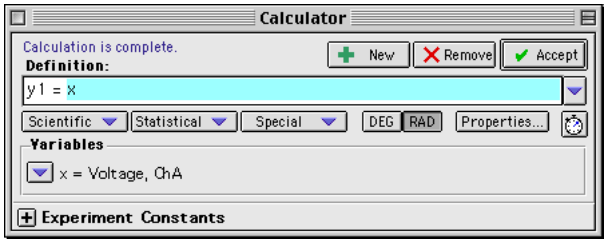


- Use the 'Smart Tool' to see the coordinates of any point.
- Use the 'Slope Tool' to see the slope of a line tangent to a point on a curve.
- Use the 'Fit' menu button to select a mathematical model.
- Use the 'Calculate' button to create a calculation on the data in your Graph.
- Use the 'Statistics' menu button to select basic statistics such as 'Minimum' or 'Maximum' or to find the area under a curve.



Click the ‘Calculate’ button in the main toolbar (

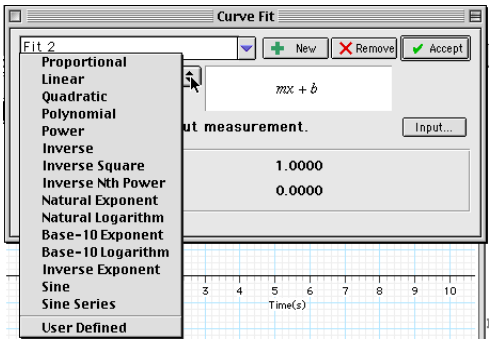
) to open the ‘**Calculator**’ window:



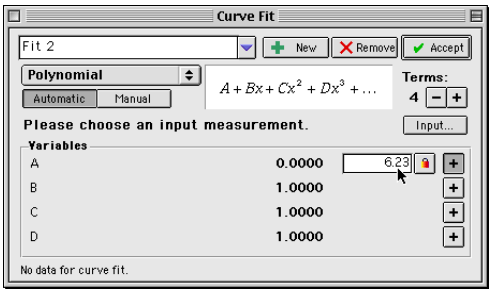
Use the ‘Definition:’ area to create your own calculation, or use the ‘Scientific’, ‘Statistical’, or ‘Special’ menus to select a specific calculation to apply to your data. After you have created the calculation, click ‘Accept’. Your calculation will appear in the Data list. You can drag your calculation to a Graph display, for example

Click the ‘Curve Fit’ button in the main toolbar (

) to open the **‘Curve Fit’** window. Click the ‘New’ button.



Select a mathematical model, or select ‘User Defined’ to create your own.



You can enter values for the coefficients or ‘lock’ a coefficient. After you have created the mathematical model, click ‘Accept’. Your curve fit will appear in the Data list. You can drag your curve fit to a Graph display, for example.

Online Help

Click ‘Contents’ or ‘Search…’ in the Help menu to open the online help file. You can use the online help file to learn about any button, icon, menu, control, function or feature of the program.

Quick Reference Guide for *ScienceWorkshop*

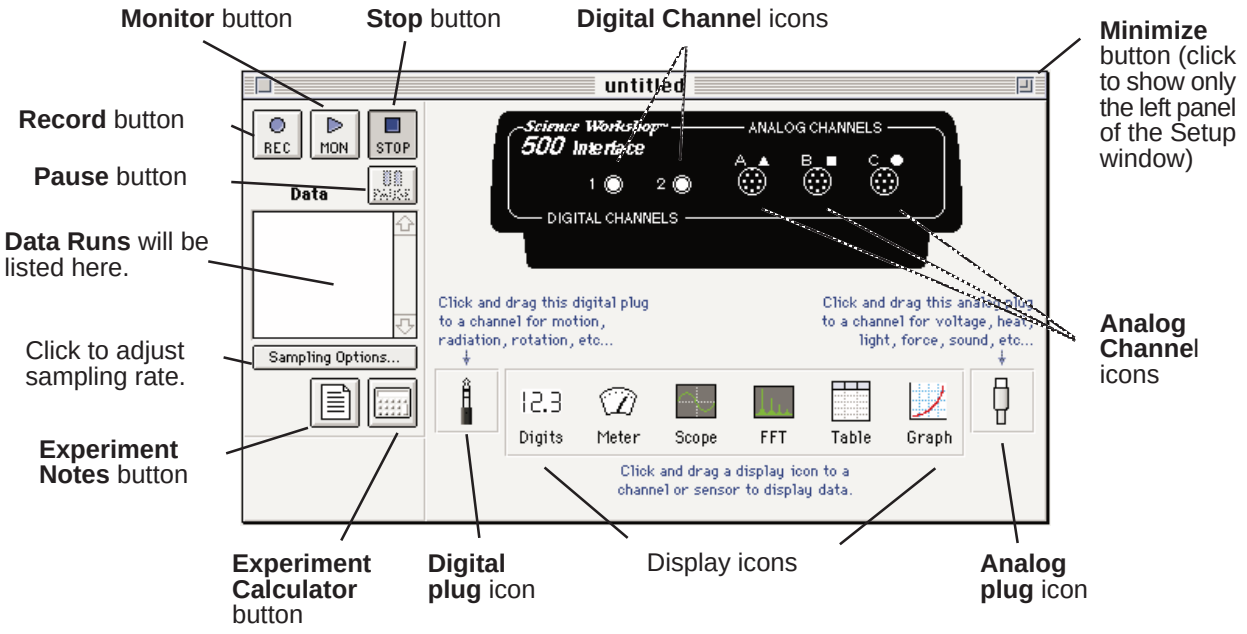
In the Experiment Setup Window:

What You Want To Do To	How You Do It	What the Button Looks Like
Begin recording data	Click the Record (REC) button or select Record on the Experiment menu (or on the keyboard press CTRL - R (Windows) or Command - R (Mac))	
Stop recording (or monitoring) data	Click the Stop (STOP) button or select Stop on the Experiment menu (or on the keyboard press CTRL - . (period) (Win) or Command - . (Mac))	
Begin monitoring data	Click the Monitor (MON) button or select Monitor on the Experiment menu (or on the keyboard press CTRL - M (Win) or Command - M (Mac))	

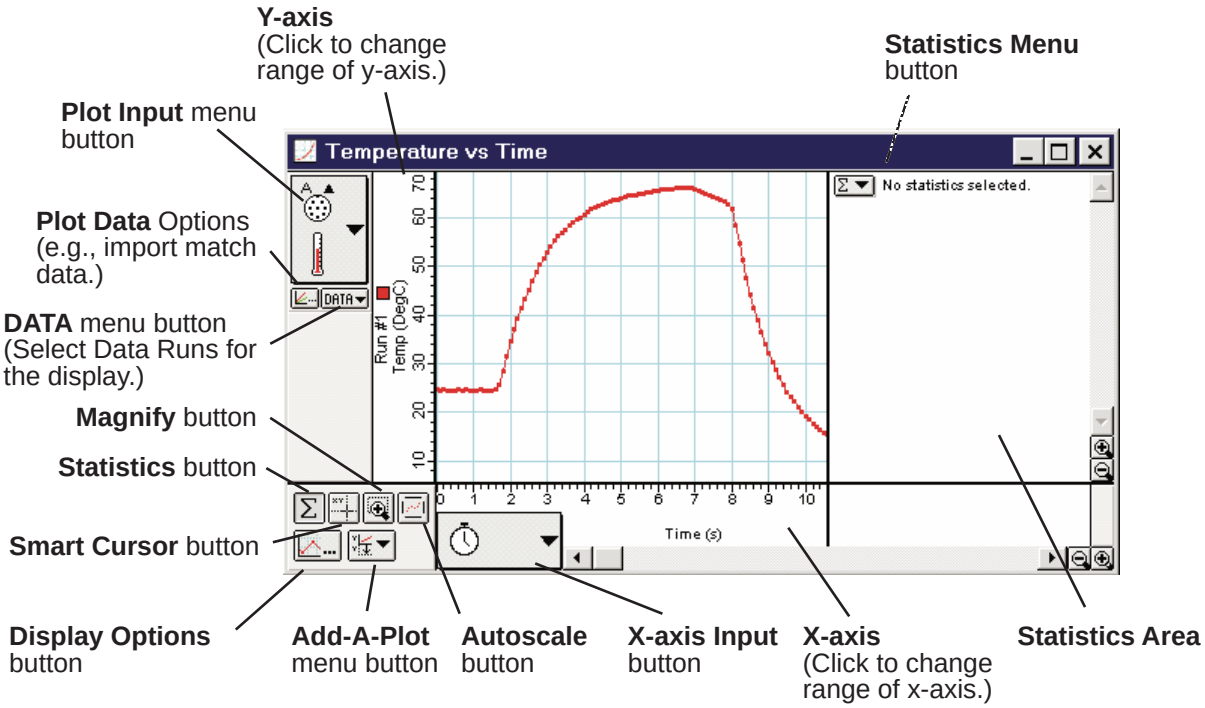
On the Graph Display:

Re-scale the data so it fills the Graph display window	Click the Graph display and click the Autoscale button	
Pinpoint the x- and y-coordinate values on the Graph display	Click the Smart Cursor button and move the cross hairs onto the graph (the exact values for the coordinates will appear next to each axis label)	
Magnify a selected portion of the plotted data	Click the Magnify button, and drag across the data section be to magnified	
Activate the Statistics Menu	Click the Statistics button	
Open the Statistics Menu	Click the Statistics Menu button	
See a list of all your Data Runs	Click the Data button	
Select Data Runs for display	Click the Run # in the Data menu (Shift-click to select more than one run)	
Add another plot to your Graph display	Click the Add-A-Plot button and select the desired input from the pop-up menu	
Import match data and plot it on the Graph display	Copy the match data to the clipboard, click the Plot Data Options button, and click Paste, OK, OK	

Experiment Setup Window



Graph Display



Instructions – Using *ScienceWorkshop®*

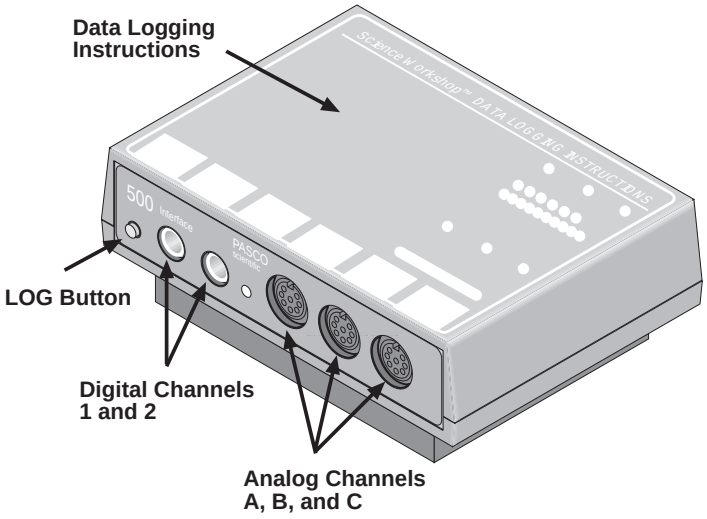
There are several features that make *ScienceWorkshop* a unique and powerful teaching tool for science and math. Section #1 covers the mechanics of the software and hardware. Section #2 covers the data analysis tools in more detail.

Hint: Working at a computer with *ScienceWorkshop* up and running while reading these instructions will bring a "hands-on" experience to the user and enhance the learning process. You should keep the *Quick Reference Guide for ScienceWorkshop* available as a reference.

Section # 1: Experiment Setup

The *ScienceWorkshop* 500 Interface Box

Use the **LOG button** when you want to disconnect the interface from the computer and take it into the field for data collection. Press it once to begin data collection, and press it a second time to end that data run. Repeat this sequence to collect more sets of data points that will be called RUN #2, RUN #3, etc. If you want to disconnect the interface box from the power supply, be sure to install four AA batteries in the bottom of the interface. (Make sure that the switch on the back of the interface is in the ON position.)



Caution: In the remote data logging mode, the ON switch at the back of the box must remain on at all times. Loss of power will result in loss of data.

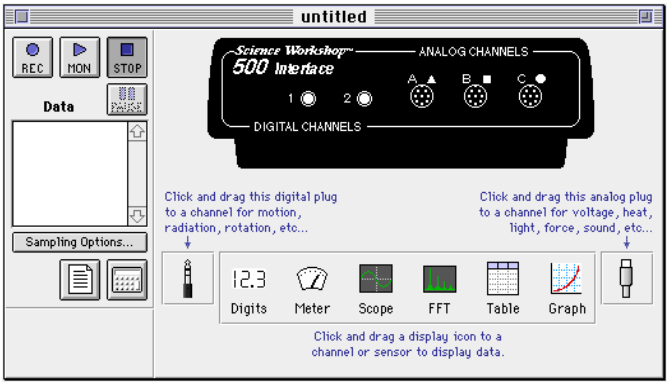
The **green LED (light-emitting diode)** on the front of the interface box indicates the mode of the interface box. A green light indicates that the power is ON. When you disconnect the interface for remote data logging the light will flash slowly when in the sleep mode and rapidly when you are collecting data. (Refer to the label on the top of the interface for details).

The **Analog Channels** allow up to three analog sensors to be plugged into the *500* interface. You can plug in an analog sensor's DIN plug in only one way. The Starter Bundle includes three analog sensors: Light, Temperature, and Voltage.

The **Digital Channels** allow one or two digital sensors to be plugged into the *500* interface. The Photogate and Motion Sensor are examples of digital sensors. The Starter Bundle does not include a digital sensor.

The Experiment Setup Window

The first step to becoming proficient with *ScienceWorkshop* is to understand the various icon and buttons in the **Experiment Setup** window. The window is automatically displayed whenever a new *ScienceWorkshop* file is opened. If you get a "Can't find interface box" message, the interface is either missing or not properly connected. Be sure that the power to the interface box is ON and that the connector cables are secure.



The Menu Bar File Edit Experiment Display

The **menu bar** at the top of the Experiment Setup window is very similar to menus bars found in Macintosh® and Windows® programs.

- Use the **File** menu to open, close, save, print, and import data.
- Use the **Edit** menu to copy, cut, clear, and paste data or runs of data.
- Use the **Experiment** menu to control the data collection.

  You can also use the Experiment menu to **Record**, **Monitor**, **Pause,** or **Stop** data collection (as if you had used the buttons in the Experiment Setup window). You can use this menu to access the sampling options, disconnect/connect (for remote data logging), display the Experiment Setup window, or go to the Experiment Notes and Calculator windows.
- Use the **Display** menu to select any of the six display windows (either to set up a new display or toggle to a display already in use).

Features of the Experiment Setup Window

The **Record button** is in the top left corner of the Experiment Setup window. Press this button to collect data and store the data in memory. The flashing bar below the button shows when *ScienceWorkshop* is collecting data.

The **Monitor Data button** is next to the **Record** button. Press this button to collect and display data in a *view* mode only. None of the data are saved in memory. For example, use this feature when you want to check to see if a sensor is working properly, and also when viewing data in the Scope display.

Press the **Stop button** to stop data collection in both the record and monitor modes.

Press the **Pause button** to temporarily interrupt data collection. Press it again when you want to continue collecting data.

Sampling Options... Press the **Sampling Option button** to open a window where you can select the Periodic Samples rate, the Start and Stop Conditions, and Keyboard Sampling. The default Periodic Samples rate is 10 samples per second (10 Hz) for an analog sensor and 10,000 samples per second for a digital sensor. You can vary the Periodic Samples rate from 20,000 Hz (Fast) to 3600 seconds (Slow).

Suggested Periodic Sampling rates for common measurements:

Temperature Sensor	2 – 10 Hz
Light Sensor	10 Hz
Voltage Sensor	10 Hz

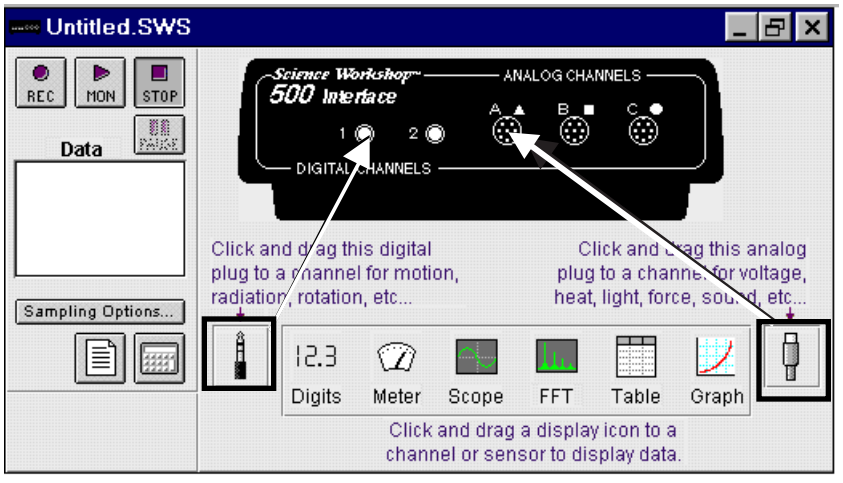
Press the **Experiment Calculator button** to open the Experiment Calculator window that allows you to do mathematical operations on collected data. You can also use it as a stand-alone calculator.

Drag the **digital plug icon** to Digital Channel 1 or 2 to add a digital sensor to the Experiment Setup window, and then select the correct digital sensor from the list of sensors that opens. Click **OK** to return to the Experiment Setup window.

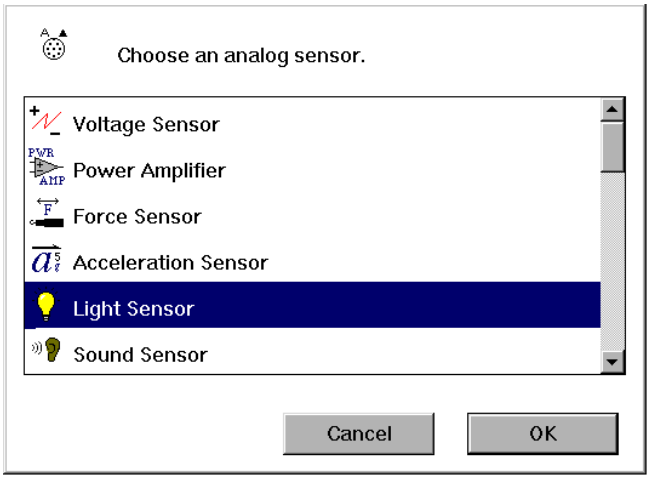
Drag the **analog plug icon** to Analog Channel A, B, or C to add an analog sensor to the Experiment Setup window. Then select the correct analog sensor from the list of sensors than opens. Click **OK** to return to the Experiment Setup window.

Setting Up Your Own Experiment in *ScienceWorkshop*

1. Drag an **analog plug icon** or a **digital plug icon** to the icon that corresponds to the channel on the *500* Interface box that you plugged the sensor into.

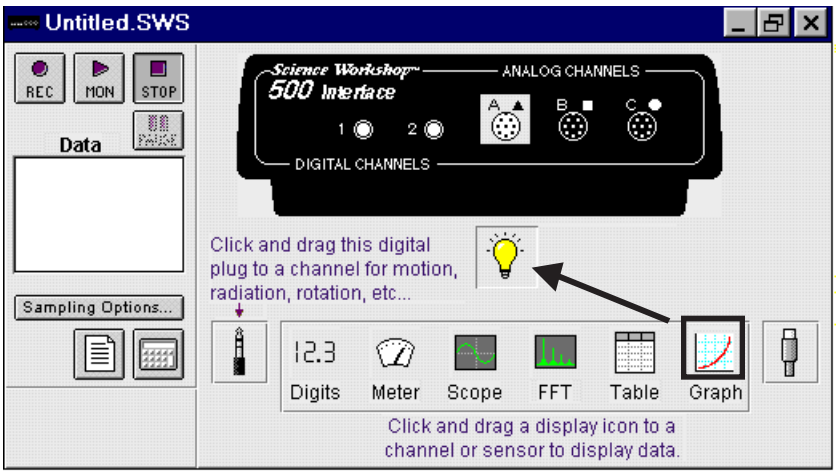


2. Choose the sensor from the sensor list that pops up. Click **OK** to return to the Experiment Setup window.



3. Drag a display icon to the Sensor icon.

You are ready to collect data!



Note: *ScienceWorkshop* has many advanced features. Refer to the *ScienceWorkshop* User's Guide that came with the interface for more information.

Section #2: Data Analysis

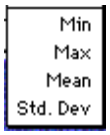
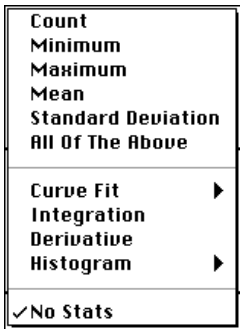
Analysis: The Smart Cursor 

The Smart Cursor allows you to investigate individual points on a graph.

Procedure: Click the **Smart Cursor** in any display that has the Smart Cursor icon (for example, the Graph display). The cursor changes to a cross hair and the y and x values for that individual position will be displayed on the y-axis and x-axis. If you desire to have the change in y or x coordinates displayed, click-and-drag the Smart Cursor over the desired area. The difference (y2 - y1 and x2 - x1) will be displayed on the y-axis and x-axis. (This ability to display the change in x and the change in y in a selected area is called the delta feature.)

The Statistics Tool 

The Table and Graph displays have built-in statistics. Click the S**tatistics button** to open the statistics area at the bottom of a Table or on the right side of a Graph.

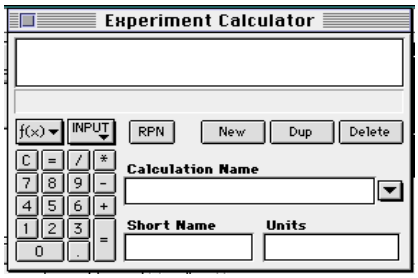
Statistics menu for a Table display	
In the Graph display, click the Statistics Menu button to see the statistics options.	
Statistics menu for a Graph display	
Curve Fit submenu	
Linear Fit will generate a basic slope equation with the slope of the best-fit line being the **a 2** value in the display.	

The Experiment Calculator

Use the **Experiment Calculator** feature of *ScienceWorkshop* to create a new calculation that is based on the input data. For example, if data is displayed in degrees Celsius, you can use the calculator to create a calculation to display the temperature data in degrees Fahrenheit or degrees Kelvin.

To set up a calculation, click the **Calculator button**  in the Experiment Setup window. You can also open the Experiment Calculator by selecting **Calculator Window** from the **Experiment** menu.

Experiment Calculator window



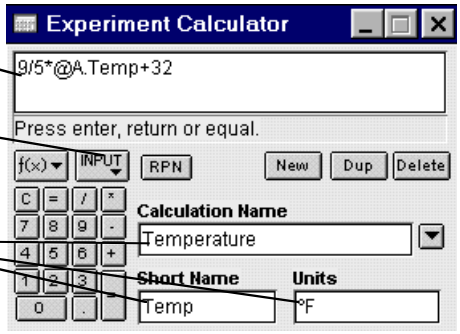
Example:
Converting the temperature data from degrees Celsius to degrees Fahrenheit for plotting on the Graph display.

1. Type the formula here

(Select the variable to be modified from the Input Menu)

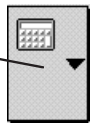
2. Fill in these dialog boxes

3. Click **=** or press ENTER



Changing the plotting parameters of the Graph display

4. On the Graph display, click the **Plot Input Menu** button, and select **Calculations, Temperature, (Temp ˚F)**



(Temperature will be plotted in ºF)

Note: The values for this calculation can also be displayed in any Table, Digits, or Meter display. To do this, select **Calculations, Temperature, (Temp ˚F)** from the **Input** menu of the display.

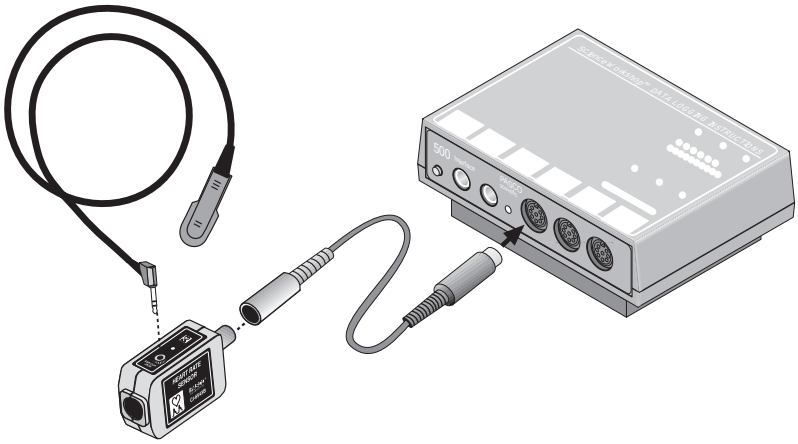
Tutorial Activities – Exploration of Sensors

Practice using the five sensors included in the Biology Bundle.

- Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.

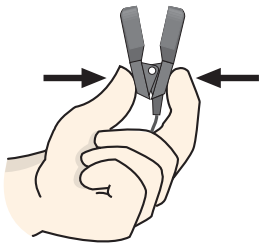
Heart Rate Sensor

The Heart Rate Sensor monitors the flow of blood through a part of the body, such as an ear lobe, by shining a light through it. The intensity of the light passing through the ear lobe depends on the amount of blood flowing through the blood vessels in the ear lobe. As the heart contracts and relaxes, the amount of blood flowing through the ear lobe changes and the light intensity transmitted through the ear lobe changes.



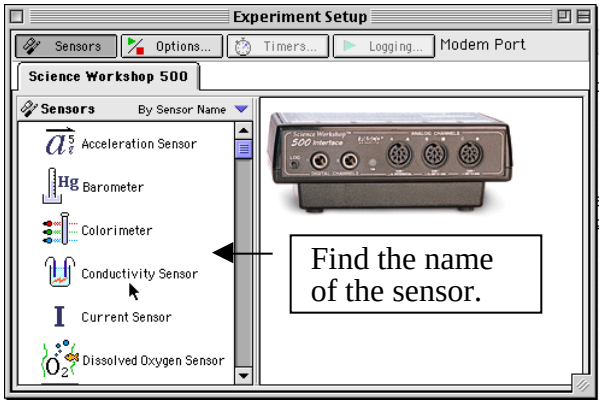
1. Set up the sensor.

- Plug the DIN connector cable into the sensor's DIN plug and then connect the cable into **Analog Channel A** on the interface.
- Connect the ear clip plug into the top of the sensor.
- Pinch the sides of the ear clip so it opens.
- Place the open ear clip on your ear lobe and release the sides of the clip.



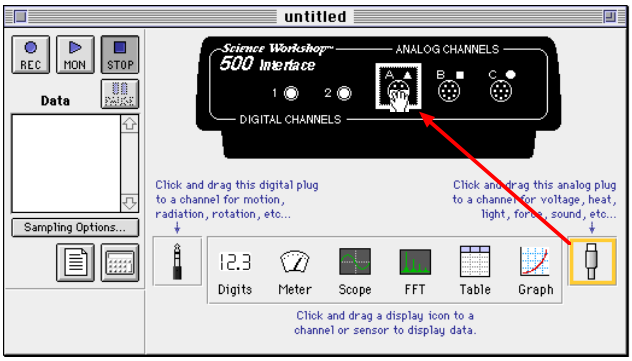
2. Set up the sensor in the software.

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window.

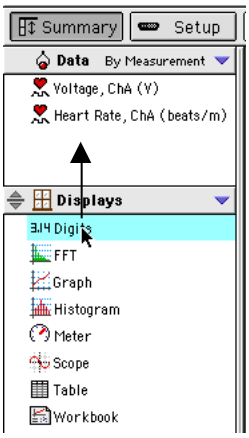


- The sensor icon will appear below Channel A of the interface. The sensor's parameters (e.g., Voltage, Heart Rate, etc.) will appear in the Data list.

- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. The sensor's icon will appear below Channel A of the interface.



3. Set up a Digits display of 'Heart Rate'.



- In *DataStudio*, click-and-drag the 'Digits' icon from the Displays list and drop it on 'Heart Rate' in the Data list.
- In *ScienceWorkshop*, click-and-drag the 'Digits' display icon to the sensor's icon in the Experiment Setup window.

4. Start recording data.

- In *DataStudio*, click the 'Start' button (

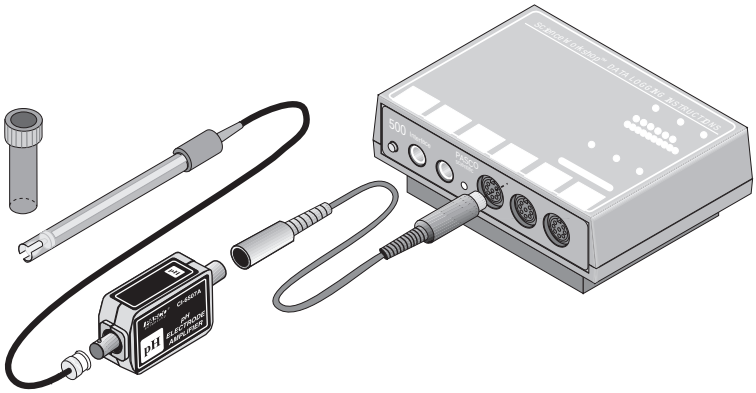
). In *ScienceWorkshop*, click the 'REC' button (

).
- Note the heart rate in the Digits display.

5. Stop recording data. (Click 'Stop' to end data recording.)

pH Sensor

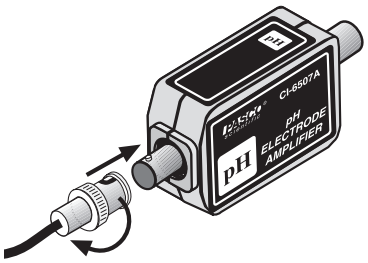
The pH Sensor has an amplifier and a pH electrode. The electrode produces a voltage that is proportional to the hydrogen ion concentration in a solution. (Store the electrode in its soaker bottle when you are not using it.) The amplifier converts the electrode voltages into the voltages required by the *ScienceWorkshop* interface.



For this activity you will need a cup or beaker, some cranberry juice (or other fruit juice), and an antacid tablet (e.g., Alka-Seltzer®). Fill the cup about half full with juice. Break the antacid tablet in half.

1. Set up the sensor.

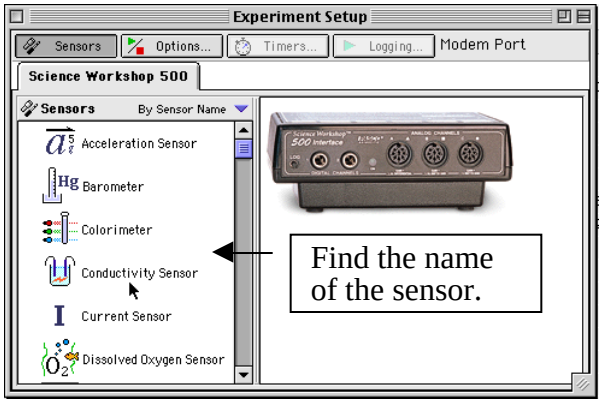
- Plug the DIN connector cable into the sensor's DIN plug and then connect the cable into **Analog Channel A** on the interface.



- Connect the pH electrode to the BNC port on the pH Sensor. Line up the connector on the end of the cable with the pin on the BNC port. Push the connector onto the port and then twist the connector clockwise about one-quarter turn until it clicks into place.
- Put the end of the pH electrode into the juice.

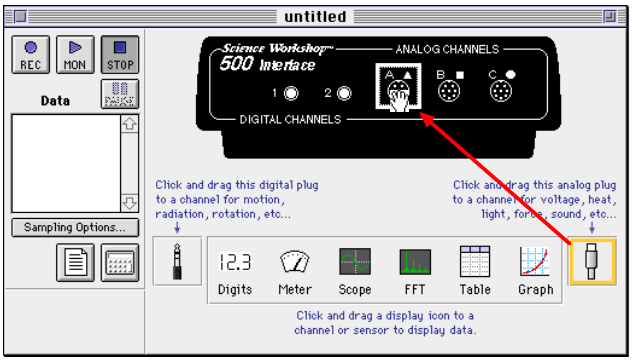
2. Set up the sensor in the software.

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window.

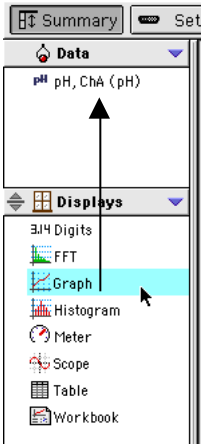


- The sensor icon will appear below Channel A of the interface. The sensor's parameters (e.g., pH, Voltage, etc.) will appear in the Data list.

- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. The sensor's icon will appear below Channel A of the interface.



3. Set up a Graph display of pH versus Time.



- In *DataStudio*, click-and-drag the 'Graph' icon from the Displays list and drop it on 'pH' in the Data list.
- In *ScienceWorkshop*, click-and-drag the 'Graph' display icon to the sensor's icon in the Experiment Setup window. Select 'pH (pH)' and click 'Display.

4. Start recording data.

- Put half of an antacid tablet into the fruit juice and stir with the end of the pH electrode.
- In *DataStudio*, click the 'Start' button (

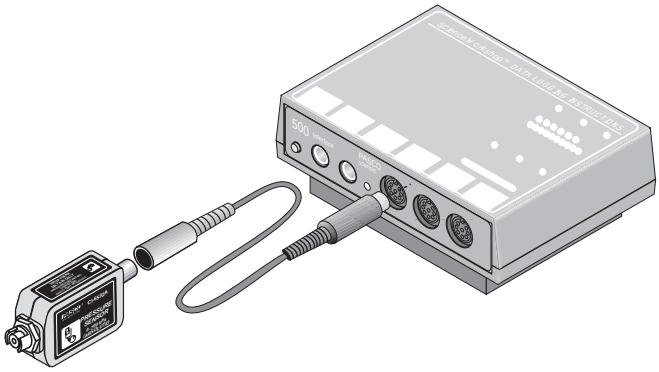
). In *ScienceWorkshop*, click the 'REC' button (

).
- Note the change in pH in the Graph display.

5. After two minutes, stop recording data. (Click 'Stop' to end data recording.)

Pressure Sensor

The Pressure Sensor includes a cable, a syringe, tubing, and connectors for the tubing.

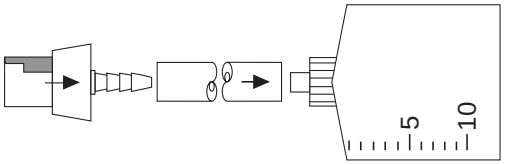


The sensor can measure pressures as high as 700 kilopascals, or about seven atmospheres. It is designed for non-corrosive gases. Do not put liquids into the sensor.

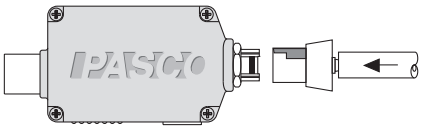
For this activity you will need two drops of glycerin, the syringe, a short piece of tubing, and a quick-release connector.

1. Set up the sensor.

- Plug the DIN connector cable into the sensor's DIN plug and then connect the cable into **Analog Channel A** on the interface.
- Prepare the syringe. Cut a short piece of tubing (about 2 cm). Put a drop of glycerin on the barb end of a quick-release connector. Put the barb end of the connector into one end of the tubing. Put a drop of glycerin on the tip of the syringe. Put the tip of the syringe into the other end of the tubing. Pull out the piston so it is at about the 10 cc mark.

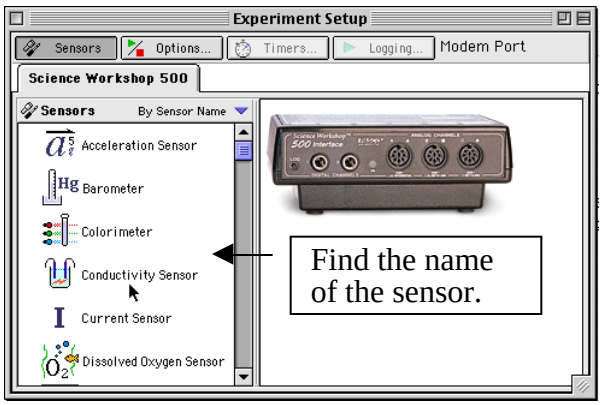


- Connect the syringe to the sensor. Line up the quick-release connector with the pressure port on the sensor. Push the connector onto the port and turn the connector clockwise until it clicks.



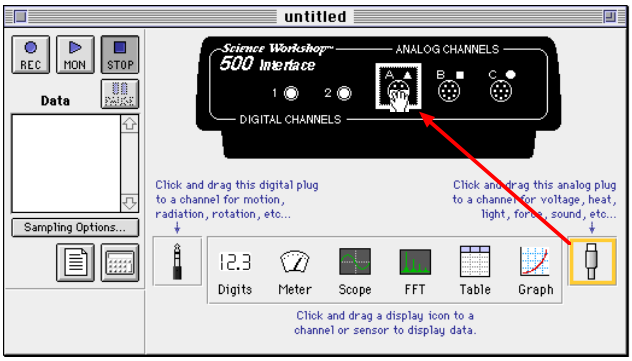
2. Set up the sensor in the software.

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window.

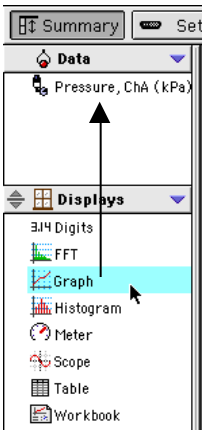


- The sensor icon will appear below Channel A of the interface. The sensor's parameters (e.g., Pressure) will appear in the Data list.

- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. The sensor's icon will appear below Channel A of the interface.



3. Set up a Graph display of Pressure versus Time.



- In *DataStudio*, click-and-drag the 'Graph' icon from the Displays list and drop it on 'Pressure' in the Data list.
- In *ScienceWorkshop*, click-and-drag the 'Graph' display icon to the sensor's icon in the Experiment Setup window.

4. Start recording data.

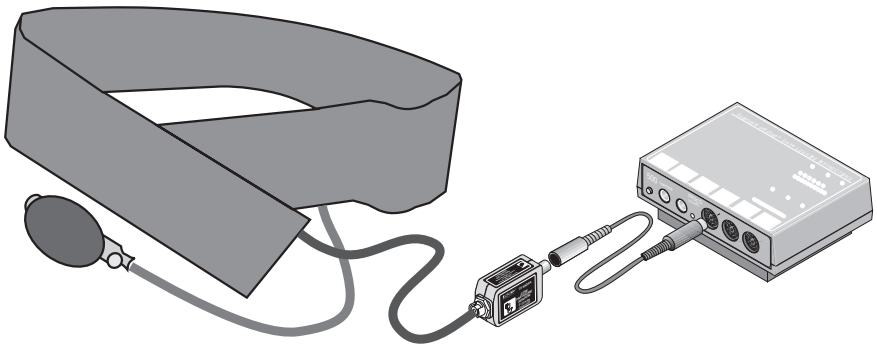
- In *DataStudio*, click the 'Start' button (

). In *ScienceWorkshop*, click the 'REC' button (

).
- After a few seconds, push the piston in so it is at the 5 cc mark. Then pull the piston out so it is at the 20 cc mark.
- Note the change in pressure in the Graph display.

5. Stop recording data. (Click 'Stop' to end data recording.)

Respiration Rate Sensor



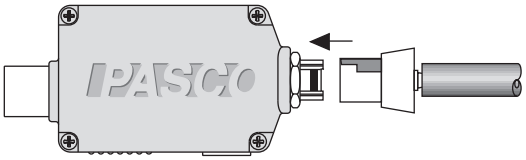
The Respiration Rate Sensor is two sensors in one. This sensor consists of the Low Pressure Sensor and a Respiration Belt. The Low Pressure Sensor includes a cable, a syringe, tubing, and connectors for the tubing.

The sensor can measure pressures as high as 10 kilopascals or about 0.1 atmospheres. It is designed for non-corrosive gases. Do not put liquids into the sensor.

The Respiration Belt attaches to the pressure port on the sensor. The belt has a squeeze bulb for inflating the rubber bladder. Use the hook-and-pile (Velcro®) strips on the ends of the belt to fasten the belt around your chest.

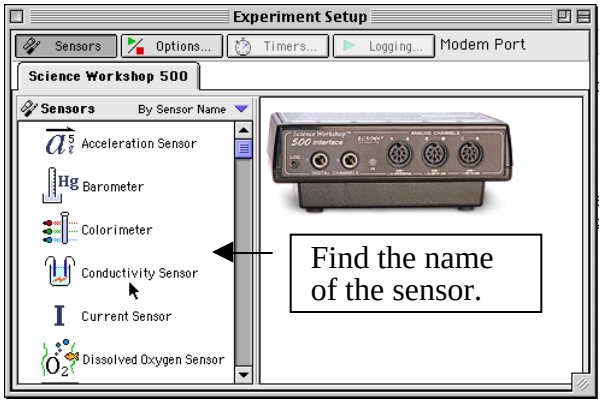
1. Set up the sensor.

- Plug the DIN connector cable into the sensor's DIN plug and then connect the cable into **Analog Channel A** on the interface.
- Put on the Respiration Belt. (See the sensor's Instruction Sheet for more information.)
- Connect the belt to the sensor. Line up the quick-release connector on the end of the tube with the pressure port on the sensor. Push the connector onto the port and turn the connector clockwise until it clicks.



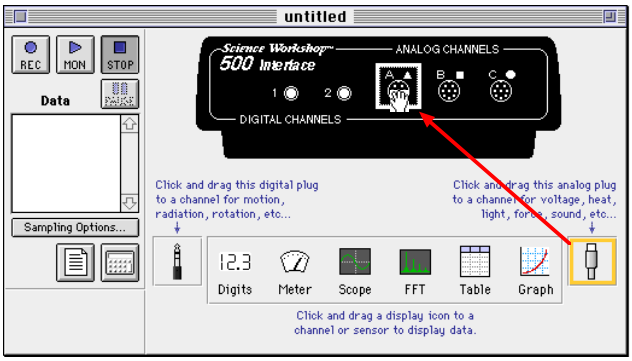
2. Set up the sensor in the software.

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window.

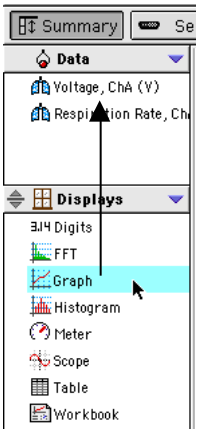


- The sensor icon will appear below Channel A of the interface. The sensor's parameters (e.g., Voltage, Respiration Rate) will appear in the Data list.

- In *ScienceWorkshop*, click-and-drag the ‘analog sensor plug’ icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click ‘OK’ to return to the Experiment Setup window. The sensor’s icon will appear below Channel A of the interface.



3. Set up a Graph display of Voltage versus Time.



- In *DataStudio*, click-and-drag the ‘Graph’ icon from the Displays list and drop it on ‘Voltage’ in the Data list.
- In *ScienceWorkshop*, click-and-drag the ‘Graph’ display icon to the sensor’s icon in the Experiment Setup window. Select ‘Voltage’ and click ‘Display.

4. Start recording data.

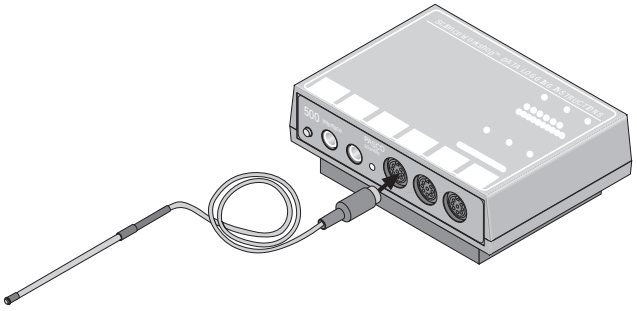
- Inflate the Respiration Belt. Turn the knurled knob fully clockwise to close the valve. Squeeze the bulb to inflate the belt until it is snug on your chest.
- In *DataStudio*, click the ‘Start’ button (

). In *ScienceWorkshop*, click the ‘REC’ button (

).
- Breath deeply several times. Note the change in voltage in the Graph display. Try holding your breath for a few moments and note what happens in the Graph display.

5. Stop recording data. (Click ‘Stop’ to end data recording.)

Temperature Sensor



The Temperature Sensor has a temperature sensitive integrated circuit in its tip that produces a voltage that is proportional to temperature. The sensor is covered with Teflon® tubing that is very chemical resistant. The sensor includes a removable Teflon sensor cover that is highly chemical resistant.

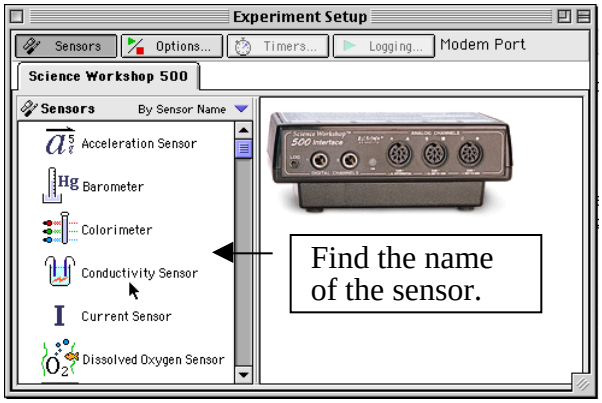
The sensor's operating range is from –5 ˚C to 105 ˚C. Do not use the sensor in a direct flame or on a hot plate.

1. Set up the sensor.

- Plug the sensor's DIN plug into **Analog Channel A** on the interface.

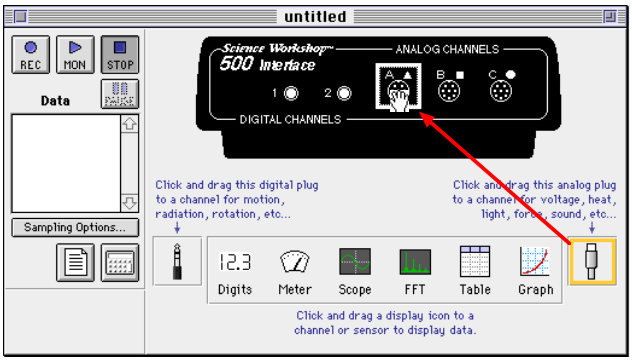
2. Set up the sensor in the software.

- In *DataStudio*, double-click the name of the sensor in the Sensors list in the Experiment Setup window.

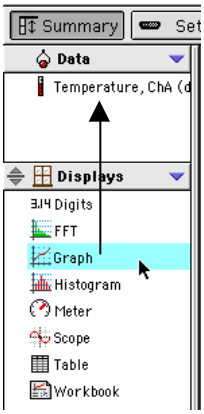


- The sensor icon will appear below Channel A of the interface. The sensor's parameters (e.g., Temperature) will appear in the Data list.

- In *ScienceWorkshop*, click-and-drag the 'analog sensor plug' icon to the Channel A icon in the Experiment Setup window, select the name of the sensor from the list of sensors and click 'OK' to return to the Experiment Setup window. The sensor's icon will appear below Channel A of the interface.



3. Set up a Graph display of Temperature versus Time.



- In *DataStudio*, click-and-drag the 'Graph' icon from the Displays list and drop it on 'Temperature' in the Data list.
- In *ScienceWorkshop*, click-and-drag the 'Graph' display icon to the sensor's icon in the Experiment Setup window.

4. Start recording data.

- In *DataStudio*, click the 'Start' button (

). In *ScienceWorkshop*, click the 'REC' button (

).
- Measure the temperature of your hand. Place the tip of the sensor in the palm of your hand and wait several seconds. Note the temperature in the Graph display. Then move the tip of the sensor from the palm along one of your fingers to the end of the finger. Notice the change in temperature as you move the sensor.
- Measure the temperature of your face. Move the sensor to the end of your nose. Slowly move the tip of the sensor along your face to your cheek, your chin, and your forehead. Note the change in temperature.

5. Stop recording data. (Click 'Stop' to end data recording.)

Remember to Use the Online Help

In *DataStudio*, click 'Contents' or 'Search…' in the Help menu to open the online help file. You can use the online help file to learn about any button, icon, menu, control, function or feature of the program.

In *ScienceWorkshop* for Macintosh, click 'Show Balloons' in the Help menu.

Name _____ Class _____ Date _____

Activity B01: Energy Content of Foods (Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Biochemistry	B01 Food Energy.DS	B02 Food Energy	B02_FOOD.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Temperature Sensor (CI-6505A)	1	Slit stopper	1
Balance (SE-8723)	1	Stirring rod	2
Base and Support Rod (ME-9355)	1	Protective gear	PS
Container (metal can), small	1	**Chemicals and Consumables**	**Qty**
Clamp, Buret (SE-9446)	1	Food samples	2
Food holder	1	Matches	2
Graduated cylinder, 100 mL	1	Water	100 mL
Ring, 4 inch	1	Wood splint	2

Imagine the Following

A sports team at your school needs to find out what kind of 'snack food' can give them the most energy. The team has asked you for help. Can you measure the amount of energy in a sample of food?

What Do You Think?

All human activity requires "burning" food for energy. When samples of different kinds of food are burned, which of the food samples will produce the most energy?

- **Marshmallow? Peanut? Cashew? Popcorn?**
- **How will you compare one food sample to another?**
- **Does the amount of the food sample make a difference?**
- **Does the time that the food takes to burn make a difference?**

Take time to write answers to these questions in the Lab Report section.

Background

When burning food heats a known quantity of water, the amount of heat given off by the food is theoretically equal to the amount of heat gained by the water. The following is an equation that describes this idea:

$$\boldsymbol{Q = m \times c \times \Delta T}$$

where $\boldsymbol{Q}$ is the amount of heat, $\boldsymbol{m}$ is the mass of the water, $\boldsymbol{c}$ is the *specific* heat of the water, and $\boldsymbol{\Delta T}$ is the change in temperature of the water.

The specific heat of water is:

$$\mathbf{c = 1\frac{calorie}{gram^{\circ}C} = 4.18\frac{joule}{gram^{\circ}C}}$$

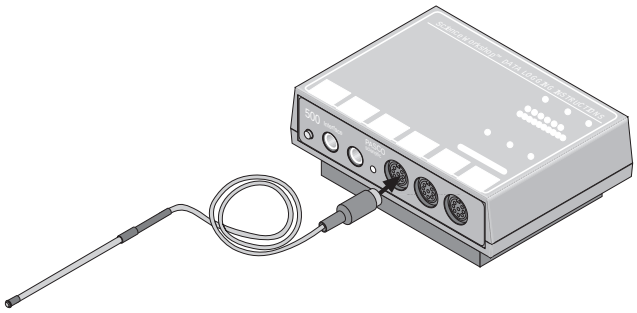
SAFETY REMINDERS	
• Follow directions carefully when using the equipment for this activity. • Take care when using matches and wooden splints. • Wear protective gear (e.g., goggles, gloves, apron).	THINK SAFETY ACT SAFELY BE SAFE!

For You To Do

In this activity, burn a sample of food under a container of water to heat the water. Use a Temperature Sensor to measure the change in temperature of the water as it is heated by the burning food. Use *DataStudio* or *ScienceWorkshop* to record and analyze the data.

Compare the amount of heat given off by one type of food to the amount of heat given off by a different type of food.

PART I: Computer Setup



1. Connect the interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Temperature Sensor into Analog Channel A of the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B01 Food Energy.DS	B02 Food Energy	B02_FOOD.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* file has a Digits display, a Graph display, and a Table display of Temperature versus Time.

Name _____ Class _____ Date _____

PART II: Sensor Calibration and Equipment Setup

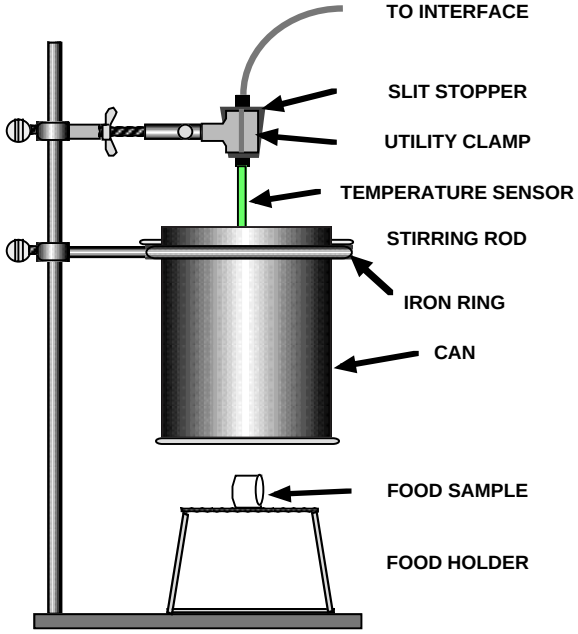
You do not need to calibrate the Temperature Sensor.

1. Set up the equipment as shown.
2. Put the bottom of the container about 2.5 cm above the food holder.

Do you need to measure the amount of water that will be heated?

Do you need to record the type of food being tested?

Do you need to measure the initial mass of the food sample that will be burned?



PART IIIA: Data Recording

1. Start recording data.
2. Light the wooden splint with a match and use the splint to light your food sample. Quickly place the burning food sample directly under the center of the container. Leave the sample under the container until the food sample stops burning.

CAUTION: Keep hair, clothing, and other items away from open flames.

3. Leave the sensor in the water for at least 45 seconds after the food has stopped burning. Stir the water until the temperature stops rising. *Stop* recording data when the temperature stops rising.

Do you need to measure the final mass of the remains of the burned food sample?

4. Repeat the data recording process for the second food sample. Use a new quantity of cold water.

What measurements do you need to record?

Analyze the Data

1. Use your recorded data to find the *change* in temperature of the water heated by the first food sample.

What measurements do you need to record?

2. Repeat the analysis for the second run of data.

3. Calculate the heat absorbed by the water, ***Q,*** for each food sample. Remember the equation:

$$Q = m \times c \times \Delta T$$

For water, the specific heat "*c*" is 4.18 J/g°C.

How would you convert the heat absorbed from *joules* to *kilojoules* (kJ)?

4. Determine the mass of the food that burned.

5. Calculate the *energy content*, or *ratio* of heat (in kilojoules) divided by the mass of burned food (in grams), for each food sample.

How do your results compare with others in your class?

Record your results in the Lab Report section.

Name _____ Class _____ Date _____

Lab Report - Activity B01: Energy Content of Foods

What Do You Think?

All human activity requires "burning" food for energy. When samples of different kinds of food are burned, which of the food samples will produce the most energy?

Data Table

Item	Sample 1 _____	Sample 2 _____	Sample 3 _____	Sample 4 _____
mass of empty container	g	g	g	g
mass of container + water	g	g	g	g
mass of water	g	g	g	g
initial mass, sample + holder	g	g	g	g
final mass, sample + holder	g	g	g	g
change of mass, food sample	g	g	g	g
initial temperature	C	C	C	C
final temperature	C	C	C	C
temperature change, ΔT	C	C	C	C
heat, Q	kJ	kJ	kJ	kJ
energy content	kJ/g	kJ/g	kJ/g	kJ/g

Class Results Table: Average Energy Content for each food type:

Food Type	Marshmallows	Peanuts	Cashews	Popcorn
Energy content	kJ/g	kJ/g	kJ/g	kJ/g

Questions

1. Which food had the highest energy content?

2. Which food had the lowest energy content?

3. Food energy is expressed in a unit called a *Calorie*. There are 4.18 kilojoules (or 4180 joules) in one Calorie. Based on the class average for peanuts, calculate the number of Calories in a 50-gram package of peanuts.

4. Two of the foods in the activity have a high *fat* content (peanuts and cashews) and two have a high *carbohydrate* content (marshmallows and popcorn). From your results, what can you conclude about the relative energy content of *fats* and *carbohydrates*?

5. What advice would you give to a sports team about the energy content of these foods?

6. Do you think that *all* of the energy released by the burning food sample was absorbed by the water?

   Why or why not?

7. What are some things you would do to change the procedure in this activity?

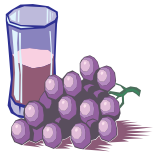
Name _____ Class _____ Date _____

Activity B02: Fermentation in Grape Juice (Pressure Sensor – Absolute, Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
cellular respiration	B02 Fermentation. DS	B03 Glycolysis	B03_GLYC.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Pressure Sensor – Abs. (CI-6532)	1	Stopper, one hole, for flask	1
Temperature Sensor (CI-6505)	1	**Tubing (w/ sensor)**	
Balance (SE-8723)	1	Protective gear	PS
Beaker, 250 mL	1	**Chemicals and Consumables**	**Qty**
Connector (640-030)	1	Glycerin	1 mL
Flask, 250 mL	1	Grape juice	300 mL
Graduated cylinder	1	Sodium fluoride, solid	1 g
Hot plate	1	Weighing paper	1
Magnetic stirrer & spin bar	1	Yeast suspension	20 mL

What Do You Think?

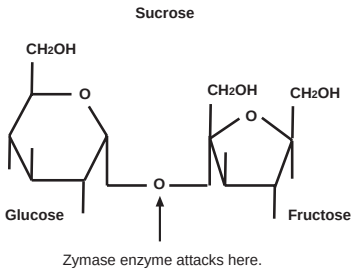


How does the pressure inside a closed vessel change as yeast converts the sucrose in grape juice into ethanol and carbon dioxide?

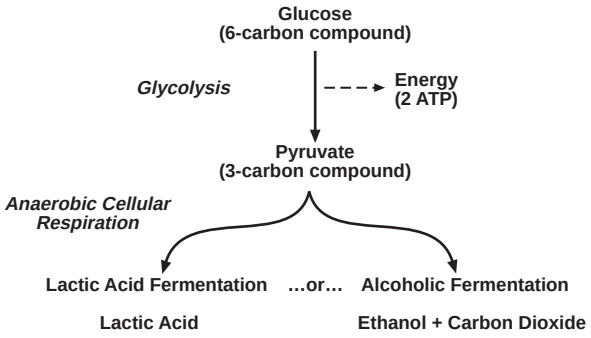
What factors can alter the rate of the fermentation of grape juice and what changes would you expect to see as you apply those factors?

Take time to write answers to these questions in the Lab Report section.

Background



All life forms need to convert or transform energy-rich organic molecules like sugars into forms of energy that can be used to perform cell work. Cellular respiration is the set of chemical reactions during which molecules are broken down to release energy. There are two types of cellular respiration – aerobic and anaerobic – and both begin with glycolysis. Prior to glycolysis, the **zymase** enzyme breaks a molecule of sucrose into glucose and fructose. During glycolysis, the glucose breaks down into pyruvic acid. Animal cells and some unicellular organisms convert the pyruvic acid to lactic acid (lactic acid fermentation). Some plant cells and unicellular organisms convert the pyruvic acid to ethanol and carbon dioxide gas (alcoholic fermentation). In this activity, the yeast cells use fermentation to transform the sugars in grape juice into useful energy and carbon dioxide.



As in most biological reactions, cellular respiration is controlled by a series of enzymes (such as zymase). The enzymes that help this system of chemical events are often sensitive to physical and chemical conditions such as temperature and pH.

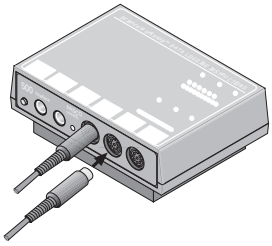
SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the Pressure Sensor to measure the change in pressure in a flask containing a mixture of activated yeast and grape juice. Then repeat the measurement for a mixture of activated yeast, grape juice, and a small amount of a chemical – sodium fluoride. Use *DataStudio* or *ScienceWorkshop* to record and display the data. Use the software to analyze the data.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Pressure Sensor DIN plug into Analog Channel A on the interface.
3. Connect the Temperature Sensor DIN plug into Analog Channel B on the interface.
4. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B02 Fermentation. DS	B03 Glycolysis	B03_GLYC.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* file has a Graph display of Pressure versus Time.
- Data recording for the Pressure Sensor is set at 1 measurement per five seconds.

NOTE: In the *DataStudio* file, data recording for the Temperature Sensor is set at 2 measurements per second (or 2 Hz). See the Appendix for instructions about how to set up the *ScienceWorkshop* file to measure temperature.

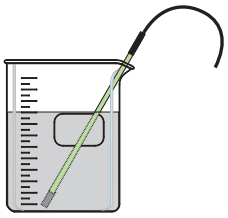
Name _____ Class _____ Date _____

PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

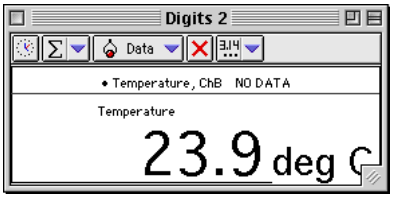
- **You do not need to calibrate the Pressure Sensor for this activity since you will measure the change in pressure.**

Prepare the Grape Juice



1. Put 150 mL of grape juice in a beaker. Place the beaker on a hot plate. Place the Temperature Sensor in the grape juice.
2. Turn on the hot plate. Warm the juice to a temperature of 35˚ Celsius. Use the software to monitor the temperature of the grape juice.

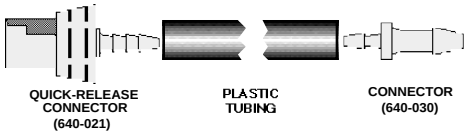
- Hint: In *DataStudio*, click 'Monitor' in the Experiment menu. In *ScienceWorkshop*, click the MON button. Watch the temperature in the Digits display.



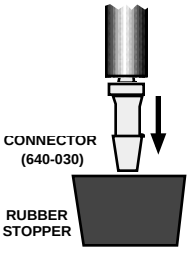
- Do not warm the grape juice above 40°C. The yeast will begin to die at around 42°C. The optimum temperature for the yeast is around 35°C.

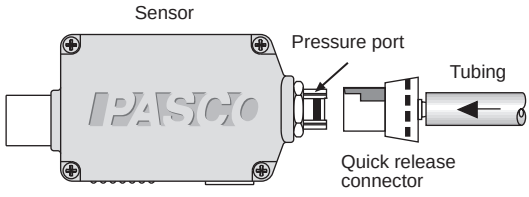
Set Up the Equipment

3. Put a drop of glycerin on the barb end of the quick-release connector and insert the barb into one end of the plastic tubing.
4. Put a drop of glycerin on the smaller diameter end of the connector that will go into the rubber stopper. Insert the small diameter end into the plastic tubing.



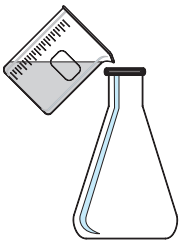
5. Put a drop of glycerin on the larger diameter end of the connector that will go into the rubber stopper, and insert the end into the rubber stopper.
6. Align the quick-release connector on the end of the plastic tubing with the connector on the pressure port of the pressure sensor. Push the connector onto the port, and then turn the connector clockwise until it clicks (about one-eighth turn).

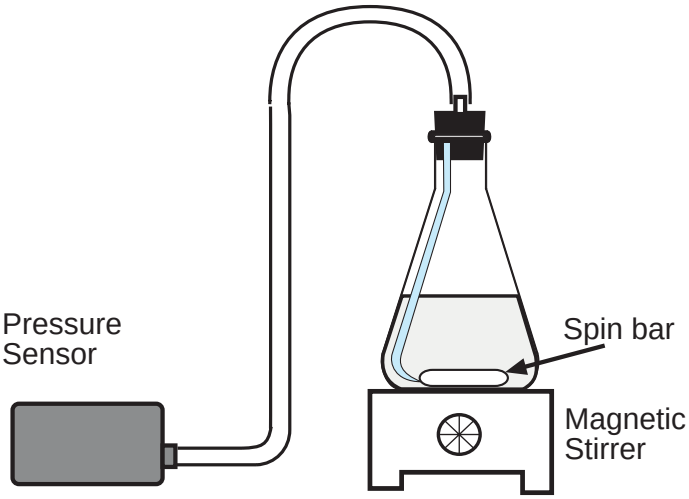




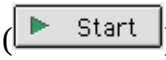
Part IIIA: Data Recording – Graph Juice and Yeast Suspension

1. Remove the Temperature Sensor from the beaker. In the software, stop monitoring the temperature of the grape juice.
2. Transfer the warmed grape juice to the flask. Add a spin bar to the flask.
3. Gently add 10 mL of yeast suspension to the juice. (Remember, the yeast are alive!)
4. Stopper the flask with the rubber stopper. Use a twisting motion to get a tight fit. Place the flask on the magnetic stirrer. Turn on the stirrer and adjust to a moderately fast stirring rate.





5. Start recording data.

- Hint: In *DataStudio*, click the 'Start' button (

). In *ScienceWorkshop*, click the 'REC' button (

).
- What happens to the pressure in the flask? What do you think the yeast are doing to the grape juice that causes this effect?

- At first, there will be little if any change in pressure. After about 5-10 minutes the pressure will begin to measurably increase and continue to increase throughout the experiment. The yeast is breaking down the sucrose to other metabolic products, including CO_2.

6. Allow the yeast to metabolize the grape juice for about 40 minutes and then stop recording data.

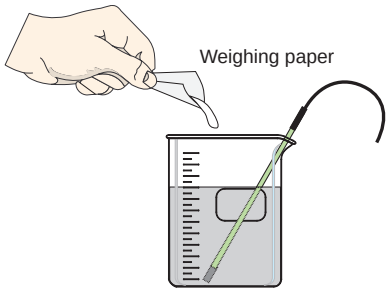
- **Be sure you have stopped recording before you carefully remove the stopper from the flask.**

7. Dispose of the grape juice/yeast mixture as instructed.

Name _____ Class _____ Date _____

Part IIIB: Data Recording – Grape Juice, Yeast Suspension and Sodium Fluoride

Prepare the Grape Juice and Sodium Fluoride



1. Put 150 mL of grape juice in a beaker. Add 1.0 g of sodium fluoride to the grape juice.
2. Place the beaker on a hot plate. Place the Temperature Sensor in the grape juice.
3. Turn on the hot plate. Warm the juice to a temperature of 35˚ Celsius. Use the software to monitor the temperature of the grape juice.

- Hint: In *DataStudio*, click 'Monitor' in the Experiment menu. In *ScienceWorkshop*, click the MON button. Watch the temperature in the Digits display.

- Do not warm the grape juice above 40°C. The yeast will begin to die at around 42°C. The optimum temperature for the yeast is around 35°C.

Record Data

1. Remove the Temperature Sensor from the beaker. In the software, stop monitoring the temperature of the grape juice.
2. Transfer the warmed grape juice/sodium fluoride mixture to the flask. Add a spin bar to the flask.
3. Gently add 10 mL of yeast suspension to the juice. (Remember, the yeast are alive!)
4. Stopper the flask with the rubber stopper. Use a twisting motion to get a tight fit. Place the flask on the magnetic stirrer. Turn on the stirrer and adjust to a moderately fast stirring rate.
5. Start recording data.

- What happens to the pressure in the flask?

6. Allow the yeast to metabolize the grape juice for about 40 minutes and then stop recording data.

- **Be sure you have stopped recording before you carefully remove the stopper from the flask.**

7. Dispose of the grape juice/yeast mixture as instructed.

Optional

- Variations to this activity can be performed by different lab teams and the results can be shared and analyzed by the entire class.

1. Vary the pH Level: Vary the pH level in the yeast/juice mixture by adding 25 mL of any of the following buffer solutions to 125 mL of grape juice: (a) pH buffer 2, (b) pH buffer 3, (c) pH buffer 4, and (d) pH buffer 6. (e) pH buffer 10
2. Vary the Yeast Concentration: Vary the amount of yeast by mixing and using suspensions of 100 mL of water and (a) 1 g, (b) 3 g, (c) 6 g, (d) 12 g, or (e) 20 g of dry yeast.

Analyzing the Data:

1. Set up your Graph display so it shows your data.
2. Use the Graph display's built-in statistics to determine the Ending Pressure, the Starting Pressure, the Ending Time and the Starting Time for the first run of data.

- Hint: In *DataStudio*, click the 'Statistics' menu button () and select 'Show All'. In *ScienceWorkshop*, click the 'Statistics' button to open the statistics area of the Graph.

  Click the 'Statistics Menu' button () and select 'All of the Above' from the Statistics menu.

3. Record the minimum X as Starting Time in the Data Table in the Lab Report section. Record the maximum X as Ending Time.
4. Record the minimum Y as Starting Pressure in the Data Table. Record the maximum Y as Ending Pressure.
5. Calculate the difference/change in pressure and record it in the Data Table. Calculate the difference/change in time and record it in the Data Table.
6. Calculate the rate of production of carbon dioxide by the yeast from grape juice and record the rate.

   Divide the difference in Pressure readings by the difference in Time.

$$\textit{Rate of Carbon Dioxide Production} = \frac{\textit{Ending Pressure} - \textit{Starting Pressure}}{\textit{Ending Time} - \textit{Starting Time}}$$

7. Repeat the process for the second run of data (grape juice and sodium fluoride).

Optional:

- Collect the data from the other experimental runs conducted in class and record them. Calculate the rate of production of carbon dioxide for each of the experimental runs.

Record your results in the Lab Report section.

Name _____ Class _____ Date _____

Lab Report - Activity B02: Fermentation of Grape Juice

How does the pressure inside a closed vessel change as yeast converts the sucrose in grape juice into ethanol and carbon dioxide?

What factors can alter the rate of the fermentation of grape juice and what changes would you expect to see as you apply those factors?

Data Table

Item	Initial Trial	With NaF	At pH = 10
Starting Time	min	min	min
Ending Time	min	min	min
Difference in Time	min	min	min
Starting Pressure	kPa	kPa	kPa
Ending Pressure	kPa	kPa	kPa
Difference in Pressure	kPa	kPa	kPa
Rate of CO_2 Production	kPa/min	kPa/min	kPa/min

Questions

1. What is the rate of production of carbon dioxide gas for the grape juice and yeast mixture?

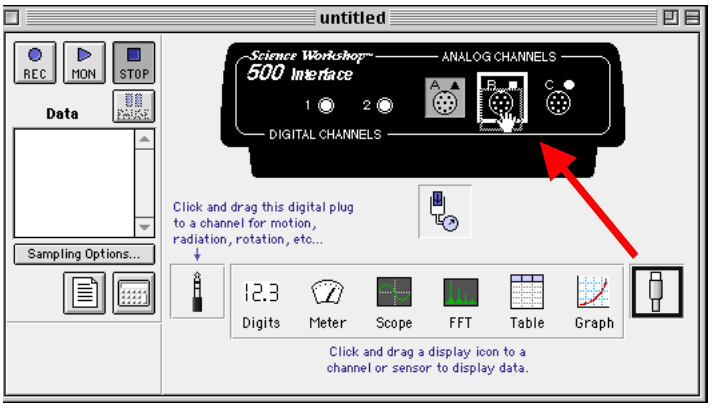
2. What happens to the rate of carbon dioxide production in the flask when the sodium fluoride is added to the grape juice?

Appendix: Set Up *ScienceWorkshop*

Modify the *ScienceWorkshop* file to monitor temperature as you warm the grape juice.

Set Up the Sensor

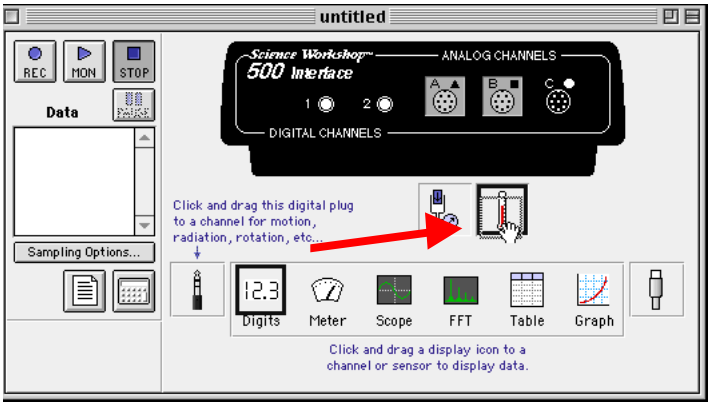
In the Experiment Setup window, click and drag the analog sensor plug to Channel B.



Select ‘Temperature Sensor’ from the list of sensors. Click ‘OK’ to return to the Experiment Setup window

Set Up the Display

In the Experiment Setup window, click and drag the Digits display icon to the Temperature Sensor icon.



Arrange the windows so you can see the Digits display of temperature.

Name _____ Class _____ Date _____

Activity B03: The Effect of Temperature on Yeast (Pressure Sensor, Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
cellular respiration	B03 Yeast. DS	See Appendix	See Appendix

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Pressure Sensor (CI-6532)	1	**Thermometer (SE-9084)**	1
Temperature Sensor (CI-6505)	1	Tongs	1
Base and support rod (ME-9355	1	**Tubing (w/ sensor)**	1
Beaker, 250 mL	1	Protective gear	PS
Beaker, 600 mL	2	**Chemicals and Consumables**	**Qty**
Clamp, buret (SE-9446)	1	Cup, insulated (e.g. Styrofoam)	1
Connector (w/ sensor)	1	Glycerin	1 mL
Coupling, quick-release (w/sensor)	1	Glucose solution	2.5 mL
Hot plate	1	Vegetable oil in dropper bottle	1 mL
Pipette, 10 mL (or larger)	1	Yeast suspension	2.5 mL
Stopper, one hole, for test tube	1	Water, cold	500 mL
Test tube, 18 by 150 mm	1	Water, hot	500 mL

What Do You Think?

When yeast is used to leaven bread, the bread dough is allowed to 'rise' in a warm place before it is baked. When wine is aged, the casks are stored in temperature controlled rooms or in underground cellars where the temperature varies by only a few degrees. How does the temperature effect the rate of anaerobic cellular respiration (fermentation) of yeast?

Take time to write an answer to this question in the Lab Report section.

Background

Organisms whose internal body temperature is determined by their surroundings are called ectotherms. Yeast cells are an example of this type of organism. The surrounding temperature can determine their metabolism. Bakers know that if the yeast they use for leavening is not warmed properly, it can't convert sugar into carbon dioxide gas and other metabolic products fast enough to cause the bread to 'rise'.

When yeast break down glucose anaerobically (without oxygen), they release ethyl alcohol (ethanol) and carbon dioxide.

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$

As the yeast break down glucose in a closed container, the carbon dioxide gas they release will change the pressure inside the container.

SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

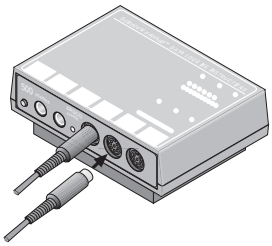
Start Heating the Water

- For this part you need the following: hot plate, beaker (600-mL), water.
- Put about 200 mL of water into a beaker and put the beaker on a hot plate. Turn on the hot plate to start heating the water to about 65 ˚C. Use a thermometer to check the progress as you set up the rest of the equipment.

Use the Pressure Sensor to measure the change in pressure in a test tube containing a mixture of activated yeast and a glucose solution that is kept at a specific temperature in a water bath. Use the Temperature Sensor to monitor the temperature of the water bath as you measure the pressure.

Use *DataStudio* or *ScienceWorkshop* to record and display the data. Use the software to analyze the data. Compare the results at one temperature to the results at other specific temperatures.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Pressure Sensor DIN plug into Analog Channel A on the interface.
3. Connect the Temperature Sensor DIN plug into Analog Channel B on the interface.
4. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B03 Yeast. DS	See Appendix	See Appendix

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook. The file has a Graph of pressure versus time and Digits displays of pressure and of temperature.
- Data recording is set at 1 measurement per two seconds. Data recording is set to stop automatically at 900 seconds (15 minutes).

NOTE: See the Appendix at the end of this activity for instructions about setting up a *ScienceWorkshop* file.

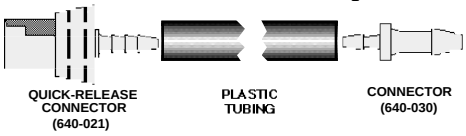
PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

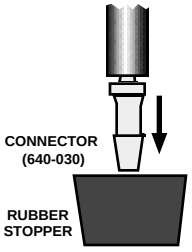
- **You do not need to calibrate the sensors for this activity.**

Set Up the Equipment

1. Put a drop of glycerin on the barb end of the quick-release coupling and insert the barb into one end of the plastic tubing.
2. Put a drop of glycerin on the smaller diameter end of the connector that will go into the rubber stopper. Insert the small diameter end into the plastic tubing.



3. Put a drop of glycerin on the larger diameter end of the connector that will go into the rubber stopper, and insert the end into the rubber stopper.



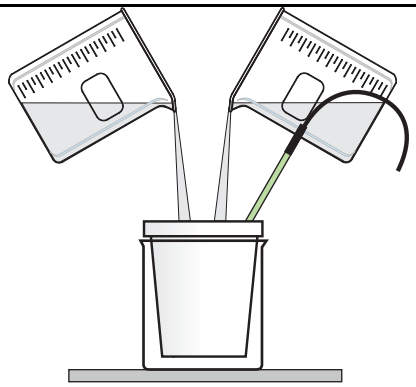
Prepare the Water Bath for the Yeast

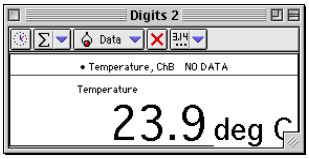
- For this part you will need the following: Styrofoam cup, beaker (250-mL), beaker of hot water, beaker of cold water, pipette, tongs, Temperature Sensor.

A water bath is a quantity of water that is kept at a specific temperature. Use the water bath to keep the yeast at a controlled and constant temperature.

1. Put the Styrofoam cup into the 250-mL beaker. Place the Temperature Sensor in the cup. Mix hot and cold water together in the cup until the mixture reaches the temperature you were assigned.

CAUTION! Use tongs to handle the beaker of hot water.

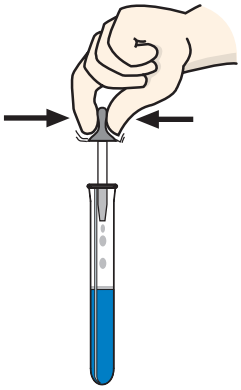




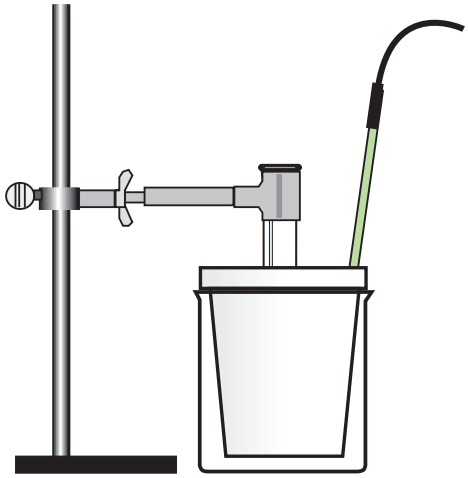
2. Use the software to monitor the temperature of the water. (Hint: In *DataStudio*, click 'Monitor' in the Experiment menu. In *ScienceWorkshop*, click the MON button. Watch the temperature in the Digits display.)
3. Fill the cup about three-quarters full of water. (Note: Use the pipette to add or remove small amounts of water to maintain the water at the specific temperature you need.)

Note: After you have mixed the hot and cold water to reach the specific temperature you need, return the beaker of hot water to the hot plate. Add more water to the beaker if needed.

Incubate the Yeast



1. Put 2.5 mL of glucose solution into a clean test tube.
2. *Gently* stir the yeast suspension and add 2.5 mL of the yeast suspension to the glucose solution.
3. Put several drops of vegetable oil on the surface of the liquid in the test tube so the oil completely covers the surface.
4. Use the clamp to support the test tube in the water bath so the water covers at least half of the test tube.
5. Incubate the yeast/glucose mixture in the water bath for 10 minutes. Use the software to monitor the temperature. If you need to add warm or cold water to raise or lower the temperature of the water bath, remove as much water as you add so the level of water stays the same. (Hint: Use the pipette if you need to add or remove water.)



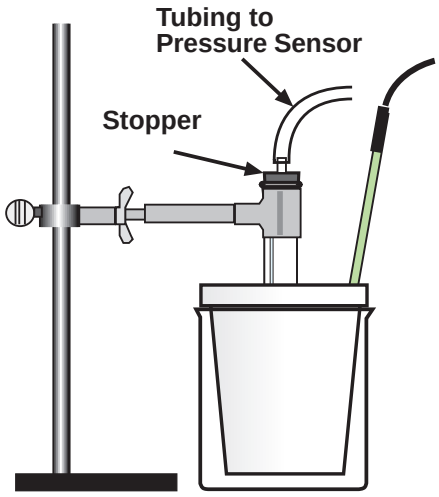
Name _____ Class _____ Date _____

Part III: Data Recording – Glucose Solution and Yeast Suspension

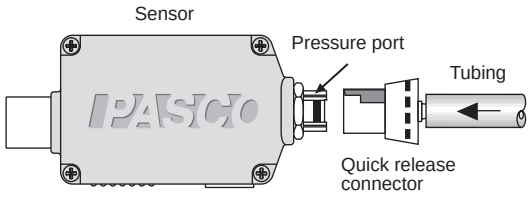
1. In the software, stop monitoring the temperature of the water bath. Hint: Click 'Stop' (

) or (

).
2. Stopper the test tube with the rubber stopper. Use a twisting motion to get a tight fit.



3. Align the quick-release connector on the end of the plastic tubing with the connector on the pressure port of the Pressure Sensor. Push the connector onto the port, and then turn the connector clockwise until it clicks (about one-eighth turn).



4. Start recording data.Hint: In *DataStudio*, click the 'Start' button (

). In *ScienceWorkshop*, click the 'REC' button (

).

- Continue to watch the Digits display of the temperature of the water bath. Don't let the temperature change by more than one or two degrees. If you need to add water, remove the same amount so the beaker does not overflow.

5. Allow the yeast to metabolize for about 15 minutes and then stop recording data.

- **Be sure you have stopped recording before you carefully remove the stopper.**

6. Dispose of the yeast/glucose mixture as instructed.

Analyze the Data

1. Set up your Graph display so it shows your data.
2. Use the Graph display's built-in statistics to determine the rate of respiration.

- Hint: Find the slope of the plot of pressure versus time. In *DataStudio*, click the 'Fit' menu button (

) and select 'Linear'. The formula for the best linear fit appears next to the plot. In *ScienceWorkshop*, click the 'Statistics' button to open the statistics area of the Graph. Click the 'Statistics Menu' button () and select 'Curve Fit, Linear Fit' from the Statistics menu. The formula for the best linear fit appears in the statistics area.

3. Record the temperature of your water bath and the respiration rate (slope of the pressure versus time plot). Also record the results from other groups for the other temperatures.

Optional

- Use the data from the other groups to create a graph of respiration rate (in kilopascals per minute) versus temperature (in degrees Celsius).
- Hint: See the instructions at the end of the Lab Report section.

Record your results in the Lab Report section.

Name _____ Class _____ Date _____

Lab Report - Activity B03: The Effect of Temperature on Yeast

When yeast is used to leaven bread, the bread dough is allowed to 'rise' in a warm place before it is baked. When wine is aged, the casks are stored in temperature controlled rooms or in underground cellars where the temperature varies by only a few degrees. How does the temperature effect the rate of anaerobic cellular respiration (fermentation) of yeast?

Answers will vary. Based on their experiences with the previous activity (Fermentation in Grape Juice) students may predict that the rate of respiration will be a maximum at around 35˚ C, and that the rate will be less than maximum below or above that temperature.

Data Table 1

Temperature (˚C)	Rate of Respiration (kPa/min)

Data Table 2 (Class Data)

Temperature (˚C)	Rate of Respiration (kPa/min)
10	
20	
30	
40	
50	
60	

Questions

1. Based on your results and the results from the other groups, does temperature affect yeast? Describe the effect of temperature on yeast.

2. What is the temperature at which yeast have the highest respiration rate?

3. What happens to the respiration rate at high temperature? What do you think causes this to happen?

4. What is the purpose of the vegetable oil on top of the glucose/yeast mixture in the test tube?

5. Based on your results, would you say that the following statement is true or false?

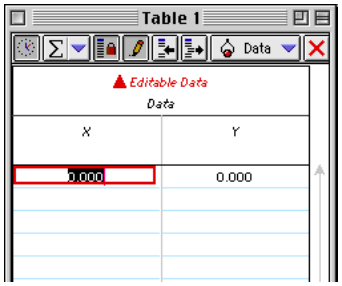
   "The metabolism of ectotherms usually doubles with every 10˚ C increase in the temperature of their environment."

Name _____ Class _____ Date _____

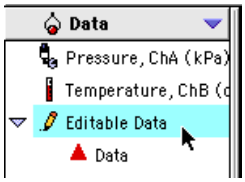
Create a Graph of Respiration Rate versus Temperature

In *DataStudio*, do the following:

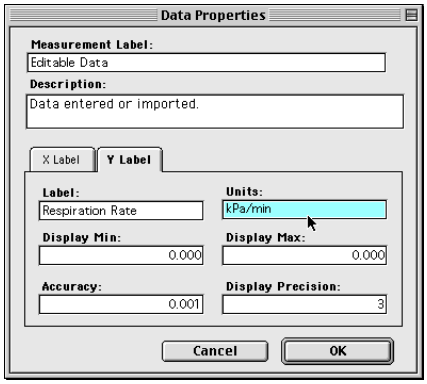
Select 'New Empty Data Table' from the Experiment menu. The empty Table display has two columns labeled 'X' and 'Y' and the number in the first cell of the 'X' column is highlighted.

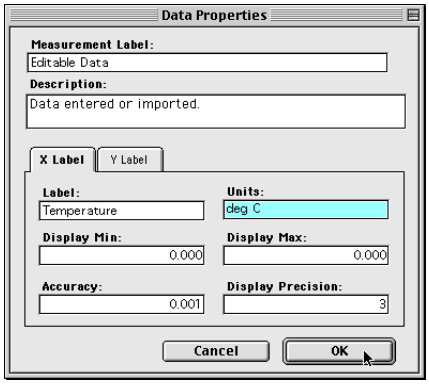


To change the default column labels, double-click 'Editable Data' in the **Data** list to open the Data Properties window.



In the Data Properties window, change the Y Label from 'Y' to 'Respiration Rate' and the Units to 'kPa/min'.



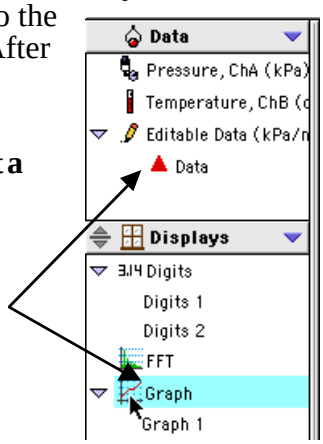


Click the 'X Label' tab. Change the X Label from 'X' to 'Temperature' and the Units to 'deg C'. Click 'OK' to return to the Table display.

In the Table, enter the first temperature from the class data, press the <enter> key, and enter the first respiration rate from the class data. Press the <tab> key to move to the second row. Enter the rest of the 'temperature-respiration rate' pairs. After you enter your data, click the 'Edit' tool () in the table toolbar.

Click and drag 'Graph' from the **Displays** list onto 'Data' in the **Data** list.

Click-and-drag 'Graph' onto 'Data'.

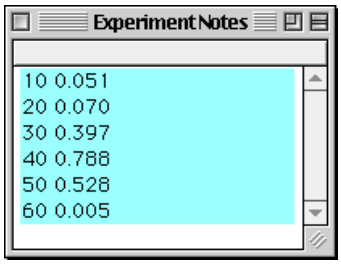


In *ScienceWorkshop*, do the following:

Select ‘Notes Window’ from the Experiment menu. In the Notes Window, enter the ordered pairs of temperature and respiration rate in the following manner:

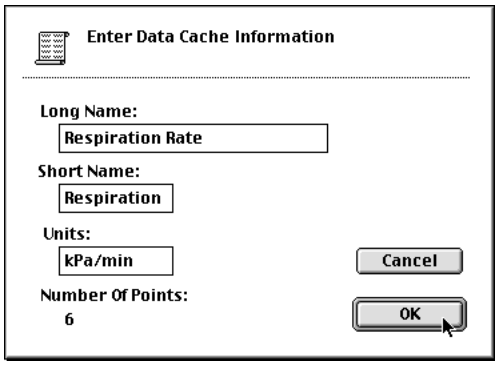
‘Temperature’ <tab> ‘Respiration Rate’ <return>

After you have entered all the ordered pairs into the Notes Window, choose ‘Select All’ from the Edit menu to highlight all the ordered pairs.

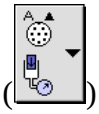


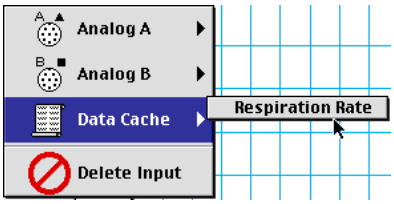
Then select ‘Copy’ from the Edit menu.

Click the Experiment Setup window to make it active. Select ‘Paste’ from the Edit menu to open the ‘Enter Data Cache Information’ window.



Enter ‘Respiration Rate’ as the Long Name and ‘Respiration’ as the Short Name and ‘kPa/min’ as the Units and click ‘OK’.

Click the Graph display to make it active. Click the Channel A Input Menu button () and select ‘Data Cache, Respiration Rate’ from the menu.

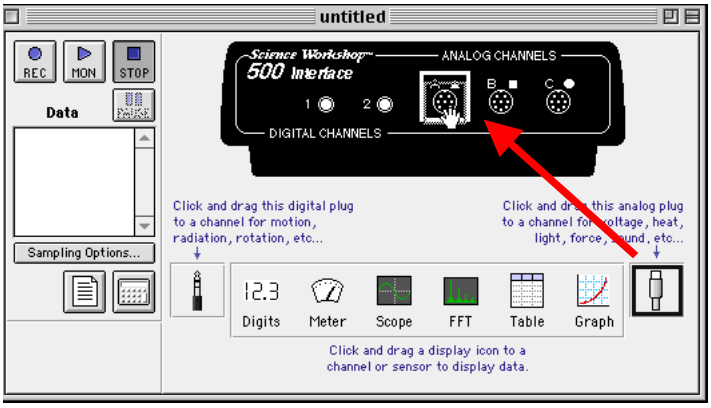


Appendix: Set Up *ScienceWorkshop*

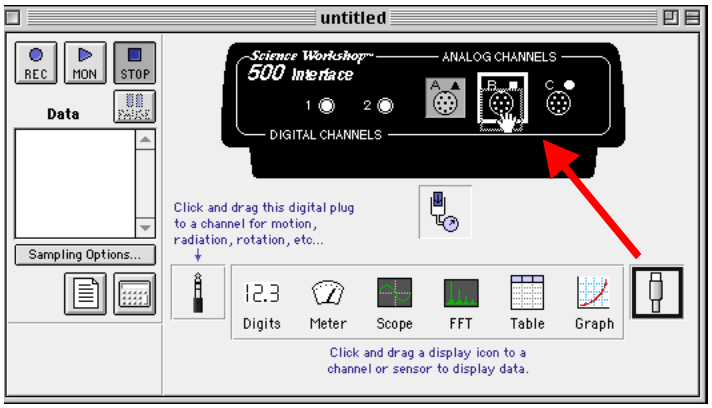
Create a *ScienceWorkshop* file to measure pressure and monitor temperature.

Set Up the Sensor

In the Experiment Setup window, click and drag the analog sensor plug to Channel A. Select 'Pressure Sensor (Absolute)' from the list of sensors. Click 'OK' to return to the Experiment Setup window.



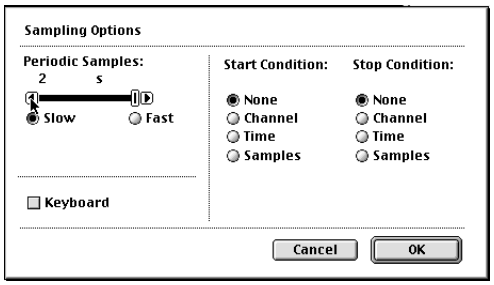
In the Experiment Setup window, click and drag the analog sensor plug to Channel B.

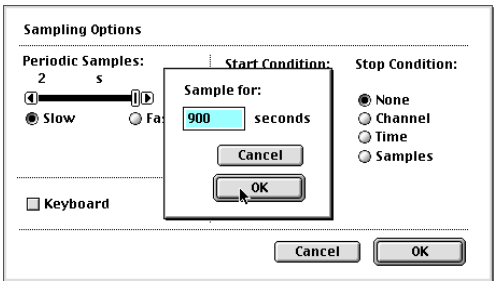


Select 'Temperature Sensor' from the list of sensors. Click 'OK' to return to the Experiment Setup window

Set the Sampling Options

Click the 'Sampling Options' button in the Experiment Setup window or select 'Sampling Options' from the Experiment menu to open the Sampling Options window. Under 'Periodic Samples' click 'Slow' and then click the left arrow to set the sample rate at '2 s' (one measurement every two seconds.).

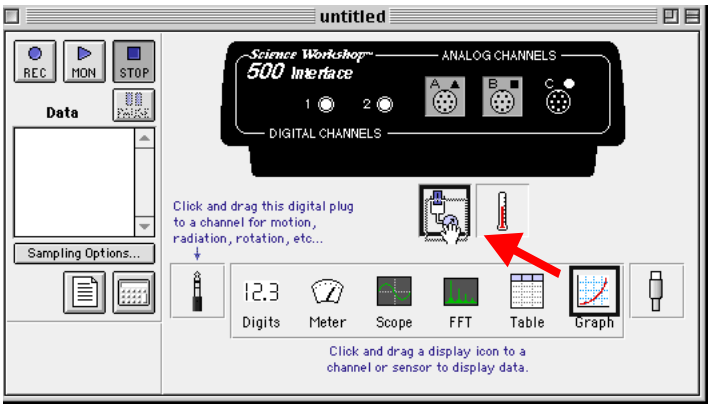




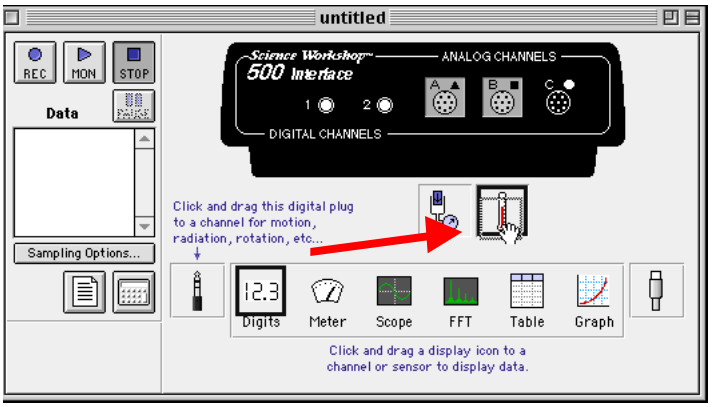
Under 'Stop Condition' click 'Time'. Type '900' as the amount of time. Click 'OK' to return to the Sampling Options window. Click 'OK' again to return to the Experiment Setup window.

Set Up the Display

In the Experiment Setup window, click and drag the Graph display icon to the Pressure Sensor icon.



In the Experiment Setup window, click and drag the Digits display icon to the Temperature Sensor icon.



Arrange the windows so you can see the Digits display of temperature.

Name _____ Class _____ Date _____

Activity B04: Catalase Enzyme Activity (Pressure Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Biochemistry - enzymes	B04 Catalase.DS	B05 Catalase Activity	B05_CATA.SWS

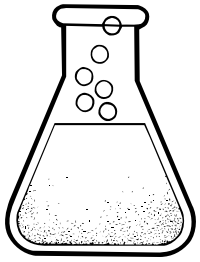
Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Pressure Sensor – Abs. (CI-6532)	1	Protective gear	PS
Balance (SE-8723)	1		
Beaker, 600 mL	1	**Chemicals and Consumables**	**Qty**
Connector (640-030)	1	Chicken liver extract	12 mL
Flask, 250 mL	1	Glycerin	1 mL
Graduated cylinder, 100 mL	1	Hydrochloric acid (HCl), 1 M	10 mL
Hot plate	1	hydrogen peroxide, 3%	100 mL
Magnetic stirrer & spin bar	1	Ice, crushed	500 mL
Stopper, one hole, for flask	1	Sodium fluoride, solid	2.0 g
Test tube	1	Sodium hydroxide (NaOH), 1 M	10 mL
Tongs	1	Water	500 mL
Tubing (w/ sensor)		Water, distilled	500 mL

What Do You Think

What are some factors that can influence the rate of enzyme activity in an organism?

Take time to write an answer to this question in the Lab Report section.

Background



Enzymes are very important molecules found in every cell. Enzymes generally act as catalysts that increase the speed or rate at which substances in a cell get converted into other substances. Without enzymes, some reactions would take place too slowly – or might not take place at all.

Each enzyme has a different job and many enzymes must work together to keep an organism alive and healthy. In the liver, for example, there are several enzymes that act on certain toxic or poisonous compounds by removing hydrogen atoms from the poisons and transferring them to oxygen molecules. This detoxifies the poison but it creates a new compound, hydrogen peroxide (H2O2) that is very active and can be harmful to the organism. Fortunately there is another enzyme in the liver that helps break down the peroxide into water and oxygen.

This enzyme is known as catalase. The catalase enzyme reduces the substrate, peroxide, to water and oxygen by the following decomposition reaction.

$$\underset{\text{(substrate)}}{2H_2O_2} \xrightarrow[\text{(enzyme)}]{\text{Catalase}} \underset{\text{(products)}}{2H_2O + O_2\,(gas)}$$

Like all enzymes, catalase helps the reaction but does not itself get used up in the reaction. Also like other enzymes, catalase must have a proper environment in which to work. Your body's enzymes, for example, work best when your temperature is normal (around 37˚ C) and when the pH is between 7.3 to 7.4. If the environmental conditions are outside the normal range, the catalase will lose its ability to catalyze the peroxide reaction or may even be destroyed.

Since the breakdown of hydrogen peroxide produces oxygen gas, what is a way to measure the rate of the production of that gas?

Take time to write an answer to this question in the Lab Report section.

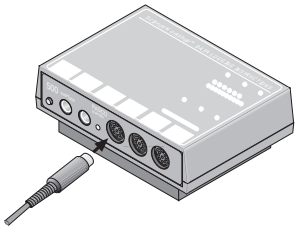
SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the Pressure Sensor to measure the change in gas pressure inside a flask containing hydrogen peroxide and a source of catalase enzyme. After you measure the rate of activity for catalase and hydrogen peroxide, compare the rate of activity for the mixture under three different conditions: change in pH, change in temperature, and in the presence of an inhibitor (sodium fluoride). Use *DataStudio* or *ScienceWorkshop* to record and analyze the data.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Pressure Sensor DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown;

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B04 Catalase.DS	B05 Catalase Activity	B05_CATA.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook. The file has a Graph of Pressure versus Time and a Digits display of Pressure.
- The *ScienceWorkshop* document opens with a Graph display of Pressure (kPa) versus Time (s).
- Data recording is set for 1 measurement per second with a 'Stop' condition at 150 s.

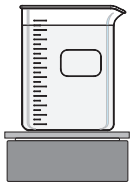
Name _____ Class _____ Date _____

PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

- **You do not need to calibrate the Pressure Sensor for this activity since you will measure the change in pressure.**

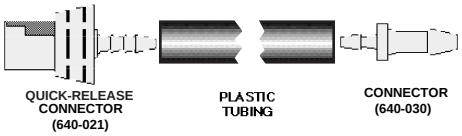
Boil Water



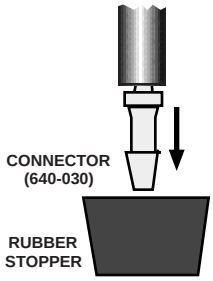
1. Put about 500 mL of water into a beaker and put the beaker on a hot plate. Start heating the water to a boil.

Set Up the Equipment

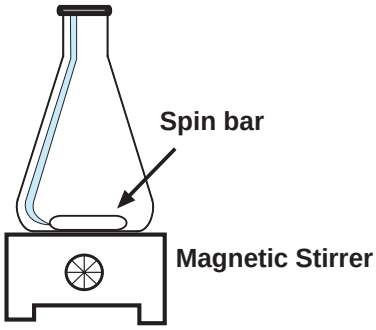
2. Put a drop of glycerin on the barb end of the quick-release connector and insert the barb into one end of the plastic tubing.
3. Put a drop of glycerin on the smaller diameter end of the connector that will go into the stopper. Insert the small diameter end into the plastic tubing.



4. Put a drop of glycerin on the larger diameter end of the connector that will go into the stopper, and insert the end into the stopper.



5. Carefully put a spin bar into the flask and place the flask on the magnetic stirrer.



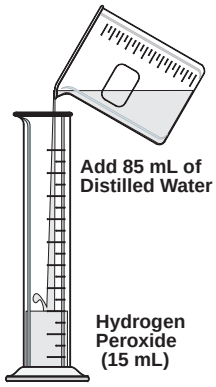
PART III: Data Recording

- **There are six parts to the data recording.**

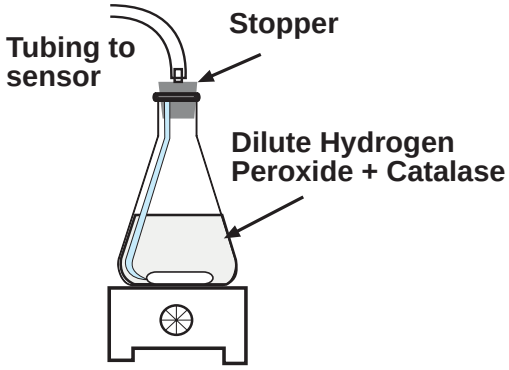
Part	Description	Part	Description
A	Catalase + Hydrogen Peroxide	D	Catalase + Hydrogen Peroxide + Acid
B	Catalase + Hydrogen Peroxide + Inhibitor	E	Chilled Catalase + Hydrogen Peroxide
C	Catalase + Hydrogen Peroxide + Base	F	Heated Catalase + Hydrogen Peroxide

PART IIIA: Catalase + Hydrogen Peroxide

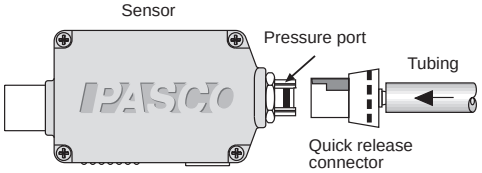
Prepare the Mixture



1. Pour 15 mL of 3% hydrogen peroxide in a 100 mL graduated cylinder. Fill the cylinder to the 100-mL mark with 85 mL of distilled water.
2. Transfer the diluted peroxide solution to the flask.
3. Turn on the stirrer.
4. Add 2 mL of catalase extract to the dilute peroxide solution in the flask.
5. Put the one-hole stopper into the flask.



6. Align the quick-release connector on the end of the plastic tubing with the connector on the pressure port of the Pressure Sensor. Push the connector onto the port, and then turn the connector clockwise until it clicks (about one-eighth turn).



Record the Data

7. Start recording data. (Hint: Click ‘Start’ in *DataStudio* or click ‘REC’ in *ScienceWorkshop*.)

- Data recording will stop automatically at 150 seconds.

Clean Up

8. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
9. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

Name _____ Class _____ Date _____

Part IIIB: Catalase + Hydrogen Peroxide + Inhibitor

Make a prediction:

What effect do you think adding an inhibitor to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide? Put your prediction and a brief explanation in the Lab Report.

Prepare the mixture

1. Repeat the data recording procedure. Put 100 mL of dilute peroxide solution in the flask. Add the spin bar.
2. Add 2.0 g of sodium fluoride to the peroxide solution. Add 2 mL of catalase extract to the flask and stopper the flask.
3. Re-connect the tubing to the Pressure Sensor.

Record the data

4. Start recording data.

- Data recording will stop automatically at 150 seconds.

Clean Up

5. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
6. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

Part IIIC: Catalase + Hydrogen Peroxide + Base

Make a prediction:

What effect do you think adding a base to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide? Put your prediction and a brief explanation in the Lab Report.

Prepare the mixture

1. Repeat the data recording procedure. Put 100 mL of dilute peroxide solution in the flask. Add the spin bar.
2. Add 10 mL of 1 Molar sodium hydroxide (NaOH) to the peroxide to raise the pH before you add the catalase. Add 2 mL of catalase extract to the flask and stopper the flask.
3. Re-connect the tubing to the Pressure Sensor.

Record the data

4. Start recording data.

- Data recording will stop automatically at 150 seconds.

Clean Up

5. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
6. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

Part IIID: Catalase + Hydrogen Peroxide + Acid

Make a prediction:

What effect do you think adding acid to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide? Put your prediction and a brief explanation in the Lab Report.

Prepare the mixture

1. Repeat the data recording procedure. Put 100 mL of dilute peroxide solution in the flask. Add the spin bar.
2. Add 10 mL of 1 Molar hydrochloric acid (HCl) to the peroxide to lower the pH before you add the catalase. Add 2 mL of catalase extract to the flask and stopper the flask.
3. Re-connect the tubing to the Pressure Sensor.

Record the data

4. Start recording data.

- Data recording will stop automatically at 150 seconds.

Clean Up

5. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
6. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

PART IIIE: Chilled Catalase + Hydrogen Peroxide

Make a prediction:

What effect do you think decreasing the temperature of the catalase will have on the enzymes's ability to catalyze the breakdown of the peroxide? Put your prediction and a brief explanation in the Lab Report.

Prepare the mixture

1. Repeat the data recording procedure. Put 100 mL of dilute peroxide solution in the flask. Add the spin bar.
2. Put 2 mL of catalase extract into a test tube. Put the test tube into a beaker and pack crushed ice around the test tube. Cool the test tube in the ice for 5 minutes.
3. Add the chilled catalase extract to the flask and stopper the flask.
4. Re-connect the tubing to the Pressure Sensor.

Record the data

5. Start recording data.

- Data recording will stop automatically at 150 seconds.

Clean Up

6. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
7. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

Name _____ Class _____ Date _____

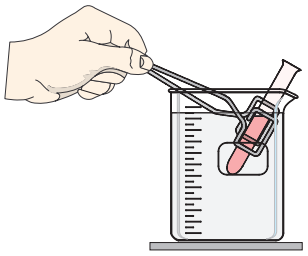
PART IIIF: Heated Catalase + Hydrogen Peroxide

Make a prediction:

What effect do you think boiling the catalase will have on the enzymes's ability to catalyze the breakdown of the peroxide? Put your prediction and a brief explanation in the Lab Report.

Prepare the mixture

1. Repeat the data recording procedure. Put 100 mL of dilute peroxide solution in the flask. Add the spin bar.
2. Put 2 mL of catalase extract into a test tube. Use tongs to hold the test tube in a beaker of boiling water. Heat the test tube in boiling water for 5 minutes.
3. Add the heated catalase extract to the flask and stopper the flask.
4. Re-connect the tubing to the Pressure Sensor.



Record the data

5. Start recording data.

- Data recording will stop automatically at 150 seconds.

Clean Up

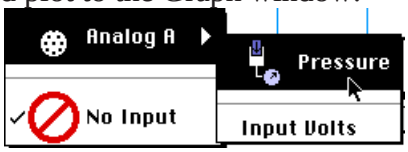
6. Disconnect the tubing from the Pressure Sensor. Remove the stopper from the flask.
7. Dispose of the peroxide mixture as directed and clean the flask thoroughly.

Analyzing the Data

1. Set up the Graph display to show all your data

- Hint: *DataStudio* automatically shows all six runs of data. In *ScienceWorkshop*, do the following to put two runs of data in a top plot, two runs in a middle plot, and two runs of data in a bottom plot.

- Click the 'Add Plot Menu' button () to add a second plot to the Graph window. Select **Analog Channel A, Pressure** from the Add Plot Menu.

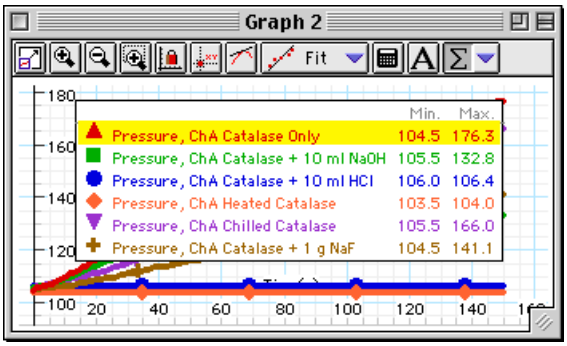


- Click the 'Add Plot Menu' button again to add a third plot to the Graph window. Select **Analog Channel A, Pressure** from the Add Plot Menu.
- Click the 'DATA Menu' button () in the top plot. Select **Run #1** from the DATA Menu. Repeat to select **Run #2** from the DATA menu.

- Click the 'DATA Menu' button in the middle plot. Select **No Data** first.
- Use the Data Menu in the second plot to select **Run #3** and then **Run #4**.
- Click the 'DATA Menu' button in the bottom plot. Use the Data Menu to add **Run #5** to the plot.

2. Use the built-in statistics for the Graph display to find the minimum pressure and the maximum pressure for each run of data.

- Hint: In *DataStudio*, click the 'Statistics Menu' button (). The default statistics are 'Minimum' and 'Maximum'. The values appear in the legend in the display area.



In *ScienceWorkshop*, click the 'Statistics' button () to open the statistics area. Click the 'Statistics Menu' button (). Select 'Maximum' from the menu. Repeat and select 'Minimum' from the menu.

3. Record the minimum pressure as the starting pressure. Record the maximum pressure as the ending pressure.
4. Calculate the difference in pressure.
5. Calculate the enzyme activity. Divide the difference in pressure by the amount of time (in minutes).

$$\underset{\text{(measured by the rate of oxygen production)}}{\text{Catalase Activity}} = \frac{\text{Ending Pressure - Starting Pressure}}{\text{2.5 minutes}}$$

Record your results in the Lab Report section.

Name _____ Class _____ Date _____

Lab Report - Activity B04: Catalase Enzyme Activity

What Do You Think

What are some factors that can influence the rate of enzyme activity in an organism?

Since the breakdown of hydrogen peroxide produces oxygen gas, what is a way to measure the rate of the production of that gas?

Predictions

Part IIIB: Catalase + Hydrogen Peroxide + Inhibitor

What effect do you think adding an inhibitor to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide?

Part IIIC: Catalase + Hydrogen Peroxide + Base

What effect do you think adding a base to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide?

Part IIID: Catalase + Hydrogen Peroxide + Acid

What effect do you think adding acid to the hydrogen peroxide will have on the enzymes's ability to catalyze the breakdown of the peroxide?

PART IIIE: Chilled Catalase + Hydrogen Peroxide

What effect do you think decreasing the temperature of the catalase will have on the enzymes's ability to catalyze the breakdown of the peroxide?

PART IIIF: Heated Catalase + Hydrogen Peroxide

What effect do you think boiling the catalase will have on the enzymes's ability to catalyze the breakdown of the peroxide?

Data Table

Item	Part IIIA	Part IIIB NaF	Part IIIC NaOH	Part IIID HCl	Part IIIE Chilled	Part IIIF Heated
Starting Pressure	kPa	kPa	kPa	kPa	kPa	kPa
Ending Pressure	kPa	kPa	kPa	kPa	kPa	kPa
Pressure Difference	kPa	kPa	kPa	kPa	kPa	kPa
Activity (kPa/min)						

Questions

1. What does the graph of the reaction between hydrogen peroxide and catalase tell you about enzyme activity?

2. Describe the effect of adding the inhibitor (sodium fluoride) to the peroxide before you add the catalase to the solution of peroxide? What explanation can you give for the results?

3. Describe the effect of adding the base (sodium hydroxide) to the solution of peroxide? What did the sodium hydroxide do to the pH of the solution in the flask? What does this tell you about the range of conditions in which catalase may be effective?

4. Describe the effect of adding the acid (hydrochloric acid) to the solution of peroxide? What did the hydrochloric acid do to the pH of the solution in the flask? What does this tell you about the range of conditions in which catalase may be effective?

5. Describe the effect of cooling the catalase before adding it to the solution of peroxide?

6. Describe the effect of heating the catalase to boiling before adding it to the solution of peroxide? How did the effect of cooling compare to the effect of boiling the catalase? How can you explain the difference between these two trials?

Name _____ Class _____ Date _____

Activity B05: The Role of Buffers in Biological Systems (pH Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Bbiochemistry	B05 Buffers.DS	B04 Role of Buffers	B04_BUFF.SWS

Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
pH Sensor (CI-6507)	1	Buffer solution: high pH	100 mL
Base and support rod (ME-9355)	1	Buffer solution: low pH	100 mL
Beaker, 250 mL	5	Club soda*	200 mL
Buret, 50 mL	1	Vinegar, 5% acetic acid	125 mL
Clamp, buret (SE-9446)	2	Water	200 mL
Graduated cylinder, 100 mL	1	Water, distilled	1 L
Magnetic stirrer and spin bar	1		
Wash bottle	1		
Protective gear	PS		

(*dilute solution of sodium and hydrogen carbonate)

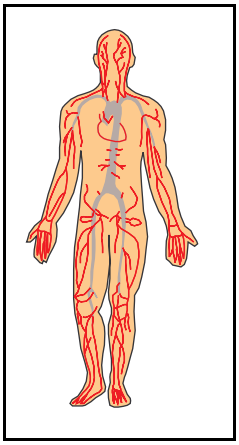
What Do You Think?

Human blood contains sodium bicarbonate/carbonic acid/carbonate buffers. What is the purpose of these buffers, and how effective are these buffers?

Take time to write an answer to this question in the Lab Report section.

Background

Living cells require constant conditions to remain alive. Individual living cells that are not part of a larger organism rely on their surroundings to provide a constant flow of nutrients and oxygen and to maintain salt balance. Their environment must also be at a nearly constant temperature and pH. If any of these physical and chemical conditions are not held constant, the living conditions may vary above or below the optimum conditions necessary for life. Under these conditions the organisms may not grow or reproduce. If the conditions are varied even more, the organism's life may be threatened.



In higher animals, living cells rely on the biological systems of the organism for constant living conditions. Specifically, they rely on the flow of nutrients and oxygen, the maintenance of a constant pH, and the removal of waste.

This is usually provided by some sort of circulatory system. The circulating tissue, often blood, is composed of cells, nutrients, oxygen, waste and cellular like particles in a buffered salt solution. A buffer is a solution of a weak acid in the presence of its salt. The combination of weak acid and its salt maintains a constant pH. Without a buffering solution, the pH of a circulating blood system might fluctuate wildly and cause biological havoc.

Blood cells and the body cells with which they come in contact must be held at a nearly constant pH. That is why a buffering system is always present in any circulatory system.

Vinegar is a solution, usually 5% acetic acid in water. Acetic acid ionizes in water to form hydrogen ions (H+). The hydrogen ions cause the pH of a solution to decrease. Without a salt, the acetic acid can cause pure water to drop to low pH levels. A buffered salt solution can prevent a large decrease in pH.

SAFETY REMINDERS

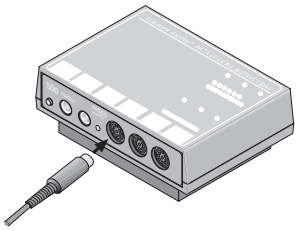
- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the pH sensor to measure the pH of water as you slowly add a 'weak' acid to it. Then measure the pH of water as you slowly add a 'strong' acid to it. Then measure the pH of a buffered salt solution (club soda) as you add a 'weak' acid to it. Finally, measure the pH of the buffered salt solution as you add a 'strong' acid to it. Use DataStudio or *ScienceWorkshop* to record and display you data.

Compare the change in pH of the water to the change of pH of the buffered salt solution when the 'weak' and 'strong' acids are added to each. Determine which is better able to keep its pH closest to the original level.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the pH Sensor DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown;

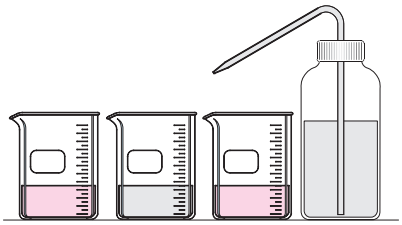
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B05 Buffers.DS	B04 Role of Buffers	B04_BUFF.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook. The file has a Graph of pH versus Time and a Digits display of pH.
- The *ScienceWorkshop* document opens with a Graph display of pH versus Time.
- Data recording is set for 10 measurements per second.

Name _____ Class _____ Date _____

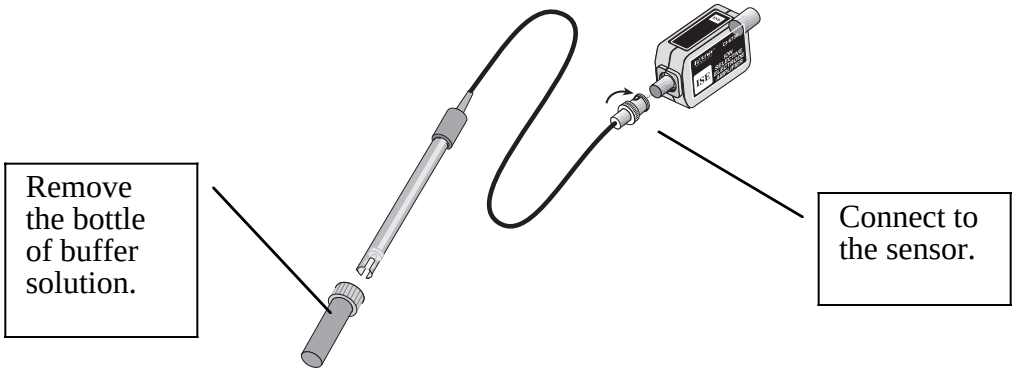
PART II: Sensor Calibration and Equipment Setup

Calibrate the Sensor



- To calibrate the pH Sensor you will need a wash bottle, distilled water, three beakers, and buffer solutions of high pH (e.g. pH 10) and low pH (e.g. pH 4). Put distilled water into the wash bottle and into one of the beakers. Put buffer solutions in the other two beakers.

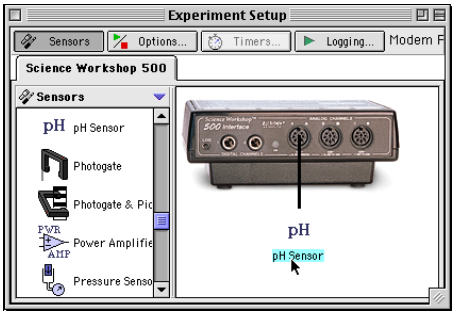
1. Remove the pH electrode from its bottle of buffer solution. Connect the electrode to the pH Sensor amplifier. To connect the electrode, push the BNC plug onto the receptacle on the Sensor amplifier and turn the BNC plug clockwise until it 'clicks' into place.

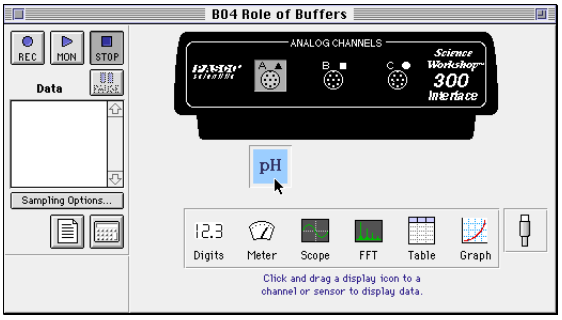


2. Use the wash bottle to rinse the end of the electrode. Soak the pH electrode in the beaker of distilled water for 10 minutes.

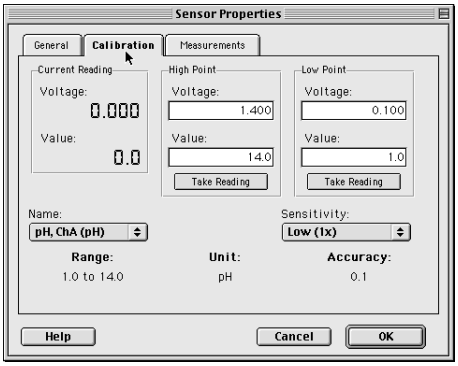
- NOTE: While the electrode is soaking you can prepare the 'weak' acid and 'strong' acid for the activity. See 'Prepare the Acid' for details.

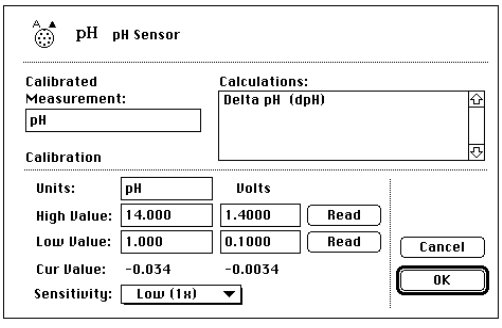
3. In the Experiment Setup window, double-click the pH Sensor icon.





- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab. In *ScienceWorkshop*, the Sensor Setup window will open.





4. Calibrate with the high pH buffer solution.

- Put the end of the pH electrode into the high pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution.

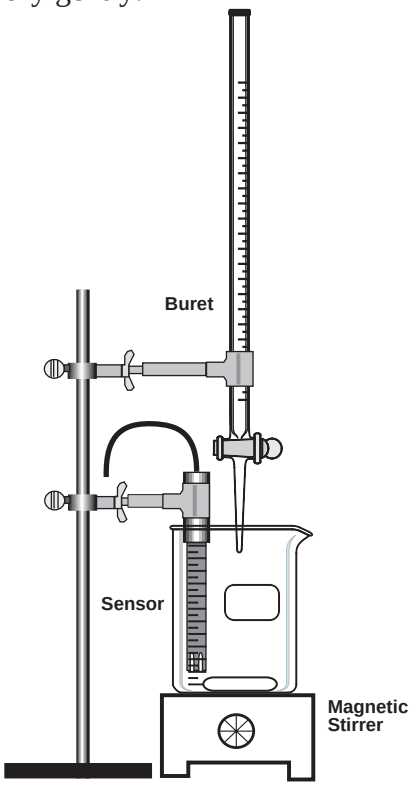
5. Thoroughly rinse the pH electrode with distilled water and dry it with a tissue.
6. Calibrate with the low pH buffer solution.

- Put the end of the H electrode in the low pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'Low Point' in *DataStudio* or the 'Read' button in the row for 'Low Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution. Click **OK** to return to the Experiment Setup window.

7. Thoroughly rinse the pH electrode with distilled water and dry gently.

Set Up the Equipment

1. Put a spin bar into a 250-mL beaker. Place the beaker on the magnetic stirrer.
2. Use a clamp and a base and support rod to position the pH electrode so that it is near the edge of the beaker but is not touching the spin bar.
3. Use a clamp to support the buret so the end of the buret is over the beaker.



Prepare the Acid

1. Make the 'weak' acid. Put 50 mL of vinegar in a 250-mL beaker. Add 50 mL of distilled water to the vinegar. Label the beaker 'weak acid'.
2. Make the 'strong' acid. Put 75 mL of vinegar in a 250-mL beaker. Add 25 mL of distilled water to the vinegar. Label the beaker 'strong acid'.

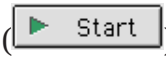
Name _____ Class _____ Date _____

PART III: Data Recording

- **There are four parts to data recording.**

Part	Description
A	10 mL 'weak' acid + 100 mL water
B	10 mL 'strong' acid + 100 mL water
C	10 mL 'weak' acid + 100 mL club soda
D	10 mL 'strong' acid + 100 mL club soda

PART IIIA: 'Weak' Acid and Water

1. Put 100 mL of water into the beaker on the magnetic stirrer. Turn on the magnetic stirrer.
2. Put 10 mL of 'weak' acid into the buret. (Make sure the buret valve is 'off'.)
3. Start recording data. Hint: In *DataStudio* click the 'Start' button (

) or in *ScienceWorkshop* click the 'REC' button (

). Allow the interface to record for about 5 seconds.
4. Open the buret valve to let the 'weak' acid (dilute vinegar solution) pour into the water.
5. Continue to record the pH data for an additional 10 seconds after the 'weak' acid has been added.
6. After the last of the solution has been added, and you have waited 10 seconds, stop recording data.
7. Dispose of the contents of the beaker as directed and thoroughly rinse the beaker and the buret.

PART IIIB: 'Strong' Acid and Water

- Repeat the procedure, but put 10 mL of 'strong' acid into the buret. Record data as the strong acid pours from the buret into the beaker of water.
- Dispose of the contents of the beaker as directed and thoroughly rinse the beaker and the buret.

PART IIIC: 'Weak' Acid and Club Soda

1. Put 100 mL of club soda into the beaker on the magnetic stirrer. Turn on the magnetic stirrer.
2. Put 10 mL of 'weak' acid into the buret. (Make sure the buret valve is 'off'.)
3. Start recording data. Allow the interface to record for about 5 seconds.
4. Open the buret valve to let the 'weak' acid (dilute vinegar solution) pour into the club soda.
5. Continue to record the pH data for an additional 10 seconds after the 'weak' acid has been added.
6. After the last of the solution has been added, and you have waited 10 seconds, stop recording data.
7. Dispose of the contents of the beaker as directed and thoroughly rinse the beaker and the buret.

PART IIID: 'Strong' Acid and Club Soda

- Repeat the procedure, but put 10 mL of 'strong' acid into the buret. Record data as the strong acid pours from the buret into the beaker of water.
- Dispose of the contents of the beaker as directed and thoroughly rinse the beaker and the buret.

Optional

To see whether or not the *quantity* of the acid makes a difference, repeat the procedure, but put 50 mL of the acid into the buret instead of 10 mL.

Analyzing the Data

1. Use the built-in analysis tools in the Graph display to determine the beginning pH and the ending pH for each run of data.

- Hint: In *DataStudio*, click the 'Smart Tool' button (). The 'Smart Tool' displays the coordinates of its position as you move it to any position in the Graph display. When the 'Smart Tool' is on a data point, the 'y' coordinate is the pH value at that point.

  In *ScienceWorkshop*, click the 'Smart Cursor' button () and move the cursor into the display area. The coordinates of the cursor are displayed in the label area of the Y-axis and the X-axis.

2. Record the beginning pH and the ending pH for each run in the Data Table.

- Note: In *ScienceWorkshop*, use the 'Data Menu' button () in the Graph display to select a run of data.

Record your results in the Lab Report section.

Name _____ Class _____ Date _____

Lab Report - Activity B05: The Role of Buffers in Biological Systems

What Do You Think

Human blood contains sodium bicarbonate/carbonic acid/carbonate buffers. What is the purpose of these buffers, and how effective are these buffers?

Data Table

Part	Run	Description	Beginning pH	Ending pH
A	1	'weak' acid + water		
B	2	'strong' acid + water		
C	3	'weak' acid + club soda		
D	4	'strong' acid + club soda		

Questions

1. Look at the graph of each of your results. Compare and contrast the combinations of weak acid and water with weak acid and club soda. How are they different? How are they the same?

2. What happened when you added the 'strong' acid to water. What happened when you added the 'strong' acid to club soda? How were the results different from when you added 10 mL of diluted vinegar to the club soda?

3. Consider the definition of a buffer. Tap water contains minerals. Club soda contains sodium bicarbonate and carbonic acid. Which starting liquid made a better buffer? How does your experiment show this?

Name _____ Class _____ Date _____

Activity B06: Organisms and pH (pH Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Biochemistry	B06 Organisms and pH.DS	B06 Organisms and pH	B06_ORG.SWS

Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
pH Sensor (CI-6507)	1	Buffer solution, high pH	100 mL
Base and support rod (ME-9355)	1	Buffer solution, low pH	100 mL
Beaker, 50 mL	1	Egg white, diluted 1:5 with water	50 mL
Beaker, 250 mL	3	Gelatin suspension, 2%, warm	50 mL
Buret, 50 mL	1	Hydrochloric acid (HCl), 0.1M	10 mL
Clamp, buret (SE-9446)	2	Liver homogenate	50 mL
Graduated cylinder, 50 mL	1	Potato homogenate	50 mL
Stir rod	1	Sodium hydroxide (NaOH), 0.1M	10 mL
Wash bottle	1	Sodium phosphate buffer solution, pH 7	50 mL
Protective gear	PS	Water	50 mL
		Water, distilled	500 mL

For instructions on preparation of solutions and materials, see the Notes section at the end of the this lab.

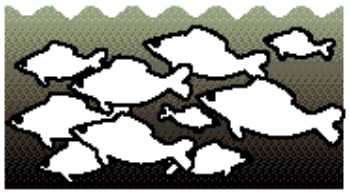
What Do You Think?

Which of the following substances can act as a buffer (maintain its pH within a relatively narrow range)? The substances are egg white, gelatin, liver, potato and water.

How do organisms maintain a stable internal environment?

Take time to answer these questions in the Lab Report section.

Background



In order to survive, living organisms must maintain a relatively stable internal environment. Both organisms and cells have learned to adapt to many environmental factors that would normally affect their internal environment.

The pH in the organism's environment is determined by the concentration of hydrogen ions (H^+) and hydroxide ions (OH^-). The pH plays an important role in many biochemical processes and can affect internal and external environments of living tissue. Living organisms have developed mechanisms to maintain a normal pH for each cell or organ system (usually between pH 6 and pH 8).

A buffer is a solution of a weak acid in the presence of its salt. A buffer maintains its pH within a relatively narrow range despite changes in the concentration of hydrogen ions or hydroxide ions.

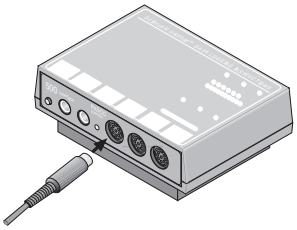
SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the pH Sensor to measure the change in pH of water, a buffer solution, and a variety of biological materials when a strong acid or strong base is added to them. Use *DataStudio* or *ScienceWorkshop* to record and analyze the data.

PART I: Computer Setup



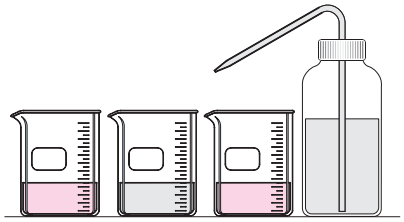
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the pH Sensor into Analog Channel A of the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B06 Organisms and pH.DS	See Appendix	See Appendix

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- See the Appendix for setting up a *ScienceWorkshop* file with a Digits display, a Table display, and a Graph display of pH.
- Data recording is set at ten measurements per second (10 Hz).

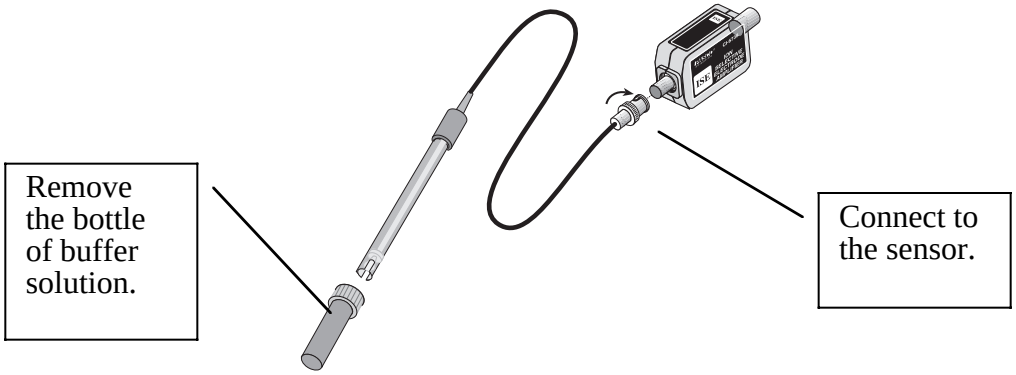
PART II: Sensor Calibration and Equipment Setup

Calibrate the Sensor



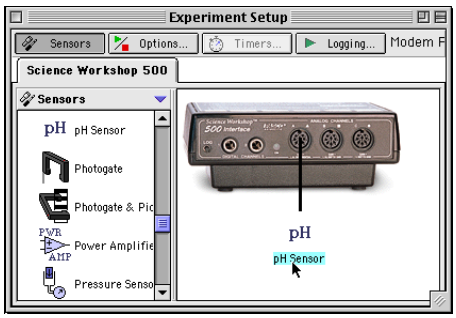
- To calibrate the pH Sensor you will need a wash bottle, distilled water, three beakers, and buffer solutions of high pH (e.g. pH 10) and low pH (e.g. pH 4). Put distilled water into the wash bottle and into one of the beakers. Put buffer solutions in the other two beakers.

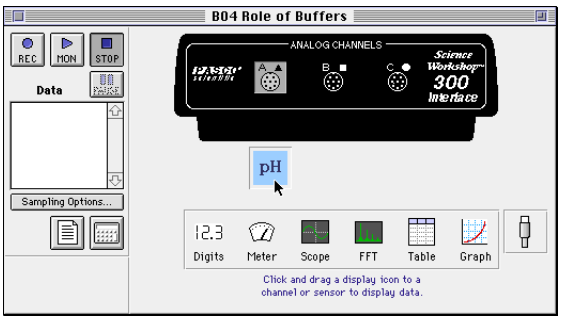
1. Remove the pH electrode from its bottle of buffer solution. Connect the electrode to the pH Sensor amplifier. To connect the electrode, push the BNC plug onto the receptacle on the Sensor amplifier and turn the BNC plug clockwise until it 'clicks' into place.



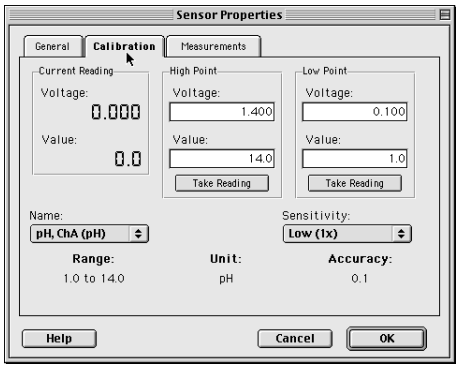
2. Use the wash bottle to rinse the end of the electrode. Soak the pH electrode in the beaker of distilled water for 10 minutes.

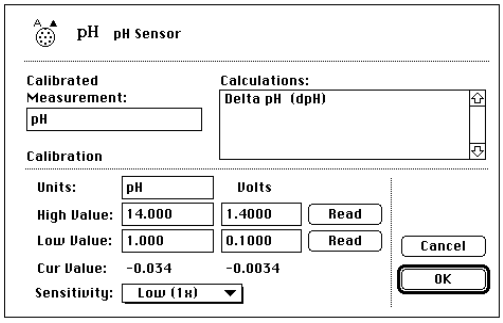
3. In the Experiment Setup window, double-click the pH Sensor icon.





- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab. In *ScienceWorkshop*, the Sensor Setup window will open.





4. Calibrate with the high pH buffer solution.

- Put the end of the pH electrode into the high pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution.

5. Thoroughly rinse the pH electrode with distilled water and dry it with a tissue.

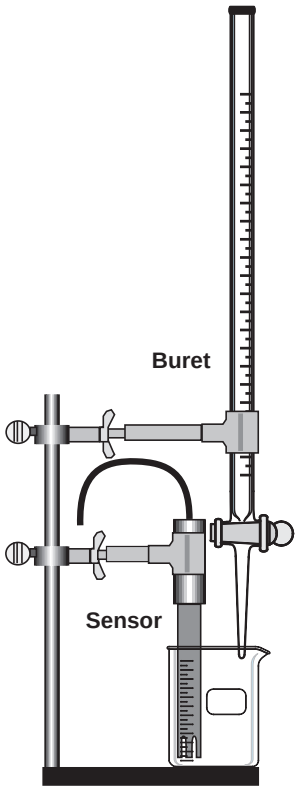
6. Calibrate with the low pH buffer solution.

- Put the end of the H electrode in the low pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'Low Point' in *DataStudio* or the 'Read' button in the row for 'Low Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution. Click **OK** to return to the Experiment Setup window.

7. Thoroughly rinse the pH electrode with distilled water and dry gently.

Set Up the Equipment

1. Set up the pH electrode in a 50-mL beaker. Use a base and support rod and a clamp to mount the pH electrode so the end of the electrode is in the beaker.
2. Set up the buret so it is above the 50-mL beaker. Use a clamp to mount the buret so the tip of the buret is over the mouth of the beaker.



3. Put a stir rod in the beaker.

PART III: Data Recording

There are six parts to data recording.

Part	Description
A	Add 1.5 mL of hydrochloric acid to tap water
B	Add 1.5 mL of hydrochloric acid to sodium phosphate buffer solution
C	Add 1.5 mL of hydrochloric acid to a biological material
D	Add 1.5 mL of sodium hydroxide to tap water
E	Add 1.5 mL of sodium hydroxide to sodium phosphate buffer solution
F	Add 1.5 mL of sodium hydroxide to a biological material

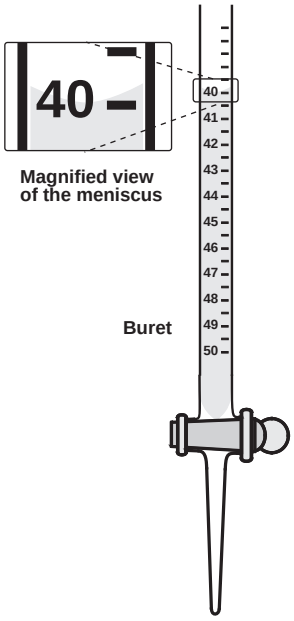
Follow the same basic procedure in each part:

- Put 25 mL of the substance to be tested into the beaker.
- *Slowly* but steadily add 1.5 mL of the acid (Parts A, B, and C) or base (Parts D, E, and F) *drop-by-drop* into the substance that is being tested.
- Stir the substance as you slowly add the acid or base. Use the sensor to record the pH.

Name _____ Class _____ Date _____

Using the Buret

Turn the valve on the buret to the 'off' position. Carefully pour enough acid into the buret so the level of the liquid is 10 mL above the lowest mark on the buret. For example, in a 50-mL buret, add fluid so the bottom of the meniscus is at the 40 mL mark.



When you are ready to begin adding the acid (or the base) to the substance you are testing, open the valve just enough so that the fluid drips into the substance one drop at a time.

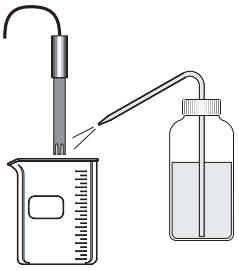
PART IIIA: Add Hydrochloric Acid to Tap Water

First, fill the buret with acid so the level of the acid is 10 mL above the lowest mark on the buret.

Make a prediction:

What will happen to the pH of the water as you add the acid? Write your prediction and a brief explanation in the Lab Report.

1. Put 25 mL of tap water into the beaker.
2. When everything is ready, start recording data. (Hint: In *DataStudio*, click 'Start'. In *ScienceWorkshop*, click 'REC'.)
3. After 5 seconds, open the valve on the buret enough so the acid can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of acid (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the tap water/acid mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.



PART IIIB: Add Hydrochloric Acid to A Buffer Solution

Make a prediction:

What will happen to the pH of the buffer solution as you add the acid? Write your prediction and a brief explanation in the Lab Report.

1. Put the beaker back under the pH electrode and buret. Put 25 mL of sodium phosphate buffer solution into the beaker.
2. When everything is ready, start recording data.
3. After 5 seconds, open the valve on the buret enough so the acid can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of acid (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the buffer solution/acid mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

PART IIIC: Add Hydrochloric Acid to A Biological Material

1. Select one biological material (egg white, liver homogenate, potato homogenate, or warm gelatin). Note: Your teacher may select the biological material for you or your group to use.

   Record the type of biological material you are testing.

   Substance = _____

Make a prediction:

What will happen to the pH of the biological material as you add the acid? Write your prediction and a brief explanation in the Lab Report.

2. Put the beaker back under the pH electrode and buret. Put 25 mL of your biological material into the beaker.
3. When everything is ready, start recording data.
4. After 5 seconds, open the valve on the buret enough so the acid can begin dripping into the substance. Stir the mixture with the stir rod.
5. Add 1.5 mL of acid (or 30 drops) and then close the buret valve.
6. Stop data recording.
7. Dispose of the material/acid mixture as directed. Rinse and clean the beaker and the stir rod.
8. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

PART IIID: Add Sodium Hydroxide to Tap Water

First, fill the buret with sodium hydroxide solution so the level of the solution is 10 mL above the lowest mark on the buret.

Make a prediction:

What will happen to the pH of the water as you add the sodium hydroxide? Write your prediction and a brief explanation in the Lab Report.

1. Put the beaker back under the pH electrode and buret. Put 25 mL of tap water into the beaker.
2. When everything is ready, start recording data.
3. After 5 seconds, open the valve on the buret enough so the base (sodium hydroxide) can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of base (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the tap water/base mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

Name _____ Class _____ Date _____

PART IIIE: Add Sodium Hydroxide to A Buffer Solution

Make a prediction:

What will happen to the pH of the buffer solution as you add the base? Write your prediction and a brief explanation in the Lab Report.

1. Put the beaker back under the pH electrode and buret. Put 25 mL of sodium phosphate buffer solution into the beaker.
2. When everything is ready, start recording data.
3. After 5 seconds, open the valve on the buret enough so the base can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of base (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the buffer solution/base mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

PART IIIF: Add Sodium Hydroxide to A Biological Material

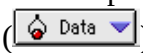
Note: Use the same biological material for Part IIIF that you used in Part IIIC.

Make a prediction:

What will happen to the pH of your biological material as you add the base? Write your prediction and a brief explanation in the Lab Report.

1. Put the beaker back under the pH electrode and buret. Put 25 mL of your biological material into the beaker.
2. When everything is ready, start recording data.
3. After 5 seconds, open the valve on the buret enough so the base can begin dripping into the substance. Stir the mixture with the stir rod.
4. Add 1.5 mL of base (or 30 drops) and then close the buret valve.
5. Stop data recording.
6. Dispose of the material/base mixture as directed. Rinse and clean the beaker and the stir rod.
7. Place an empty beaker under the pH electrode. Use the wash bottle with distilled water to thoroughly rinse the pH electrode. Dispose of the rinse water in the beaker as directed.

Analyzing the Data

1. Set up your Graph display so you can see all your data. (Hint: In *DataStudio* the Graph already shows all the runs. In *ScienceWorkshop*, use the 'Add a Plot' menu () to add a second plot to the Graph. Then use the 'Data' menu in each plot to select Runs #1, #2, and #3 for one plot and Runs #4, #5, and #6 for the other plot.)
2. Set up your Table display so you can see all your data. (Hint: In *DataStudio*, use the 'Data' menu button (

) to select each run. In *ScienceWorkshop*, click the 'Add a Column' menu button () to add more columns to the Table. Then click the 'Data' menu (

) to select Run #1 for the first column, Run #2 for the second column, and so on for all the data.)
3. Use the built-in analysis tools of the Graph or Table display to find the beginning pH and the ending pH for each trial.

- Hint for Graph display: In *DataStudio*, click the 'Smart Tool' button () in the Graph. The 'Smart Tool' displays the coordinates of its position as you move it to any position in the Graph display. When the 'Smart Tool' is on a data point, the 'y' coordinate is the pH value at that point.

  In *ScienceWorkshop*, click the 'Smart Cursor' button () and move the cursor into the display area. The coordinates of the cursor are displayed in the label area of the Y-axis and the X-axis.

- Hint for Table display: Look at the beginning value of pH and then scroll to the end of the column to see the ending value of pH.

4. Record the values of the beginning pH and the ending pH for each of your runs of data.
5. Obtain the pH data for other biological materials from your classmates and record them in your data table in the Lab Report.
6. Calculate the change in pH (if any) for each substance. Record the change in the data table.
7. Finally, calculate the percent difference between the beginning pH and the ending pH for each substance (tap water, buffer solution, egg white, gelatin, liver and potato). Record the percent difference in the data table.

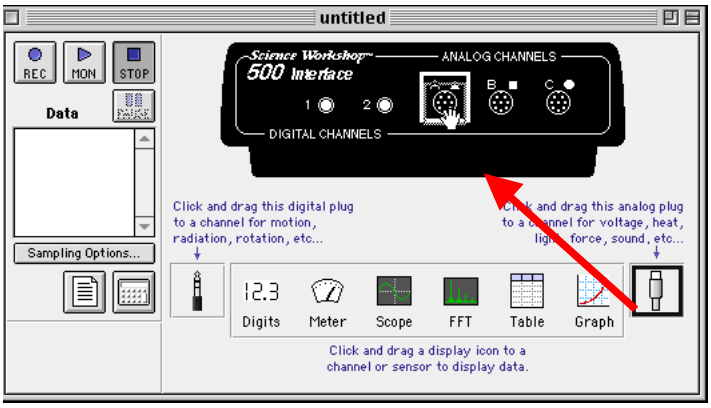
Record your results in the Lab Report section.

Appendix: Set Up *ScienceWorkshop*

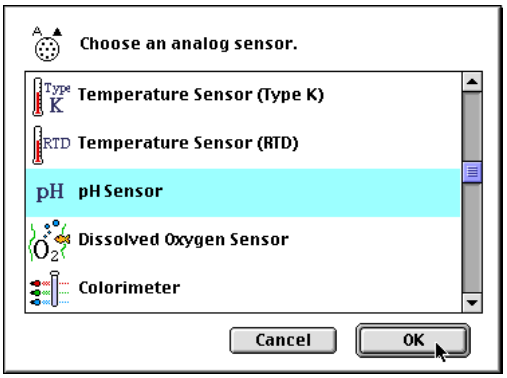
Create a *ScienceWorkshop* file to measure pH.

Set Up the Sensor

In the Experiment Setup window, click and drag the analog sensor plug to Channel A.

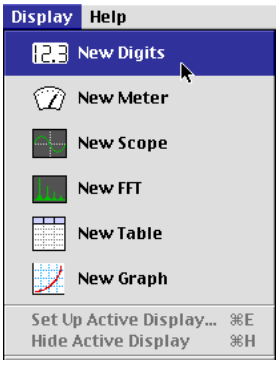


Select 'pH Sensor' from the list of sensors. Click 'OK' to return to the Experiment Setup window.



Set Up the Displays

In the Display menu, select 'New Digits' from the list of displays. Return to the Display menu and select 'New Table'. Finally, return to the menu and select 'New Graph'.



Arrange the windows so you can see the Digits display of pH.

Name _____ Class _____ Date _____

Lab Report - Activity B06: Organisms and pH

What Do You Think?

How do organisms maintain a stable internal environment? Why is maintaining a stable internal environment important?

Predictions:

Part IIIA: What will happen to the pH of the water as you add the acid?

Part IIIB: What will happen to the pH of the buffer solution as you add the acid?

Part IIIC: What will happen to the pH of the biological material as you add the acid?

Part IIID: What will happen to the pH of the water as you add the base (sodium hydroxide)?

Part IIIE: What will happen to the pH of the buffer solution as you add the base?

Part IIIF: What will happen to the pH of the biological material as you add the base?

Data Table

	0.1 M hydrochloric acid (HCl)				0.1 M sodium hydroxide (NaOH)			
Substance	Begin pH	End pH	ΔpH	% diff.	Begin pH	End pH	ΔpH	% diff.
Tap Water								
Buffer								
Egg White								
Gelatin								
Liver								
Potato								

Questions

1. What was the total pH change when HCl is added to your biological material? Compare this change to the pH change for the tap water and acid.

2. What was the total pH change when NaOH is added to your biological material? Compare this change to the pH change for the tap water and base.

3. Describe how each biological material responded to changes in pH.

4. How does the buffer solution respond to HCl and NaOH? Is it more like the tap water or a biological material?

5. Would buffers help or hinder the maintenance of a stable internal environment inside living tissue and cells? Explain.

6. Suggest a mechanism for pH regulation in organisms.

7. It is known that there are buffers in the human blood system. How might that be important for you?

Name _____ Class _____ Date _____

Activity B07: Membrane Permeability (pH sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Cell biology	B07 Membrane.DS	B07 Membrane	B07_MEMB.SWS

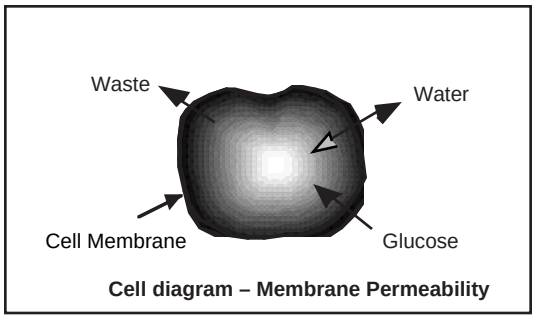
Equipment	Qty	Chemicals and Consumables	Qty
pH Sensor (CI-6507)	1	Buffer solution: high pH	100 mL
Base and support rod (ME-9355)	1	Buffer solution: low pH	100 mL
Beaker, 250 mL	4	Dialysis tubing, 15 cm length	2
Binder clip	2	Hydrochloric acid, 1.0 M	15 mL
Clamp, buret (SE-9446)	2	Sodium hydroxide, 1.0 M	15 mL
Graduated cylinder	1	String, 10 cm length	2
Magnetic stirrer & spin bar	1	Water, distilled	1 L
Wash bottle	1		
Protective gear	PS		

What Do You Think?

The purpose of this laboratory activity is to test the permeability of a membrane to hydrogen and hydroxide ions. Which do you think will move through the membrane more quickly: the hydrogen ion or the hydroxide ion?

Take time to answer this question in the Lab Report section.

Background



Cell diagram – Membrane Permeability

The contents of a cell are separated from the outside environment by a membrane. A biological membrane is the **cellular organelle** which isolates biochemical reactions, enzymes and genetic material essential to the vitality of the individual cell from the outside world. In some cases, the cell membrane acts as a passive barrier. When the membrane acts passively, the materials migrate in or out due to a difference in concentration (or osmotic gradient) between the inside and outside of the membrane.

In other cases, the membrane can be very selective to what passes from one side to the other. It is through the membrane that essential nutrients pass into and waste products pass out of the cell. An active membrane is also the anchorage site for many enzymes and coenzymes. The cell membrane is NOT a simple bag holding cell parts . The active nature of a biological membrane makes it a living part of the cell.

While membranes are selectively permeable, this experiment investigates the role of the cell as a passive mediator of diffusion of materials from one side of the membrane to the other.

SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

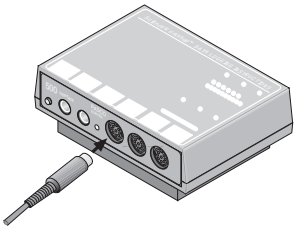
- **CAUTION:** Hydrochloric acid (HCl) and sodium hydroxide (NaOH) are irritants and can ruin clothing. Avoid contact to eyes and skin. DO NOT INGEST. Immediately flush spills with water for 15 minutes. Notify your teacher of any contact with HCl or NaOH.

Procedure

Use piece of dialysis tubing as a model of the cell membrane. Tie the tubing at one end, fill it with a chemical solution, and place it in distilled water. Use the pH Sensor to measure the change in pH of the distilled water around the dialysis tubing. Use *DataStudio* or *ScienceWorkshop* to record and display the data.

Compare the rate of change of pH around the dialysis tubing when the tubing contains an acid to the rate of change of pH around the dialysis tubing when the tubing contains a base.

PART I: Computer Setup



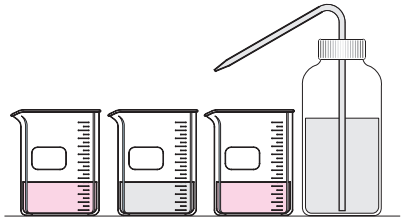
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the pH Sensor into Analog Channel A of the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B07 Membrane.DS	B07 Membrane	B07_MEMB.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The ScienceWorkshop file has a Digits display of pH and a Graph display of pH versus time.
- Data recording is set for ten measurements per second (10 Hz) and a 'Stop' condition at 200 seconds

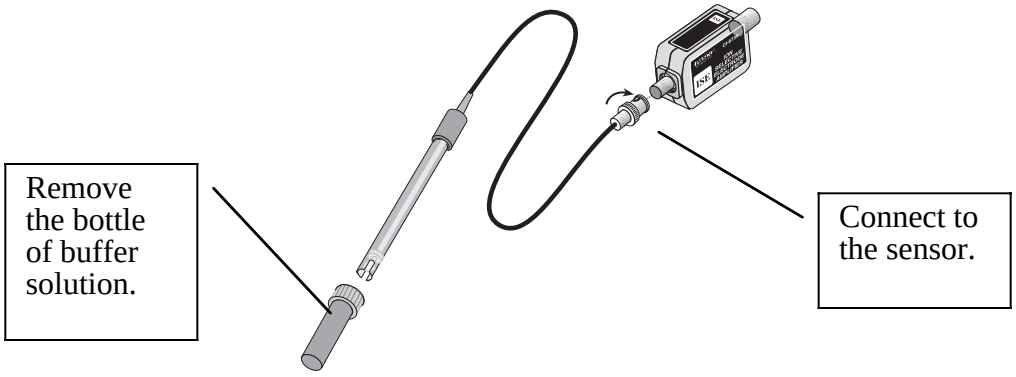
PART II: Sensor Calibration and Equipment Setup

Calibrate the Sensor



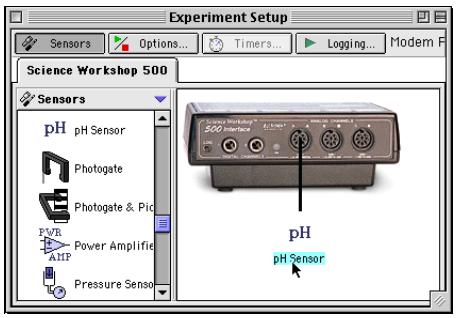
- To calibrate the pH Sensor you will need a wash bottle, distilled water, three beakers, and buffer solutions of high pH (e.g. pH 10) and low pH (e.g. pH 4). Put distilled water into the wash bottle and into one of the beakers. Put buffer solutions in the other two beakers.

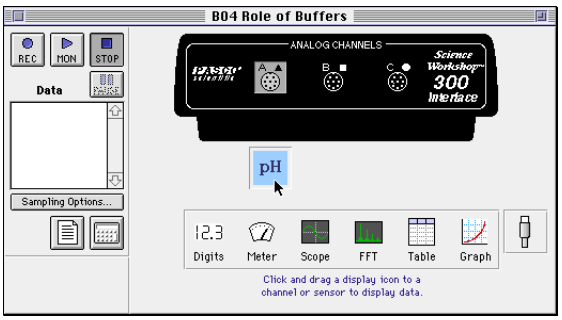
1. Remove the pH electrode from its bottle of buffer solution. Connect the electrode to the pH Sensor amplifier. To connect the electrode, push the BNC plug onto the receptacle on the Sensor amplifier and turn the BNC plug clockwise until it 'clicks' into place.



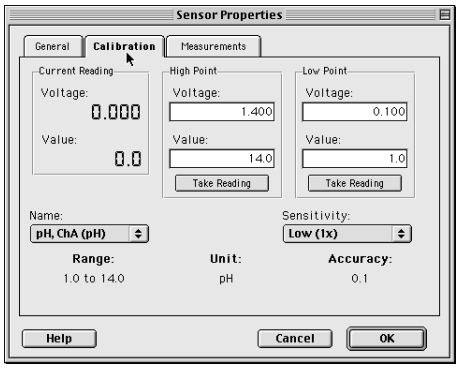
2. Use the wash bottle to rinse the end of the electrode. Soak the pH electrode in the beaker of distilled water for 10 minutes.

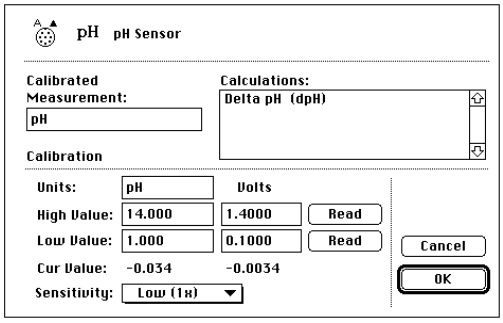
3. In the Experiment Setup window, double-click the pH Sensor icon.





- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab. In *ScienceWorkshop*, the Sensor Setup window will open.





4. Calibrate with the high pH buffer solution.

- Put the end of the pH electrode into the high pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution.

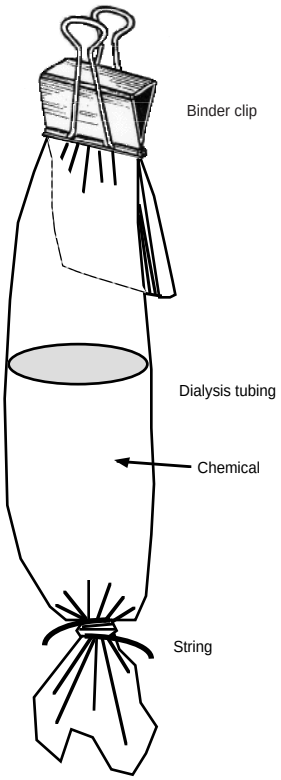
5. Thoroughly rinse the pH electrode with distilled water and dry it with a tissue.

6. Calibrate with the low pH buffer solution.

- Put the end of the H electrode in the low pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'Low Point' in *DataStudio* or the 'Read' button in the row for 'Low Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution. Click **OK** to return to the Experiment Setup window.

7. Thoroughly rinse the pH electrode with distilled water and dry gently.

Dialysis Bag Preparation



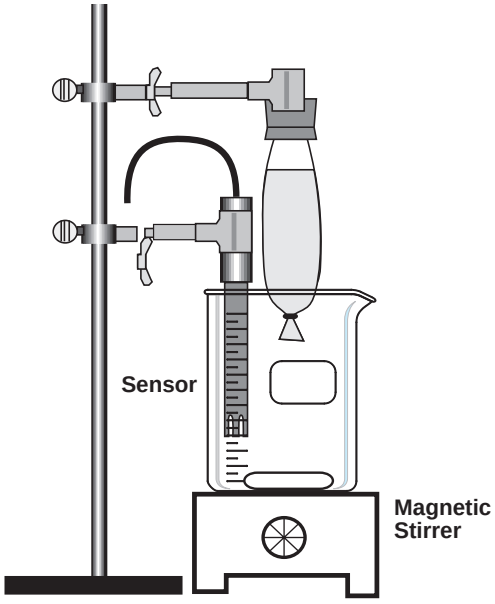
1. Cut two pieces of dialysis tubing about 15 centimeters (6 inches) long. Tie one end of one piece of dialysis tubing with string to form the tubing into a bag.
2. Add 15 mL of 1.0 Molar hydrochloric acid to one of the dialysis tubing bags. Place the exterior of the bag under a gentle stream of running water to wash off any acid that may have fallen on the exterior of the bag.
3. Fold over the open end of the bag. Place a binder clip over the folded end.
4. Prepare the second piece of dialysis tubing. Add 15 mL of 1.0 M sodium hydroxide instead of the hydrochloric acid. Rinse the outside of the second bag.

Do not allow the exteriors of the bags to come in contact with each other.

Set your bags aside on a labeled paper towel.

Equipment Setup

1. Put a spin bar in a 250-mL beaker and place the beaker on a magnetic stirrer.
2. Use a base and support rod and a clamp to mount the pH electrode so the end of the sensor is in the beaker
3. Position the sensor so the electrode cannot hit the spin bar.
4. Use a clamp to suspend the dialysis tubing bag containing hydrochloric acid *above* the beaker.



PART III: Data Recording

There are two parts to data recording. In the first part, use the dialysis tubing that contains hydrochloric acid. In the second part, use the dialysis tubing that contains sodium hydroxide.

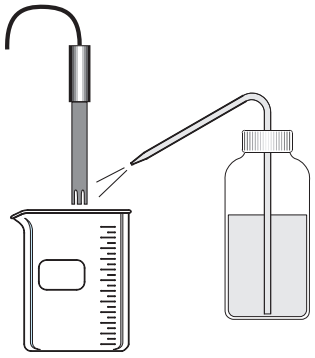
Follow the same basic procedure for both parts:

- Put distilled water into the beaker and turn on the magnetic stirrer.
- Start recording data.
- Lower the dialysis tubing into the water.

PART IIIA: Migration of Hydrogen Ions Through the Membrane

1. Put 100 mL of distilled water into the beaker. Turn on the magnetic stirrer. Get ready to lower the dialysis tubing into the water.
2. When you are ready, start recording data. (Hint: In *DataStudio*, click 'Start'. In *Scienceworkshop*, click 'REC'.) Allow the interface to record for about 5 seconds.
3. After about 5 seconds, lower the dialysis tubing bag containing the hydrochloric acid into the water.

- The pH Sensor will measure the pH of the water bath for 200 seconds and then data recording will stop automatically.



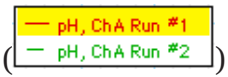
4. Dispose of the dialysis tubing bag and hydrochloric acid as directed.
5. Turn off the magnetic stirrer. Raise the pH electrode out of the water. Use the wash bottle to thoroughly rinse the pH electrode. Catch the rinse water in the beaker.
6. Remove the spin bar and dispose of the rinse water in the beaker as directed. Clean and dry the beaker.

Part IIIB: Migration of Hydroxide Ions Across a Membrane

1. Put 100 mL of distilled water in the beaker. Add the spin bar and place the beaker on the magnetic stirrer. Turn on the stirrer.
2 Position the pH electrode so it is in the water in the beaker, but does not hit the spin bar in the beaker.
3. Suspend the second dialysis tubing bag (with sodium hydroxide) above the water in the beaker.
4. Start recording data.
5. After about 5 seconds, lower the dialysis tubing bag containing the sodium hydroxide into the water.
6. After data recording stops automatically, dispose of the dialysis tubing bag and sodium hydroxide as directed.
7. Turn off the magnetic stirrer. Raise the pH electrode out of the water. Use the wash bottle to thoroughly rinse the pH electrode. Catch the rinse water in the beaker.
8. Remove the spin bar and dispose of the rinse water in the beaker as directed.

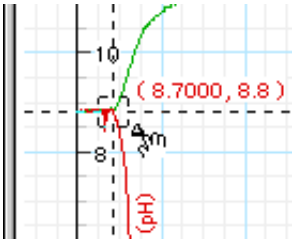
Analyzing the Data

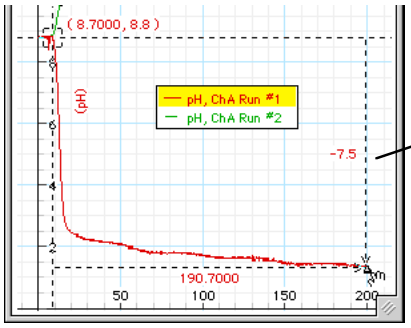
1. Use the Graph's built-in analysis tools to find the rate of change of pH for each run of data.

- Hint: In *DataStudio*, click 'Run #1' in the Graph legend (

) to make it the active run. Click the 'Smart Tool' button () in the Graph. The 'Smart Tool' displays the coordinates of its position as you move it to any position in the Graph display. When the 'Smart Tool' is on a data point, the 'x' coordinate is the time and the 'y' coordinate is the pH value at that point.

- Move the 'Smart Tool' to the point on Run #1 where the pH begins to change. Move the cursor to a corner of the 'Smart Tool'. Notice that the cursor changes to a delta shape (). Click-and-drag the delta cursor to the end of Run #1. The 'Smart Tool' shows the change in time and the change in pH between the starting and ending points.





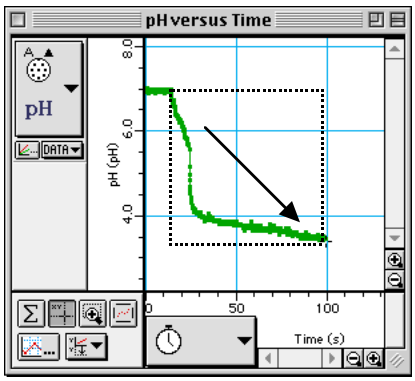
The 'Smart Tool' shows the change.

- In *ScienceWorkshop*, click the 'Smart Cursor' button () and move the cursor into the display area. The coordinates of the cursor are displayed in the label area of the Y-axis and the X-axis.

- Move the 'Smart Cursor' to the point on the first run where the pH begins to change. Click-and-drag the 'Smart Cursor' to the end of the run. The change in pH appears along the Y-axis and the change in time appears along the X-axis.

2. Record the change of pH and the change of time between the beginning and end points for the first run of data.

3. Repeat the process to find the change of pH and time for the second run of data.



Record your results in the Lab Report section.

Name _____ Class _____ Date _____

Lab Report - Activity B07: Membrane Permeability

What Do You Think?

The purpose of this laboratory activity is to test the permeability of a membrane to hydrogen and hydroxide ions. Which do you think will move through the membrane more quickly: the hydrogen ion or the hydroxide ion?

Data Table

Convert the amount of time to minutes. Calculate the 'Rate of change of pH' by dividing the change in pH by the amount of time. Record the 'Rate of change of pH'

Trial	Run	ΔpH	ΔTime	Rate of change of pH
HCl			min	pH/min
NaOH			min	pH/min

Questions

1. Which ion appears to have migrated across the membrane the fastest?

2. How could the migration rate of the ions be increased?

3. How could you use a series of ions to determine the size of the pores in the membrane?

Name _____ Class _____ Date _____

Activity B08: Rate of Photosynthesis (Low Pressure Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Cell biology	B08 Photosynthesis.DS	B08 Rate of Photosynthesis	B08_PHOT.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Low Pressure Sensor (CI-6534)	1	**Tubing (w/ sensor)**	
Base and support rod (ME-9355)	1	Protective gear	PS
Beaker, 1000 mL	1		
Bowl	1	**Chemicals and Consumables**	**Qty**
Clamp, buret (SE-9446)	1	Aluminum foil, 10 by 10 cm sheet	1
Connector (640-030)	1	*Elodea* plant	1
Knife or single edge razor blade	1	Glycerin	1 mL
Lamp,150 watt (SE-9473)	1	Green food coloring	1 mL
Stopper, one-hole, for test tube	1	Sodium bicarbonate, $NaHCO_3$ solution	50 mL
Test tube, 20 by 150 mm	1	Water	1 L

What Do You Think?

The purpose of this laboratory activity is to measure the rate of photosynthesis for a plant, *Elodea*, when it is exposed to different light conditions. What do you think the rate of photosynthesis will be when the plant is exposed to green light compared to the rate of photosynthesis when the plant is exposed to white light?

Take time to answer this question in the Lab Report section.

Background

The process of photosynthesis is the chemical pathway by which all plants and some protists and monerans make food from carbon dioxide, water and sunlight. The entire photosynthetic pathway is a complex series of enzyme transformations that take place in chloroplasts. During the transformation, hydrogen from water is added to molecules of carbon dioxide to make carbohydrates. The generalized equation for this process is given below:

$$6CO_2 + 6H_2O \xrightarrow{light/chlorophyll} C_6H_{12}O_6 + 6O_2$$

carbon dioxide + water ----------> carbohydrate + oxygen

During the "light reactions" (or light-dependent) cycle of the photosynthesis process, chloroplasts use sunlight energy to split water molecules into hydrogen ions and oxygen (**photolysis**). The reaction produces ATP and $NADPH_2$ and releases oxygen as a "waste product". This process is the source of nearly all the oxygen in Earth's atmosphere. (Scientists have shown by using isotopes as tracers that the released oxygen comes from the oxygen in the water molecule rather than the oxygen from carbon dioxide.) The light-dependent reaction takes place within the membrane of thylakoids that make up the grana.

The light-independent reaction reduces carbon dioxide, utilizing the ATP and $NADPH_2$ supplied during the light-dependent cycle. The light-independent reaction takes place in the stroma of the chloroplast.

The overall effect is that carbon dioxide is combined with hydrogen to produce carbohydrate molecules – mainly sugars, starch, and cellulose.

The rate of photosynthesis depends on several conditions including which colors of light are available to be absorbed by the pigments in a plant leaf. The principal pigment in advanced

plants is chlorophyll *a*. Chlorophyll *b*, carotenes, and xanthophylls play a secondary role. They transfer the energy they absorb to chlorophyll *a* for use in photosynthesis. The different pigments absorb different colors of light.

When a plant is exposed to light, it undergoes photosynthesis and aerobic cellular respiration at the same time. When the plant is not exposed to light, it undergoes aerobic cellular respiration (and uses oxygen), but it does not undergo photosynthesis.

SAFETY REMINDERS

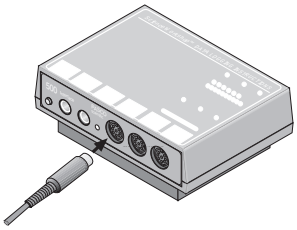
- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

Use the Low Pressure Sensor to measure the change in pressure in a test tube containing an aquatic plant, *Elodea*, that is exposed to white light, and then measure the change in pressure when the plant is exposed to green light. Use *DataStudio* or *ScienceWorkshop* to record and display the pressure versus time.

When photosynthesis occurs in the *Elodea*, the released oxygen increases the pressure in the test tube. When aerobic cellular respiration occurs, oxygen is consumed and the pressure in the test tube decreases slightly. (Carbon dioxide released during respiration is easily dissolved in water.). When both photosynthesis and aerobic cellular respiration occur, the pressure increases, but not as much as it would due to photosynthesis alone.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Low Pressure Sensor's DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B08 Photosynthesis.DS	B08 Rate of Photosynthesis	B08_PHOT.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Digits display of pressure and a Graph display of pressure versus time.

Data recording is set at 1 measurement per second and a 'Stop' condition at 600 seconds.

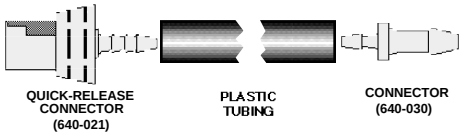
Name _____ Class _____ Date _____

PART II: Sensor Calibration and Equipment Setup

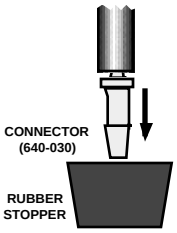
- **You do not need to calibrate the Pressure Sensor for this activity since you will measure the change in pressure.**

The sensor is durable, but it is designed to be used with non corrosive gases such as air, helium, nitrogen, etc. Do not let the sensor get wet. The sensor comes with a length of plastic (polyurethane) tubing and several "quick-release" style connectors.

Connect the Tubing



- You will need one "quick-release" connector (included with the sensor), a connector to fit into the rubber stopper (640-030), about 15 cm of plastic tubing (included with the sensor), a one-hole rubber stopper, and glycerin.



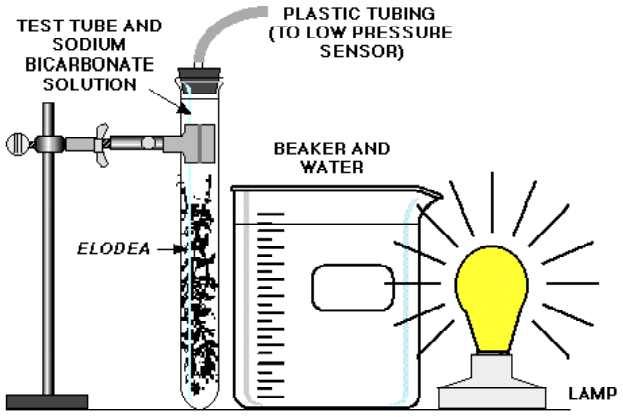
1. Put a drop of glycerin on the barb end of the quick-release connector and insert the barb into one end of the plastic tubing.
2. Put a drop of glycerin on the smaller diameter end of the other connector. Insert the small diameter end into the plastic tubing.
3. Put a drop of glycerin on the larger diameter end of the connector that will go into the rubber stopper, and insert the end into the rubber stopper.

Prepare the Elodea

4. Fill a bowl with water, and hold the *Elodea* plant under the water. Make fresh cuts on the stem ends of a generous quantity of *Elodea*. Place the *Elodea* with the cut ends up into a test tube.
5. Fill the test tube to about 2 cm below the top with 3% sodium bicarbonate solution.
6. Use the buret clamp to mount the test tube on the base and support rod. Put the rubber stopper into the top of the test tube.

Equipment Setup

7. Fill the beaker with plain water and place the beaker next to the test tube. The water in the beaker acts as a heat absorber.



8. Place a 150-watt lamp next to the beaker. The tube, beaker, and lamp should be as close together as possible. DON'T TURN ON THE LAMP YET!

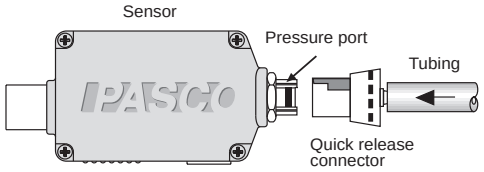
PART III: Data Recording

There are four parts of data recording.

Part	Description
A	Plant exposed to white light
B	Plant exposed to no light
C	Plant exposed to green light
D	Plant exposed to no light

PART IIIA: Plant Exposed to White Light

1. When you are ready to record data, connect the tubing to the Low Pressure Sensor. Push the quick-release connector on the other end of the plastic tubing onto the pressure port connector on the sensor. Turn the connector clockwise until it clicks.



Turn on the lamp.

2. Start recording data. (Hint: In *DataStudio*, click 'Start'. In *ScienceWorkshop*, click the REC button.) Be careful not to bump the tubing or loosen the rubber stopper.

• Data recording stops automatically after ten minutes.

3. CAREFULLY disconnect the tubing from the Low Pressure Sensor to release the pressure in the tubing, and then re-connect the tubing.

PART IIIB: Plant Exposed to No Light

1. For the second trial, turn off the lamp. CAREFULLY wrap the test tube containing the *Elodea* with aluminum foil so that no light can reach the plants.
2. Start recording data.

• Data recording stops automatically after ten minutes.

3. After the data recording ends, remove the aluminum foil from the test tube.
4. CAREFULLY disconnect the tubing from the sensor to release the pressure in the tubing, and then re-connect the tubing.

PART IIIC: Plant Exposed to Green Light

1. Add enough green food coloring to the water in the beaker so the water has a medium green color.
2. Turn on the lamp.
3. Start recording data.

• Data recording stops automatically after ten minutes.

4. CAREFULLY disconnect the tubing from the sensor to release the pressure in the tubing, and then re-connect the tubing.

PART IIID: Plant Exposed to No Light

1. For the final trial, turn off the lamp. CAREFULLY wrap the test tube containing the *Elodea* with aluminum foil so that no light can reach the plants.
2. Start recording data.

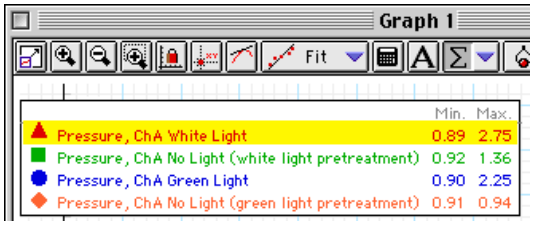
- Data recording stops automatically after ten minutes.

3. After the data recording ends, remove the aluminum foil from the test tube.
4. CAREFULLY disconnect the tubing from the sensor to release the pressure in the tubing.

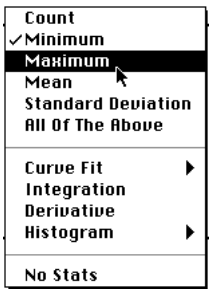
Analyzing the Data

1. Use the Graph display to determine the minimum and maximum pressure for each run of data.

- Hint: In *DataStudio*, click the 'Statistics' menu button (). Minimum and Maximum are selected by default. The values for 'Min.' and 'Max.' are shown in the legend in the Graph.



- In *ScienceWorkshop*, click the Graph display to make it active. Click the 'Statistics' button () to open the statistics area on the right side of the Graph display. Click the 'Statistics Menu' button () in the statistics area and select 'Minimum'. Repeat the process and select 'Maximum'.



2. Record your values for the minimum and maximum pressure for each run in the Data Table in the Lab Report section.
3. Calculate the difference between the minimum and maximum pressure for Run #1 and record this as Net Change – Photosynthesis (White Light).
4. Calculate the difference between the minimum and maximum pressure for Run #2 and record this as Net Change – Aerobic Cellular Respiration (White Light).
5 Add the net change during photosynthesis to the net change during aerobic cellular respiration. Record the sum as Gross Change – Photosynthesis (White Light).
6. Calculate the Rate of Photosynthesis –White Light (per hour) by multiplying Gross Change – Photosynthesis (White Light) by 6.

7. Calculate the difference between the minimum and maximum pressure for Run #3 and record this as Net Change – Photosynthesis (Green Light).
8. Calculate the difference between the minimum and maximum pressure and record this as Net Change – Aerobic Cellular Respiration (Green Light).
9. Add the net change during photosynthesis to the net change during aerobic cellular respiration. Record the sum as Gross Change – Photosynthesis (Green Light).
10. Calculate the Rate of Photosynthesis –Green Light (per hour) by multiplying Gross Change – Photosynthesis (Green Light) by 6.

Record your results in the Lab Report section.

Name _____ Class _____ Date _____

Lab Report - Activity B08: Rate of Photosynthesis

What Do You Think?

The purpose of this laboratory activity is to measure the rate of photosynthesis for a plant, *Elodea*, when it is exposed to different light conditions. What do you think the rate of photosynthesis will be when the plant is exposed to green light compared to the rate of photosynthesis when the plant is exposed to white light?

Data Table 1: White Light

Item	Value
Maximum Pressure (White Light - Run #1)	kPa
Minimum Pressure (White Light - Run #1)	kPa
Net Change – Photosynthesis (White Light)	kPa

Maximum Pressure (no light - Run #2)	kPa
Minimum Pressure (no light - Run #2)	kPa
Net Change – Aerobic Cellular Respiration (no light - Run #2)	kPa

Gross Change - Photosynthesis (White Light)	kPa
Rate of Photosynthesis – White Light (per hour)	kPa/hour

Data Table 2: Green Light

Item	Value
Maximum Pressure (Green Light - Run #3)	kPa
Minimum Pressure (Green Light - Run #3)	kPa
Net Change – Photosynthesis (Green Light)	kPa

Maximum Pressure (no light - Run #4)	kPa
Minimum Pressure (no light - Run #4)	kPa
Net Change – Aerobic Cellular Respiration (no light - Run #4)	kPa

Gross Change - Photosynthesis (Green Light)	kPa
Rate of Photosynthesis – Green Light (per hour)	kPa/hour

Questions

1. The rate of photosynthesis for green light is what percentage of the rate of photosynthesis for white light?

2. Does photosynthesis use green light?

3. Carotenes tend to absorb blue light. Chlorophyll *a* and chlorophyll *b* tend to absorb blue and red light. Why do red and blue light, but not green light, promote photosynthesis?

Name _____ Class _____ Date _____

Activity B09: Transpiration in a Plant Leaf (Low Pressure Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Cell biology	B09 Transpiration. DS	B09 Transpiration	B09_TRAN.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Low Pressure Sensor (CI-6534)	1	Pipette (or eye dropper)	1
Base and support rod (ME-9355)	1	**Tubing (w/ sensor)**	
Bowl	1	Protective gear	PS
Clamp, buret (SE-9446)	1	**Chemicals and Consumables**	**Qty**
Clamp, three-finger (SE-9445)	1	Glycerin	1 mL
Connector (w/ sensor)	1	Petroleum jelly	2 – 3 g
Electric fan	1	Plant seedling	1
Knife or razor blade (single edge)	1	Water	1 L

What Do You Think?

The purpose of this activity is to study the rate of transpiration in a plant. How will the rate of transpiration under normal conditions compare to the rate of transpiration on a windy day?

Take time to answer this question in the Lab Report section.

Background

Transpiration is the evaporation of water from a plant surface. ***Guttation*** is the loss of water from the ends of vascular tissues at the margins of leaves. The amount of water needed by plants for growth and maintenance of tissue is small compared to the amount that is lost through the transpiration and guttation. If water lost from leaves is not replaced by water transported up from the plant roots, the plant will wilt and die.

The transport of water up the **xylem** tissue in plants is controlled by differences in the concentration of water molecules (water potential or pressure difference). In a root, minerals transported from the soil accumulate in the xylem vessels of the **vascular tissues** of the stem. This, along with the negative pressure (tension) in the xylem tissues, lowers the water potential of the xylem. Because of this difference, water will move into the xylem by osmosis, forcing fluid up the xylem vessels. This upward movement results in root pressure, but this pressure only moves water a short distance up the xylem. Transpiration "pulls" the water and dissolved minerals (xylem sap) further up the xylem.

Transpiration involves a linked chain of processes: a) The concentration of water molecules in the air surrounding the leaf is lower than the concentration of water molecules in the moist air surrounding the leaf's **mesophyll** cells, resulting in the movement of water vapor through the leaf's **stomatal** openings into the surrounding air; b) the concentration of water molecules in the moist air spaces surrounding the mesophyll cells is now decreased, resulting in evaporation of water from the outside of the mesophyll cells; c) evaporation of water from the outside of the mesophyll cells causes water to be drawn from the inside of the mesophyll cell to its outer surface; d) the mesophyll cells now have a lower water potential than the xylem, resulting in water moving from the xylem to the mesophyll cells; e) the water potential in the xylem at the top of the plant becomes less than the water potential in the xylem in the lower part of the plant; f) through the combined forces of the differences in water potential, **cohesion** of water molecules due to hydrogen bonds, **adhesion** of the water molecules to the walls of the xylem cells, and root pressure, the upward force on the water molecules becomes greater than the force

of gravity, and the water moves upward in the plant; g) as water moves up the xylem, the water potential in the roots' xylem tissue decreases; h) when water potential in the roots becomes less than that of the surrounding soil, water moves into the roots, allowing the transpiration process to continue.

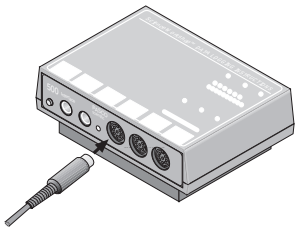
SAFETY REMINDER	THINK SAFETY ACT SAFELY BE SAFE!
• Be careful as you handle the knife or razor blade used in this activity.	

For You To Do

Connect a small plant to a Low Pressure Sensor. The plant's leaves will experience transpiration – the evaporation of water from their surface. Use the Low Pressure Sensor to measure the change in pressure at the end of the plant stem as a result of transpiration. Then use a fan to blow air across the plant's leaves and use the sensor to measure the change in pressure. Use *DataStudio* or *ScienceWorkshop* to record and display pressure versus time.

Compare the rate of transpiration under normal conditions to the rate of transpiration when air blows across the leaves.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Low Pressure Sensor DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B09 Transpiration. DS	B09 Transpiration	B09_TRAN.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document will open with a Graph display of Pressure versus Time and a Digits display showing pressure.
- Data recording is set for 1 measurement per second.

Name _____ Class _____ Date _____

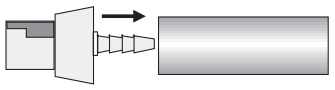
PART II: Sensor Calibration and Equipment Setup

- **You do not need to calibrate the Pressure Sensor for this activity since you will measure the change in pressure.**
- **Equipment Setup is easier with two people: one to hold the plant seedling in place, and one to attach the plastic tubing and clamp.**

The sensor is durable, but it is designed to be used with non corrosive gases such as air, helium, nitrogen, etc. Do not let the sensor get wet. The sensor comes with a length of plastic (polyurethane) tubing and several "quick-release" style connectors.

Prepare the Tubing

- You will need one "quick-release" connector (included with the sensor), about 35 cm of plastic tubing (included with the sensor), and glycerin.

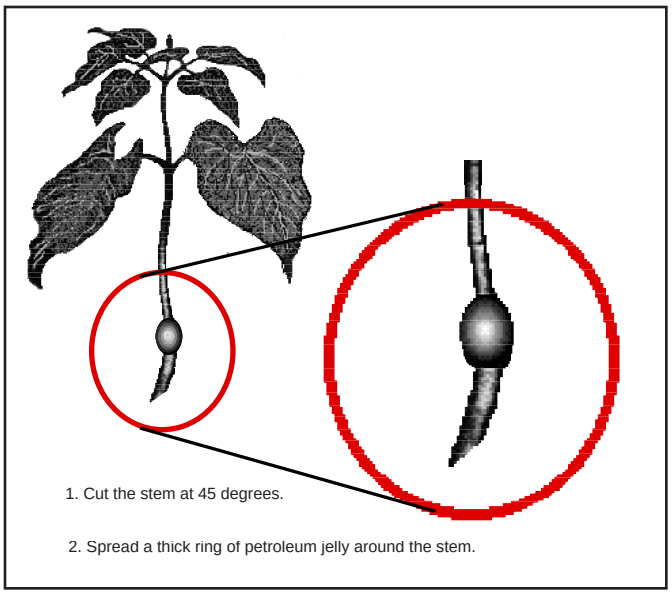


1. Put a drop of glycerin on the barb end of the quick-release connector and insert the barb into one end of the plastic tubing.

Prepare the Plant

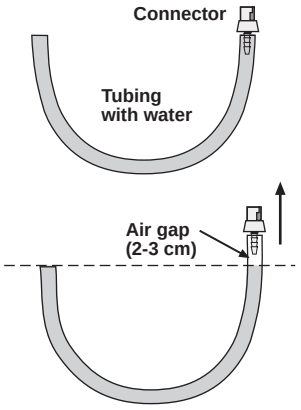
- You will need a plant, a knife or single edge razor blade, a bowl of water, and petroleum jelly.

2. Use a knife or single edge razor blade to cut the stem of a plant seedling 2-3 cm above the soil. Immediately immerse the cut end of the seedling in a bowl of water.
3. Shave the freshly cut end of the stem to a 45-degree angle, keeping the cut end submerged.
4. Make a thick ring of petroleum about 1 cm wide on the plant stem about 5 cm from cut end. Make sure no jelly touches the cut end.



Put Water into the Tubing

5. Bend the piece of plastic tubing into a U-shape. Use a pipette or an eye dropper to fill the tubing with water.
6. Hold the tubing over the bowl of water. Slowly raise the end of the tubing that has the quick-release connector until there is a 2 or 3 cm air gap beneath the connector. (Note: Some water will spill out of the other end of the tubing.)



Put the Plant into the Tubing

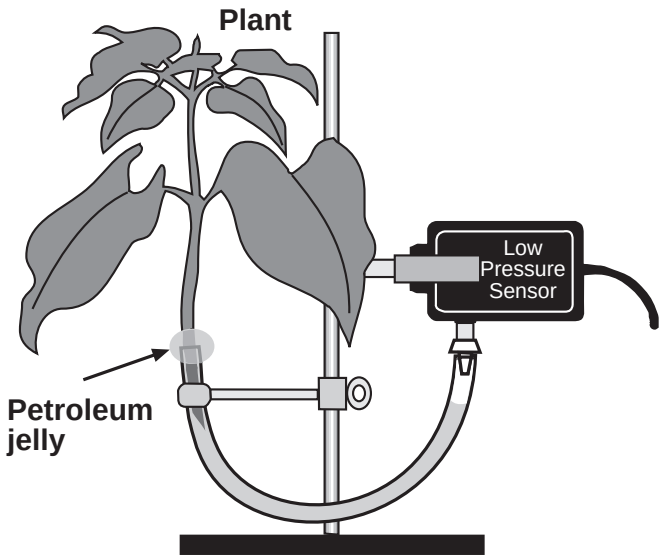
7. Put your thumb over the end of the tubing and put the end of the tubing into the bowl of water. Remove your thumb and insert the plant stem, cut-end first, into the tubing.

   Avoid creating any air bubbles in the tubing.

8. Spread the petroleum jelly around the end of the tube to create an airtight seal between the top edge of the plastic tubing and the plant stem.

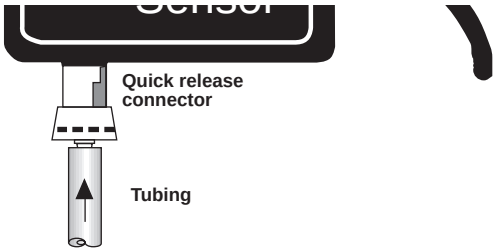
> • **NOTE: If air bubbles do form around the cut end of the stem, pull the tubing away from the stem. Use the eyedropper to refill the open end of the tubing with water. Put the stem back into the water in the tubing.**

9. Secure the plant seedling in an upright position with a clamp and the base and support rod.



10. Mount the Low Pressure Sensor to the support rod with the three-finger clamp. The pressure port should be above the cut end of the stem. This will prevent water from entering the pressure sensor.

11. Align the quick-release connector on the tubing with the connector on the pressure port of the sensor. Push the connector onto the port, and then turn the connector clockwise until it clicks (about one-eighth turn). Make sure that no water enters the Low Pressure Sensor. There should be a 2 to 3-cm air pocket between the water level and the pressure port.



Name _____ Class _____ Date _____

PART III: Data Recording

There are two parts to data recording. First, record the change in pressure while the plant is under 'normal' conditions. Second, use a fan to blow air across the leaves of the plant.

PART IIIA: Transpiration – No Fan

- **Note: DO NOT MOVE the Low Pressure Sensor up or down on the support rod while recording data.**

1. Start data recording. Hint: In DataStudio, click 'Start'. In ScienceWorkshop, click 'REC'.
2. Record data for at least 500 seconds.
3. Stop data recording after 500 seconds.

PART IIIB: Transpiration – Fan

1. Place the electric fan at least 1 meter from the plant seedling. Turn the fan on to a low setting so it blows a light breeze over the seedling.
2. Record data for at least 500 seconds.

Optional

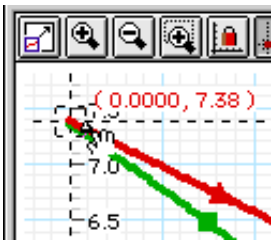
Determine the effect of the following environmental factors on the rate of transpiration:

- Light intensity
- Humidity
- Temperature

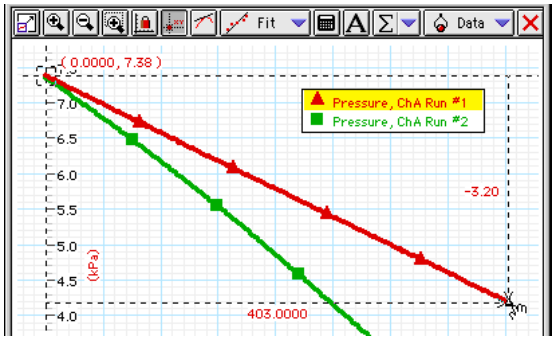
Analyzing the Data

1. Use the Graph's built-in analysis tools to find the rate of change of pressure for each run of data.

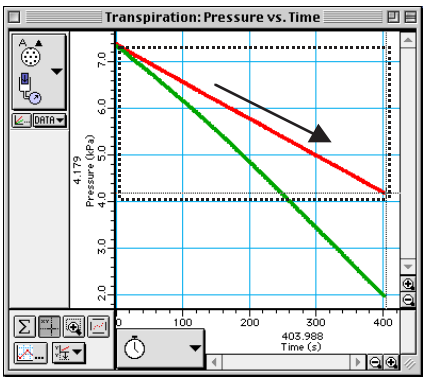
- Hint: In *DataStudio*, click 'Run #1' in the Graph legend to make it the active run. Click the 'Smart Tool' button () in the Graph. The 'Smart Tool' displays the coordinates of its position as you move it to any position in the Graph display. When the 'Smart Tool' is on a data point, the 'x' coordinate is the time and the 'y' coordinate is the pressure value at that point.



- Move the 'Smart Tool' to the point on Run #1 where the pressure begins to change. Move the cursor to a corner of the 'Smart Tool'. Notice that the cursor changes to a delta shape (). Click-and-drag the delta cursor to the end of Run #1. The 'Smart Tool' shows the change in time and the change in pressure between the starting and ending points.



- In *ScienceWorkshop*, click the 'Smart Cursor' button () and move the cursor into the display area. The coordinates of the cursor are displayed in the label area of the Y-axis and the X-axis.
- Move the 'Smart Cursor' to the point on the first run where the pressure begins to change. Click-and-drag the 'Smart Cursor' to the end of the run. The change in pressure appears along the Y-axis and the change in time appears along the X-axis.



2. Record the change of pressure and the change of time between the beginning and end points for the first run of data.
3. Repeat the process to find the change of pressure and time for the second run of data (transpiration with a fan).

- Hint: In *DataStudio*, click the second run of data in the Graph legend. In *ScienceWorkshop*, click the Experiment menu and select 'Run #2' from the end of the menu.

4. Calculate the rate of transpiration in kilopascals per minute. (Hint: Convert the time from seconds to minutes.)

Record your results in the Lab Report section.

Name _____ Class _____ Date _____

Lab Report - Activity B09: Transpiration

What Do You Think?

The purpose of this activity is to study the rate of transpiration in a plant. How will the rate of transpiration under normal conditions compare to the rate of transpiration on a windy day?

Data Table

Transpiration Run	ΔP (kPa)	Δt (s)	Rate of Transpiration (kPa/min)
No Fan			
With Fan			

Questions

1. What was the rate of pressure change in the plastic tubing? Does a decrease in pressure in the tubing correspond to an increase or a decrease in water loss through the seedling's stomates? Explain.

2. Did the fan affect the rate of pressure change? Explain how the fan affects transpiration. What natural phenomena does the fan mimic?

3. Describe some adaptations that enable plants to minimize water loss from their leaves?

Name _____ Class _____ Date _____

Activity B10: Regulation of Body Heat (Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Physiology	B10 Body Heat.DS	B11 Regulation of Body Heat	B11_BODY.SWS

Equipment Needed	**Qty**	**Equipment Needed**	**Qty**
Temperature Sensor (CI-6505A)	2	Small fan*	1
Clock	1	Protective gear	PS
Gloves	1 pair	**Chemicals and Consumables**	**Qty**
Mittens	1 pair	Rubber bands, small	3
Ruler	1	Tape	1 roll

(*or hair dryer that blows unheated air)

What Do You Think?

How does your body regulate (control) its internal temperature?

Take time to write an answer to this question in the Lab Report section.

Background

Your body produces metabolic heat as a by-product of every reaction that occurs inside you. The more active you are, the more heat your body produces. Your body radiates the heat generated by metabolic reactions to maintain your internal temperature. Your internal temperature must remain relatively constant because your enzymes work best at 37 ˚C.

SAFETY REMINDER

- Follow all safety instructions.

For You To Do

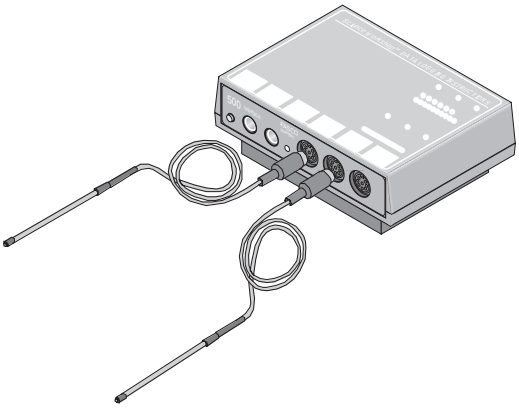
For this activity, use one Temperature Sensor to measure the temperature of the air just above the skin of the palm of your hand, or the temperature of the skin itself on the palm of your hand. Use the second Temperature Sensor to measure the temperature of the environment in which your hand is placed (called the **ambient temperature**). Use *DataStudio* or *ScienceWorkshop* to record the data from both Temperature Sensors.

Compare the normal temperature of the air near your skin to the **ambient temperature** for several different conditions: air flowing over the skin, hand in glove with no air flowing over the glove, and hand in glove with air flowing over the glove.

Note: This activity requires two people.

PART I: Computer Setup

1. Connect the interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of one Temperature Sensor into Channel A and the DIN plug of the other Temperature Sensor into Channel B on the interface.



3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B10 Body Heat.DS	B11 Regulation of Body Heat	B11_BODY.SWS

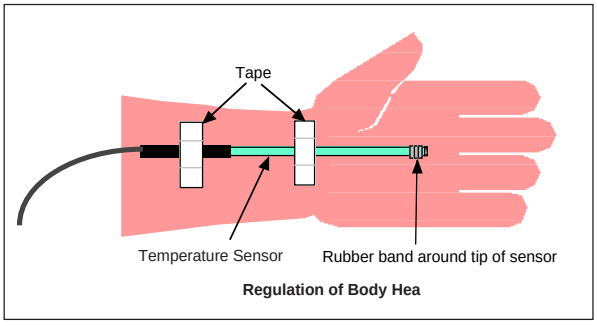
- The *ScienceWorkshop* file has graph display of temperature vs time.
- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.

PART II: Sensor Calibration and Equipment Setup

You do need to calibrate the Temperature Sensors.

Equipment Setup

1. Wrap a small rubber band around the Channel A Temperature Sensor, about 1/4” from the tip. The rubber band will keep the tip of the sensor from touching your skin during the parts of the data recording process when you will be measuring the temperature of the air next to your skin.
2. Tape the Channel A Temperature Sensor to the palm of your hand. Align the sensor cable with your arm so you can put a glove or mitten on your hand over the sensor.



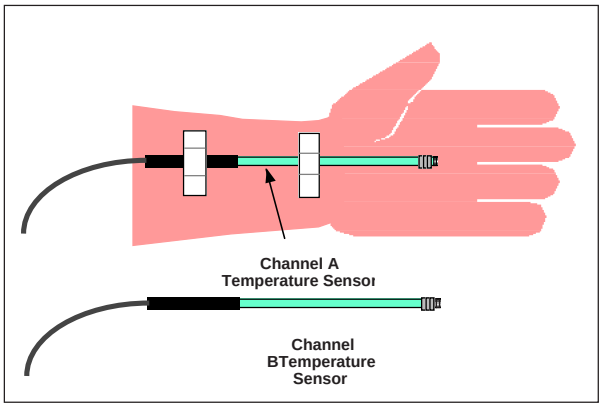
3. Flex your hand backward in such a way that the rubber band is NOT touching the palm. Don’t let the palm of your hand make contact with the rubber band on the tip of the sensor until you are ready to record data. (Your goal is to start data recording with both Temperature Sensors at approximately the same temperature.)

Why should both sensors be at approximately the same temperature at the beginning?

Name _____ Class _____ Date _____

PART IIIA: Data Recording – Effects of Air Flow, No Skin Contact

1. Hold the Channel B Temperature Sensor in a position parallel to your hand but so its tip is not touching anything.
2. Flex your hand forward so the skin on the palm of your hand makes contact with the rubber band on the tip of the Temperature Sensor, but not the tip of the sensor itself.



Why should the sensor be close to the skin but not touching it?

3. Start recording data.

Watch the two temperatures on the Digits displays.

4. AFTER TWO MINUTES, turn the fan on. Place your hand and the Channel B Temperature Sensor in the flow of air about 30 centimeters (12 inches) in front of the fan. Continue to record data for another two minutes.
5. Stop recording data.
6. Turn off the fan. Flex your hand backwards so the tip of the sensor is away from the palm of your hand.
7. Monitor the temperature data. Watch both Digits displays until both sensors show approximately the same temperature (within a few degrees).

Why do the two sensors need to return to the same temperature?

8. When both sensors are at approximately the same temperature, stop monitoring the data and prepare for the next part of the data recording process.

PART IIIB: Data Recording – Effects of Air Flow, Direct Skin Contact

1. Carefully remove the rubber band from the tip of the sensor.
2. Flex your hand forward so the skin of the palm of your hand makes direct contact with the tip of the sensor. Place the Channel B sensor so it is parallel to your hand but its tip is not touching anything.
3. Start recording data.
4. AFTER TWO MINUTES, turn the fan on. Place your hand and the Channel B Temperature Sensor in the flow of air about 30 centimeters (12 inches) in front of the fan. Continue to record data for another two minutes.
5. Stop recording data.
6. Turn off the fan. Flex your hand backward so the tip of the sensor is away from the palm of your hand.
7. Start monitoring the temperature data. Watch both Digits displays until both sensors show approximately the same temperature.
8. When both sensors are at approximately the same temperature, stop monitoring the data and prepare for the next part of the data recording process.

PART IIIC: Data Recording – Hand in Glove

1. With your hand flexed away from the tip of the sensor, wrap the rubber band around the tip of the sensor again.
2. Flex your hand forward so the skin on the palm of your hand makes contact with the rubber band on the tip of the sensor. Carefully but quickly put the glove on your hand over the sensor. Put the Channel B Temperature Sensor so it is parallel to your gloved hand, but its tip is not touching anything.
3. Start recording data.
4. AFTER TWO MINUTES, turn the fan on. Place your gloved hand and the Channel B Temperature Sensor in the flow of air about 30 centimeters (12 inches) in front of the fan. Continue to record data for another two minutes
5. Stop recording data.
6. Turn off the fan.
7. Remove the glove. Carefully remove the Channel A Temperature Sensor from your hand.

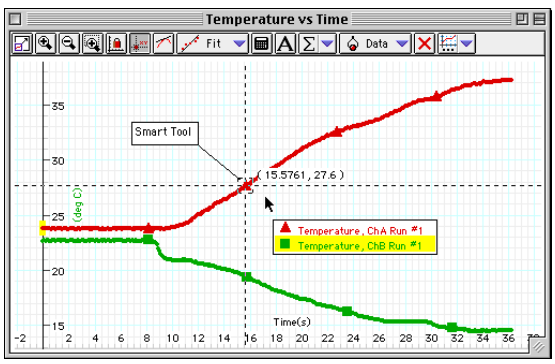
Name _____ Class _____ Date _____

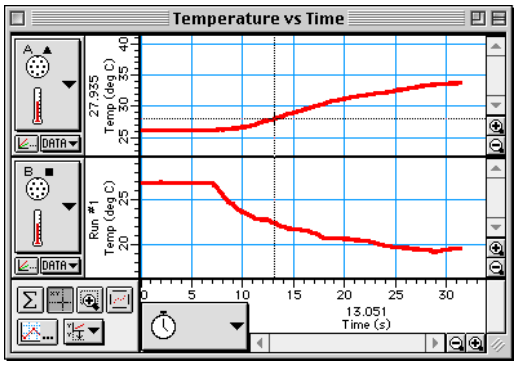
Analyzing the Data

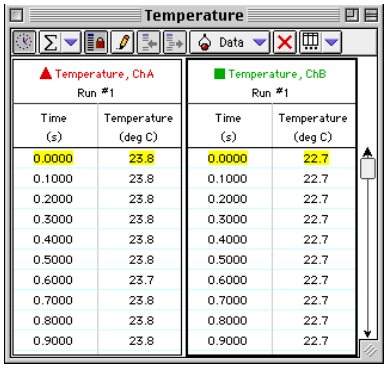
1. Set your Graph so it displays your first run of data (**No Skin Contact**) for both Temperature Sensor A and Temperature Sensor B.

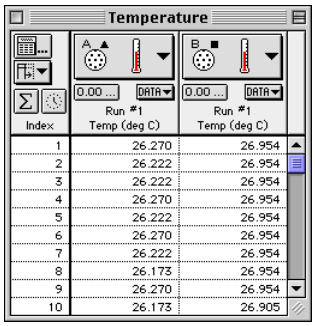
2. Find the temperature at the beginning of the plots for Temperature Sensor A and for Temperature Sensor B.

- Hint: In a Graph display, use the Smart Tool in *DataStudio* or the Smart Cursor in *ScienceWorkshop* or use a Table display and look at the first row in the display.









3. Use display's tools to find the maximum temperature during the first two minutes (before the fan is turned on) in the plots for Temperature Sensor A and Temperature Sensor B.

- Hint: In a Table display, set the statistics to show the maximum value.

4. After you find the maximum temperature, use the display's tools to find the minimum temperature during the last two minutes (after the fan is turned on) in the plots for both temperatures.

- Hint: In a Table display, set the statistics to show the minimum value.

5. Set your Graph so it displays your second run of data (Direct Skin Contact) and repeat the data analysis process to find the beginning, maximum, and minimum temperatures for both the skin and the air.

6. Set your Graph so it displays your third run of data (Hand in Glove) and repeat the data analysis process to find the beginning, maximum, and minimum temperatures for both the skin and the air for the third run of data.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B10: Regulation of Body Heat

What Do You Think?

How does your body regulate (control) its internal temperature?

Data Table

	'Hand' Temperature Sensor (Ch. A)			'Air' Temperature Sensor (Ch. B)		
Run #	1	2	3	1	2	3
Initial Temperature						
Maximum Temperature (before fan)						
Minimum Temperature (during fan)						

Questions

Cooling Effects of Air Flow

1. For the first run of data before the fan is turned on, describe the temperature from the 'hand' Temperature Sensor compared to the temperature from the 'air' Temperature Sensor when the 'hand' sensor is near the palm of the hand, but not in contact with the skin.

2. For the first run of data, what happens to the temperature from the 'hand' Temperature Sensor when the fan is turned on?

3. For the first run of data, what happens to the temperature from the 'air' Temperature Sensor when the fan is turned on?

4. Compare the second run of data to the first run of data. What difference (if any) is there when the tip of the 'hand' Temperature Sensor is in contact with the skin of the palm of the hand?

5. How does air flow on your hand make your hand cooler? Does perspiration play a role in cooling?

Effect of Gloves

6. How did the glove affect the temperature near your skin before the fan is turned on?

7. Did you feel a cooling effect when you placed your gloved hand in front of the fan? More or less than without the glove? Why?

8. What happened to the temperature from the 'hand' Temperature Sensor when the fan is turned on?

9. Explain the insulation concepts that make gloves work.

Name _____ Class _____ Date _____

Activity B11: Exercise and Pulse Rate (Heart Rate Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Physiology	B11 Pulse Rate.DS	B10 Exercise & Pulse Rate	B10_EPR.SWS

Equipment Needed	**Qty**
Heart Rate Sensor (CI-6543A)	1
Chair or couch	1

NOTE: This activity requires the person whose heart rate is being measured to perform exercise (e.g., jogging in place) for several minutes. Do NOT perform this activity if vigorous activity will cause discomfort or be hazardous to the health of the person.

What Do You Think?

The purpose of this laboratory exercise is to determine how mild exercise affects heart rate and recovery time. What do you predict will happen to the heart rate after mild exercise?

Take time to write an answer to this question in the Lab Report section.

Background

You probably have experienced the sensation of your heart beating strongly when you participated in physical activity. Your nervous system monitors your entire body and signals your heart to beat faster in response to increased activity. **Pulse rate** measures how fast your heart is beating. **Recovery time** is how long it takes for the heart to return to its normal resting rate.

SAFETY REMINDER

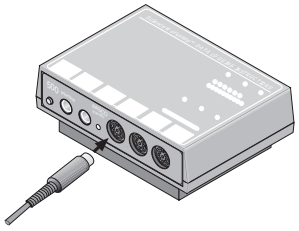
- Follow all safety instructions.

For You To Do

Use the Heart Rate Sensor to measure pulse rate before mild exercise and after mild exercise. Use *DataStudio* or *ScienceWorkshop* to record and display the pulse rate versus time.

Compare pulse rate at rest to pulse rate after mild exercise. Estimate the approximate amount of recovery time needed for the pulse rate to return to its normal resting rate.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Heart Rate Sensor DIN plug into Analog Channel A on the interface.
3. Open the *ScienceWorkshop* file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B11 Pulse Rate.DS	B10 Exercise & Pulse Rate	B10_EPR.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document opens with a Digits display and a Table display for Heart Rate and a Graph display for Heart Rate versus Time.
- Data recording is set at 50 measurements per second (50 Hz) with a Stop condition at 60 seconds.

PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

- You do not need to calibrate the Heart Rate Sensor.
- The Heart Rate Sensor is a small photogate-type device that sends light through your ear lobe. As your heart beats, the amount of blood in the capillaries near the surface of the skin will vary. The amount of light that passes through your ear lobe varies as the amount of blood in the capillaries varies. The sensor measures changes in light transmittance of your ear lobe. The change in transmittance corresponds to beats of the heart. The *DataStudio* or *ScienceWorkshop* program automatically calculates the heart beat rate.

Check the Heart Rate Sensor:

1. Attach the clip to your ear lobe. There is a small light bulb in the clip, so you may feel warmth on your ear lobe.
2. Monitor the heart rate.

- Hint: In *DataStudio*, select ‘Monitor Data’ from the Experiment menu. In *ScienceWorkshop*, click the ‘MON’ button.

3. Watch the plot of voltage versus time in the Graph display, and the value of heart rate in the Digits display. It may take a few seconds for the readings to stabilize. If the voltage versus time plot is “flat”, try adjusting the clip on your ear lobe.
4. When you are sure that the Heart Rate Sensor is working properly, click the STOP button.

Name _____ Class _____ Date _____

- NOTE: This activity requires the person whose heart rate is being measured to perform exercise (e.g., jogging in place) for several minutes. Do NOT perform this activity if vigorous activity will cause discomfort or be hazardous to the health of the person.

PART III: Data Recording

There are three parts to data recording.

- Measure your resting heart rate.
- Exercise.
- Measure your heart rate after exercise.

PART IIIA: Resting Heart Rate

1. Relax in a chair for about a minute. When you are ready, start recording data.

- Hint: In *DataStudio*, click 'Start'. In *ScienceWorkshop*, click 'REC'.
- Data collection begins immediately, but the value of heart rate in the Digits display may not change for a few seconds. Data recording will end automatically after 60 seconds.

PART III: Heart Rate After Exercise

In this trial you will measure heart rate after exercise.

1. Before you begin recording, remove the ear clip from your ear. Stand up and begin to "jog in place". Continue to jog vigorously for at least two minutes.
2. At the end of two minutes, sit down. Re-attach the ear clip to your ear.
3. Start recording data. Click **REC** to record data during the recovery period after exercise.

- Data recording ends automatically after 60 seconds.

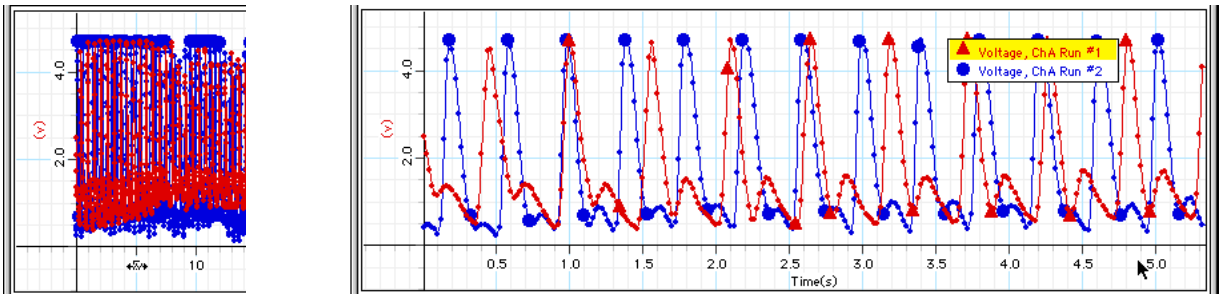
4. Remove the ear clip from your ear.

Analyzing the Data

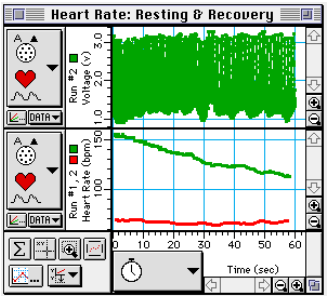
View the Graph of Heart Rate

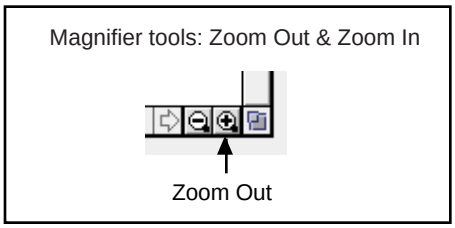
1. Set up your Graph display to view the data from the Heart Rate Sensor.

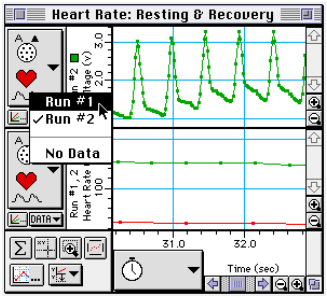
- Hint: In *DataStudio*, rescale the horizontal axis so the range is from 0 to about 5 seconds. Place the cursor over a number on the horizontal axis. Notice that the cursor changes to a spring shape ( ). Click-and-drag the cursor to the right or left to change the horizontal axis scale.



- Hint: In *ScienceWorkshop*, click the 'Zoom Out Magnifier' tool in the lower right corner of the Graph several times to rescale the X-axis.







Determine the Heart Rate Before and After Exercise

2. Use the built-in statistics in the Table display to determine the heart rate before exercise.

- Hint: In *DataStudio*, click the 'Statistics' menu button (). Minimum and Maximum are selected by default. Click 'Mean' to add it to the statistics displayed at the bottom of the Table display.

- Hint: In *ScienceWorkshop*, click the 'Statistics' button (). The Statistics area at the bottom of the Table will display Min (minimum), Max (maximum), Mean, and Std. Dev (standard deviation)

3. Record you minimum, maximum, and mean heart rate for Run #1 (before exercise) in the Lab Report section.

4. Use the built-in statistics to determine the heart rate after exercise.

- Hint: Use the 'Data' menu button to select Run #2. (In *DataStudio*, click (

). In *ScienceWorkshop*, click (

).

5. Record you minimum, maximum, and mean heart rate for Run #2 (after exercise) in the Lab Report section.

6. Calculate your recovery rate after exercise. Determine the change in heart rate (subtract the minimum heart rate from the maximum heart rate). You recorded data for 60 seconds (one minute) so the change in heart rate is your Recovery Rate per minute. Record your recovery rate in the Lab Report section.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B11: Exercise & Pulse Rate

What Do You Think?

The purpose of this laboratory exercise is to determine how mild exercise affects heart rate and recovery time. What do you predict will happen to the heart rate after mild exercise?

Data Table

Heart Rate	Resting	After Exercise
Minimum	bpm	bpm
Maximum	bpm	bpm
Mean	bpm	bpm

Recovery Rate = _____ bpm/min

Questions

1. What was the control in your experiment?

2. What is the influence of exercise on your heart rate?

3. How do different types of exercise affect heart rates and recovery rates among the students in your class? Explain.

4. Are there any differences between male and female heartbeat rates and recovery rates among the students of your class?

Optional — Calculating Pulse Rate Using the Wrist Method

1. Calculate your pulse using the wrist method. Place the index and middle fingers of your left hand on your right wrist. Find your pulse.
2. Count the number of heart beats for a specified time interval.

   Number of Beats = _____

   Time Interval = _____ sec
3. Determine your pulse rate.

   Pulse Rate = _____ beats/sec
4. Repeat steps 2-3 twice and determine an average pulse rate. Compare to the value determined using the interface and the Heart Rate Sensor.

Name _____ Class _____ Date _____

Activity B12: Exercise and Respiration Rate (Respiration Rate Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Physiology	B12 Respiration.DS	B12 Respiration Rate	B12_RESP.SWS

Equipment Needed	Qty
Respiration Rate Sensor (CI-6535)	1

NOTE: This activity requires the person whose respiration rate is being measured to perform exercise (e.g., jogging in place) for several minutes. Do NOT perform this activity if vigorous activity will cause discomfort or be hazardous to the health of the person.

What Do You Think?

The purpose of this laboratory activity is to record respiration rate (breathing rate) before and after exercise. What do you predict will happen to the respiration rate after mild exercise?

Take time to write an answer to this question in the Lab Report section.

Background

Respiration rate (number of breaths per unit of time) depends on several factors: altitude, lung capacity, health, and level of activity. Higher altitudes and levels of activity would tend to increase respiration rate. Larger lung capacity and generally good health would tend to decrease respiration rate.

SAFETY REMINDER

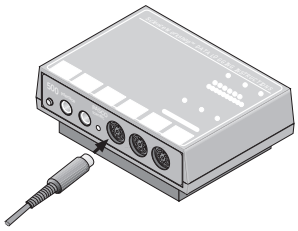
- Follow all safety instructions.

For You To Do

The Respiration Rate Sensor consists of two parts: a Low Pressure Sensor and a respiration rate belt. In this activity, use the Respiration Rate Sensor to measure the change in pressure created as the chest cavity expands and relaxes during breathing. Use DataStudio or *ScienceWorkshop* to record and display the change in pressure, and a calculation of the respiration (breath) rate.

Compare the respiration rate before exercise to the respiration rate during a recovery period after exercise.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Low Pressure Sensor to Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B12 Respiration.DS	B12 Respiration Rate	B12_RESP.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document will open with a Graph display of Voltage versus Time and Breath Rate versus Time and a Digits display of Breath Rate.

Data recording is set at 10 measurements per second (10 Hz).

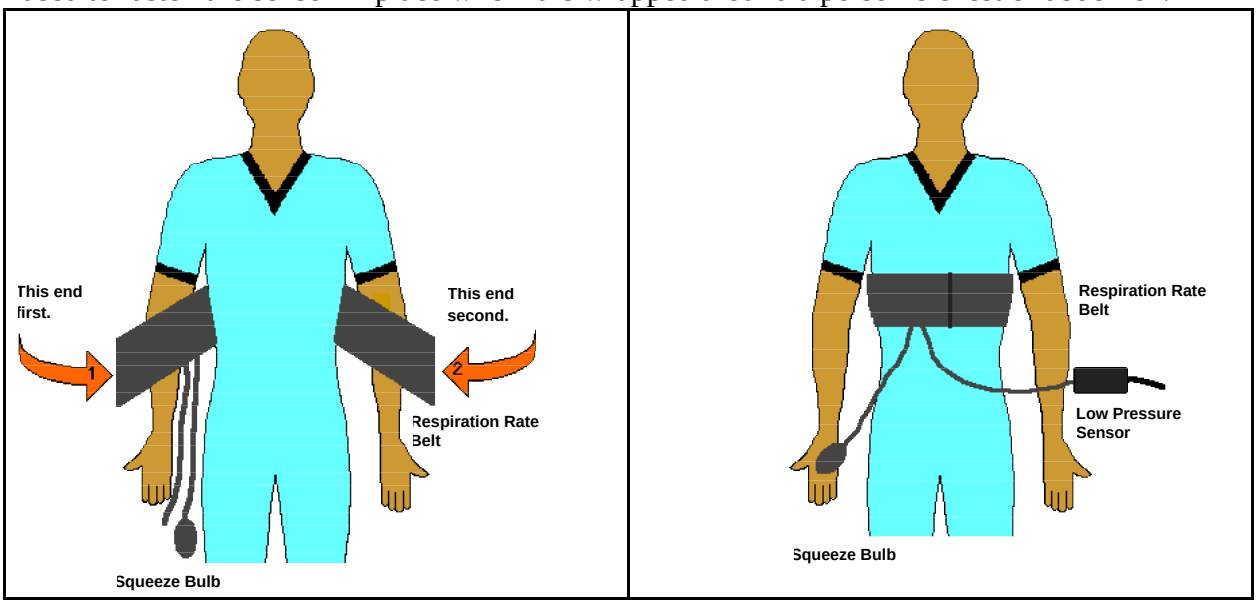
PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

- You do not need to calibrate the Respiration Rate Sensor.

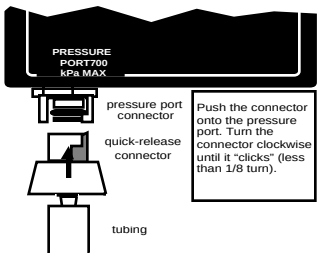
Using the Respiration Rate Sensor

- The Respiration Rate Sensor is a wide nylon belt that can be wrapped around a person's abdomen or chest region. The belt has a rubber bladder inside that can be inflated using the attached squeeze bulb. The squeeze bulb has a thumbscrew valve to allow air in the bladder to be released. The rubber bladder has a tube that can be connected to the "quick-release" connector of the Low Pressure Sensor.
- The section of the Respiration Rate Sensor that contains the rubber bladder has a rectangular piece of "pile" material attached to one side. The other end of the nylon belt has strips of "hook" material attached to one side. The "hook" and "pile" materials can be used to fasten the sensor in place when it is wrapped around a person's chest or abdomen.



Name _____ Class _____ Date _____

Equipment Setup



1. Place the belt of the Respiration Rate Sensor around the chest of the person whose breathing rate is going to be measured. Arrange the belt so that the rubber bladder is in front. Use the "hook" and "pile" materials on the ends of the belt to fasten it snugly in place.
2. Connect the end of the tube that comes from the rubber bladder to the quick-release connector on the pressure port of the Low Pressure Sensor.
3. Close the thumbscrew valve (turn it clockwise) on the squeeze bulb of the Respiration Rate Sensor. Use the squeeze bulb to inflate the rubber bladder (between twenty and thirty 'squeezes'). The belt should be tight but not uncomfortable.

PART III: Data Recording

NOTE: This activity requires the person whose respiration rate is being measured to perform exercise (e.g., jogging in place) for several minutes. Do NOT perform this activity if vigorous activity will cause discomfort or be hazardous to the health of the person.

There are three parts to data recording

- Measure the resting respiration rate.
- Measure respiration rate during exercise.
- Measure respiration rate after exercise.

PART IIIA: Resting Respiration Rate

1. Start recording data.

   - Hint: In *DataStudio*, click 'Start' (

). In *ScienceWorkshop*, click 'REC' (

) to begin recording data.

     Have the person whose respiration is being measured breath normally. The values of data will be recorded in the Graph display and shown in the other display.

2. After sixty seconds, stop recording data.

PART IIIB: Respiration Rate During Exercise

1. Start recording data again, but have the person whose respiration is being measured exercise by jogging in place or "stepping-in-time".
2. After sixty seconds, stop recording data.

NOTE: Have the person continue to jog or "step-in-time" until you begin PART IIIC.

PART IIIC: Respiration Rate After Exercise

1. Have the person stop exercising. As soon as the person stops exercising, start recording data.
2. Have the person sit down or stand very still. The person should continue to breathe as normally as possible (don't hold your breath or try to breath more rapidly than is comfortable).
3. After about sixty seconds, stop recording data.

Analyzing the Data

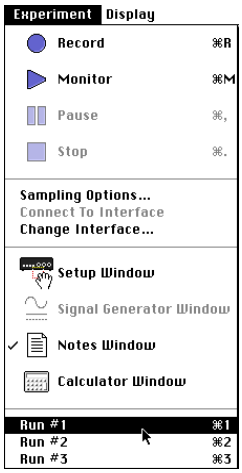
1. Set up your Graph display to view the data from the Respiration Rate Sensor.

- Hint: In *ScienceWorkshop*, click the 'Autoscale' button () to resize the graph to fit the data.

2. Use the built-in analysis tools to determine the minimum, maximum and mean Respiration Rate for each run of data.

- Hint: In *DataStudio*, click the plot of 'Respiration Rate' to make it active. In the Graph toolbar, click the 'Statistics Menu' button () and select 'Mean'. The 'Minimum' and 'Maximum' are already selected by default. The values for 'Min', 'Max' and 'Mean' appear in the Legend.

- Hint: In *ScienceWorkshop*, use the Experiment menu to select 'Run #1'.



In the Graph display, click the 'Statistics' button ()to open the statistics area. In the plot of Respiration Rate click the 'Statistics Menu' button () and select 'All of the Above'. The values for 'Count', minimum x and y, maximum x and y, the mean of x and y, and the standard deviation of x and y appear in the statistics area. The y-values correspond to the respiration rate.

Use the Experiment menu to select 'Run #2' and then 'Run #3'.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B12: Exercise and Respiration Rate

What Do You Think?

The purpose of this laboratory activity is to record respiration rate (breathing rate) before and after exercise. What do you predict will happen to the respiration rate after mild exercise?

Data Table

Data Run/Breath Rate	Minimum	Maximum	Mean
Run #1: resting			
Run #2: exercise			
Run #3: recovery			

Questions

1. How does the respiration rate for exercise compare to the respiration rate for resting?

2. How does the respiration rate for recovery change over time?

Name _____ Class _____ Date _____

Activity B13: EKG – Demonstration (EKG Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Physiology	B13 EKG Demo.DS	B13 EKG Demonstration	B13_EKGD.SWS

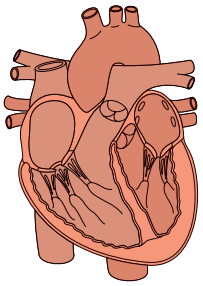
Equipment Needed	Qty	Chemicals and Consumables	Qty
EKG Sensor (CI-6539)	1	electrode patches (inc. with sensor)	3
chair or couch	1	paper towel	1

What Do You Think?

How does the electrical activity of the heart muscle look?

Take time to write an answer to this question in the Lab Report section.

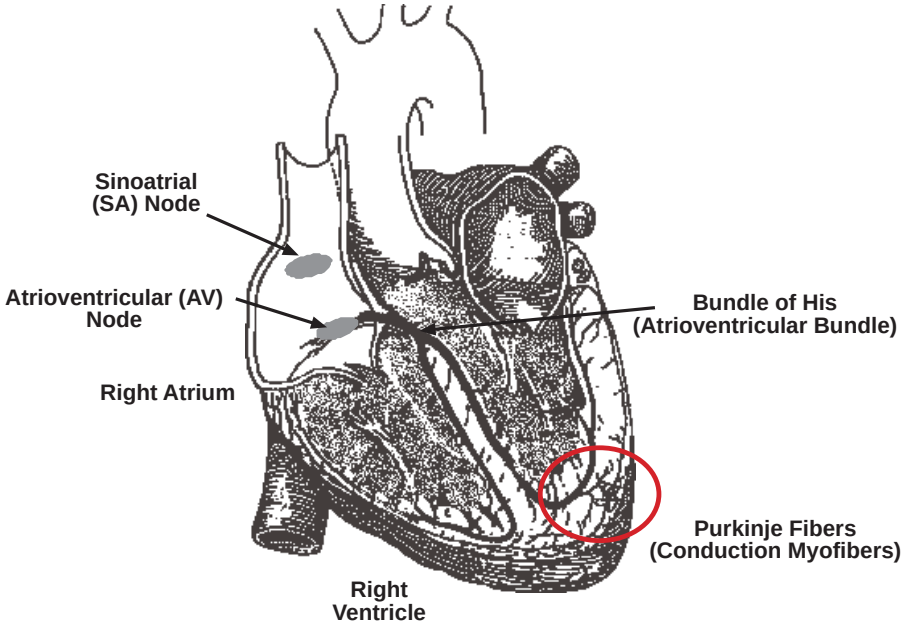
Background



The EKG (electrocardiogram) sensor measures cardiac electrical potential waveforms (voltages) produced by the heart as its chambers contract. Heart muscle cells are polarized at rest. This means the cells have a very small potential difference (voltage) from one side to the other of their cell membranes.

The cells of the heart can depolarize without an outside stimulus; that is, they will depolarize spontaneously. The group of cells that depolarize the fastest is called the **pacemaker** (also known as the *sinoatrial* or **SA node**). These cells are located in the **right atrium**. All the cells of both atria depolarize and contract almost simultaneously.

The atria and the ventricles are isolated from each other electrically. Therefore, the depolarization of the atria does not directly affect the ventricles. Another group of cells in the right atria called the *atrioventricular* or **AV node** sends electrical signals from the atria down a special bundle of conducting fibers (called the **Bundle of His**) to the ventricles. In the muscle wall of the ventricles are the **Purkinje fibers**, which are a special system of muscle fibers that bring depolarization to all parts of the ventricles almost simultaneously. This process causes a small time delay and so there is a short pause after the atria contract before the ventricles contract. Because the cells of the



heart muscle are interconnected, this wave of depolarization, contraction and repolarization spreads across all the connected muscle of the heart.

When a portion of the heart is polarized and the adjacent portion is depolarized this creates an electrical current that moves through the body. The changes in these currents can be measured, amplified, and plotted over time. The EKG is the graphical representation of the measured electrical currents.

Note: An excellent text about the electrocardiogram and other phenomena of bioelectricity is Physics with Health Science Applications by Paul Peter Urone, ©1986, John Wiley & Sons, Inc., New York.

The Electrocardiogram

One part of a typical EKG (electrocardiogram) is a 'flat line' or trace indicating no detectable electrical activity. This line is called the **Isoelectric line**. Deviation from this line indicates electrical activity of the heart muscles.

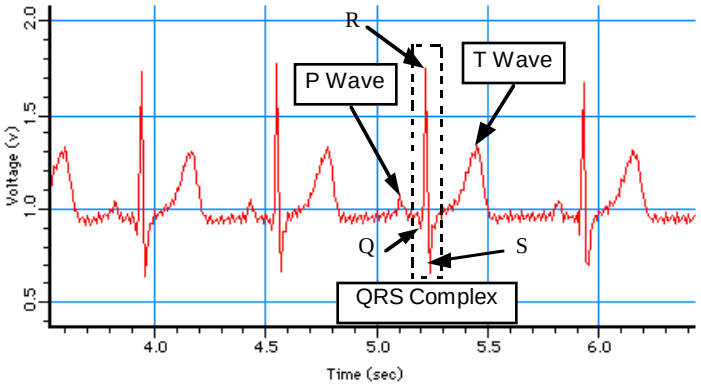
The first deviation from the Isoelectric line in a typical EKG is an upward pulse following by a return to the Isoelectric line. This is called the **P wave** and it lasts about 0.04 seconds. This wave is caused by the depolarization of the atria and is associated with the contraction of the atria.

After a return to the Isoelectric line there is a short delay while the heart's **AV node** depolarizes and sends a signal along the atrioventricular bundle of conducting fibers (**Bundle of His**) to the **Purkinje fibers**, which bring depolarization to all parts of the ventricles almost simultaneously.

After the AV node depolarizes there is a downward pulse called the **Q wave**. Shortly after the Q wave there is a rapid upswing of the line called the **R wave** followed by a strong downswing of the line called the **S wave** and then a return to the Isoelectric line. These three waves together are called the **QRS complex**. This complex is caused by the depolarization of the ventricles and is associated with the contraction of the ventricles.

After a short period of time the chemical ions that have been involved in the contraction migrate back to their original locations. The movement of these ions generates an upward wave that then returns to the Isoelectric line. This upward pulse is called the **T wave** and indicates repolarization of the ventricles.

The sequence from P wave to T wave represents one heart cycle. The number of such cycles in a minute is called the **heart rate** and is typically 70-80 cycles (beats) per minute at rest.



Name _____ Class _____ Date _____

Some typical times for portions of the EKG are given below.

If your EKG does not correspond to the above numbers, DO NOT BE ALARMED! These numbers represent typical averages and many healthy hearts have data that fall outside of these parameters. To read an EKG effectively takes considerable training and skill. This sensor is NOT intended for medical diagnoses.

P-R interval... 120-200 milliseconds (0.120 to 0.200 seconds)

QRS interval... under 100 milliseconds (0.100 seconds)

Q-T interval... under 380 milliseconds (0.380 seconds)

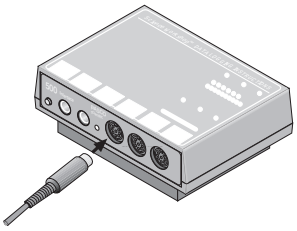
SAFETY REMINDER

- Follow all safety instructions.

For You To Do

Use the EKG sensor to measure the electric potential associated with the polarization and depolarization of heart muscle tissue during the heart's contractions. Use *DataStudio* or *ScienceWorkshop* to record and display the heart voltage signal (electrocardiogram) and to calculate heart rate based on the peaks and valleys in the EKG trace.

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the EKG sensor's DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B13 EKG Demo.DS	B13 EKG Demonstration	B13_EKGD.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* file opens with a Graph display of "EKG Voltage (mV) " versus "Time (s)" on one plot, and "Heart Rate (bpm)" versus "Time (s)" on the second plot.
- Data recording is set for 100 samples per second (100 Hz). Data recording stops automatically at 15 seconds.

PART II: Sensor Calibration and Equipment Setup

About the EKG Sensor

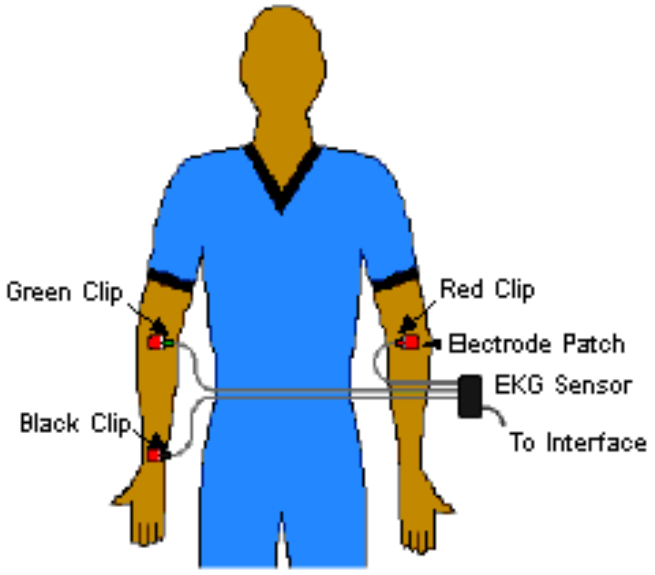
The sensor consists of the EKG amplifier case and a cable for connecting to the interface. Three electrode leads are attached to the amplifier case. The circuitry isolates the user from the possibility of electrical shock in two ways. The sensor signal is transmitted through an opto-isolation circuit. Power for the sensor is transferred through a transformer. The circuitry protects against accidental over-voltages of up to 4,000 volts.

The sensor is designed to produce a signal between 0 and five volts with 1 volt being the Isoelectric line. Deviation from the Isoelectric line indicates electrical activity. The shape and periodicity of the signal is of primary importance, so the sensor does not need to be calibrated.

Use three electrode patches. The electrodes can be reused but they tend to absorb moisture (they are very hygroscopic), and therefore, reuse is not recommended. The electrodes should be kept in an airtight, clean, dry container for storage. Because the electrical signal produced by the heart and detected at the body's surface is so small, it is very important that the electrode patch makes good contact with the skin. Scrub the areas of skin where the patches will be attached with a paper towel to remove dead skin and oil.

1. Peel three electrode patches from the backing paper. Firmly place the first electrode on the right wrist. Place a second electrode on the right elbow pit. Place the third electrode on the left elbow pit.

- Place each electrode so it is on the inside part of the arm (closer to the body) and the tab on the edge of the electrode patch points down, so the wire of the sensor can hang freely without twisting the edge of the electrode patch.



2. Connect the micro alligator clips from the sensor to the tabs on the edges of the electrode patches.

- Connect the black (or "reference") alligator clip to the wrist electrode patch. This is the reference point for the "Isoelectric" line (baseline).
- Connect the green (or negative) alligator clip to the right elbow electrode patch.
- Connect the red (or positive) alligator clip to the left elbow electrode patch.

There are several different ways to connect the EKG sensor. This simple arrangement is appropriate for the classroom.

Name _____ Class _____ Date _____

PART III: Data Recording - Resting EKG

- The person whose EKG is being measured should remain calm and relaxed. Encourage the person to breathe normally.

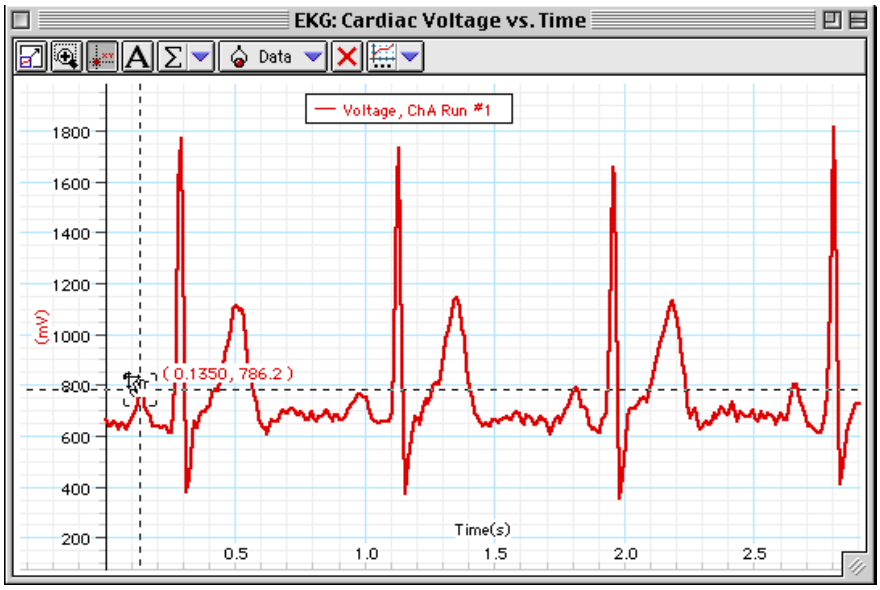
1. When everything is ready, start recording data. The values of data will be recorded in the Graph display. Data recording stops automatically at 15 seconds.

Muscle activity in the arms causes electrical signals that may overwhelm the cardiac signals. Remind the person whose EKG is being measured to relax and remain as still as possible. If the EKG trace is very irregular, remove the electrode patches. Use rubbing alcohol to more thoroughly clean the areas of skin where the electrodes will be placed. After the alcohol evaporates, put new electrode patches on the cleaned areas of skin.

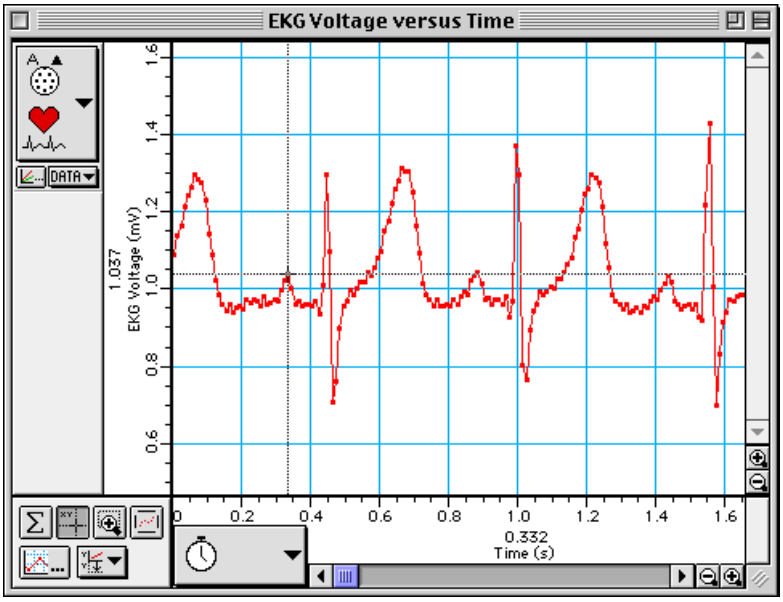
Analyzing the Data

1. Zoom in on a region of the Graph display that includes three or four complete heart cycles.
2. Use the built-in analysis tools to measure the peaks of the **P**, **Q**, and **R** waves. Record the times in the Lab Report section.

- Hint: In *DataStudio*, click the 'Smart Tool' button ().The 'Smart Tool' displays the coordinates of its position as you move it to any position in the Graph display. When the 'Smart Tool' is on a data point, the 'x' coordinate is the time and the 'y' coordinate is the voltage value at that point.



- In *ScienceWorkshop*, click the 'Smart Cursor' button () and move the cursor into the display area. The coordinates of the cursor are displayed in the label area of the Y-axis and the X-axis.



3. Calculate the **P-R** interval and record the time.
4. Measure the peak of the **S** wave. Record the time.
5. Calculate the **Q-R-S** interval and record the time.
6. Measure the peak of the **T** wave. Record the time.
7. Calculate the overall **Q-T** interval and record the time.
8. Using the graph's built-in statistics tools, find the minimum, maximum, and mean for the Heart Rate.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B14: EKG – Demonstration

What Do You Think?

How does the electrical activity of the heart muscle look?

Data Table: Interval Analysis

Item	Time
P wave begins	sec
Q wave begins	sec
R wave begins	sec
S wave begins	sec
T wave begins	sec

Item	Time	Typical Time
P-R interval	sec	sec
QRS interval	sec	sec
Q-T interval	sec	sec

Data Table: Heart Rate Analysis

Item	Rate (bpm)
Minimum	
Maximum	
Mean	

Questions

1. Compare your values for the P-R, Q-R-S, and Q-T intervals to the ones given earlier. What could explain the differences?

2. How does the heart rate measured by the EKG compare to your heart rate measured with the Heart Rate sensor or by the direct measurement of the pulse at the wrist or neck? What could explain the differences?

Name _____ Class _____ Date _____

Activity B14: EKG – Rest and Exercise (EKG Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Physiology	B14 EKG Exercise.DS	B14 EKG Rest & Exercise	B14_EKGR.SWS

Equipment Needed	Qty	Chemicals and Consumables	Qty
EKG Sensor (CI-6539)	1	**electrode patches (inc. with sensor)**	1
chair or couch	1	paper towel	3
clock	1		

NOTE: This activity requires the person whose EKG is being measured to perform mild exercise (e.g., jogging in place) for three minutes. Do NOT perform this activity if vigorous activity will cause discomfort or be hazardous to the health of the person.

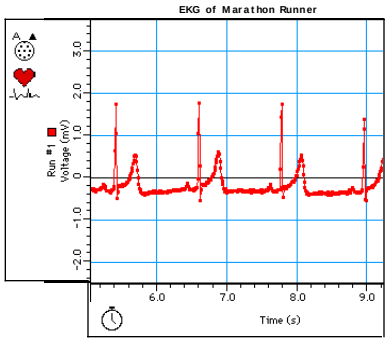
What Do You Think?

How does a person's electrocardiogram (EKG) of a person at rest compare to the electrocardiogram of the same person after mild exercise?

Take time to write an answer to this question in the Lab Report section.

Background

Activity stimulates the heart to contract more vigorously than it does when the body is at rest. The EKG (electrocardiogram) sensor measures cardiac electrical potential waveforms (voltages) produced by the heart as its chambers contract. The EKG is not a direct measure of heart muscle activity. However, a comparison of the EKG measured during rest and the EKG measured after mild exercise may indicate the changes that take place in the cycle of heart contractions due to activity.



The Electrocardiogram

One part of a typical EKG (electrocardiogram) is a 'flat line' or trace indicating no detectable electrical activity. This line is called the **Isoelectric line**. Deviation from this line indicates electrical activity of the heart muscles.

The first deviation from the Isoelectric line in a typical EKG is an upward pulse following by a return to the Isoelectric line. This is called the **P wave** and it lasts about 0.04 seconds.

After a return to the Isoelectric line there is a short delay while the heart's **AV node** depolarizes and sends a signal along the atrioventricular bundle of conducting fibers (**Bundle of His**) to the **Purkinje fibers**, which bring depolarization to all parts of the ventricles almost simultaneously.

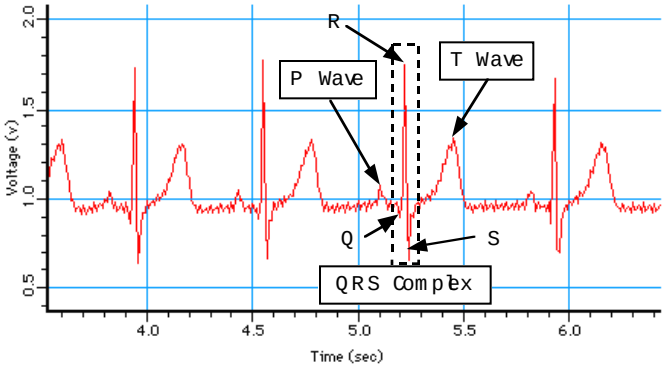
After the AV node depolarizes there is a downward pulse called the **Q wave**. Shortly after the Q wave there is a rapid upswing of the line called the **R wave** followed by a strong downswing of the line called the **S wave** and then a return to the Isoelectric line. These three waves together are called the **QRS complex**. This complex is caused by the depolarization of the ventricles and is associated with the contraction of the ventricles.

After a short period of time the chemical ions that have been involved in the contraction migrate back to their original locations. The movement of these ions generates an upward wave that then returns to the Isoelectric line. This upward pulse is called the **T wave** and indicates repolarization of the ventricles.

The sequence from P wave to T wave represents one heart cycle. The number of such cycles in a minute is called the **heart rate** and is typically 70-80 cycles (beats) per minute at rest.

Some typical times for portions of the EKG are given below.

If your EKG does not correspond to the numbers, DO NOT BE ALARMED! These numbers represent typical averages and many healthy hearts have data that fall outside of these parameters. To read an EKG effectively takes considerable training and skill. This sensor is NOT intended for medical diagnoses.



P-R interval... 120-200 milliseconds (0.120 to 0.200 seconds)

QRS interval... under 100 milliseconds (under 0.100 seconds)

Q-T interval... under 380 milliseconds (under 0.380 seconds)

SAFETY REMINDER

- Follow all safety instructions.
- This activity requires the person whose EKG is being measured to perform mild exercise (e.g., jogging in place) for three minutes. Do **NOT** perform this activity if vigorous activity will cause discomfort or be hazardous to the health of the person.

THINK SAFETY
ACT SAFELY
BE SAFE!

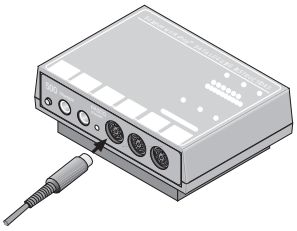
For You To Do

Use the EKG sensor to measure the electrical current associated with the heart's contractions when a person is at rest and then after the person has done mild exercise. Use *DataStudio* or *ScienceWorkshop* to record and display the electrocardiogram (heart voltage signals). Use the software to calculate heart rate based on the peaks and valleys in the EKG trace.

Compare the EKG during rest to the EKG after mild exercise.

Name _____ Class _____ Date _____

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the EKG sensor's DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B14 EKG Exercise.DS	B14 EKG Rest & Exercise	B14_EKGR.SWS

- The DataStudio file has a Workbook display. Read the instructions in the Workbook.
- The ScienceWorkshop file opens with a Graph display of "EKG Voltage (mV) " versus "Time (s)" on one plot, and "Heart Rate (bpm)" versus "Time (s)" on the second plot.
- Data recording is set for 100 samples per second. Data recording stops automatically at 15 seconds.

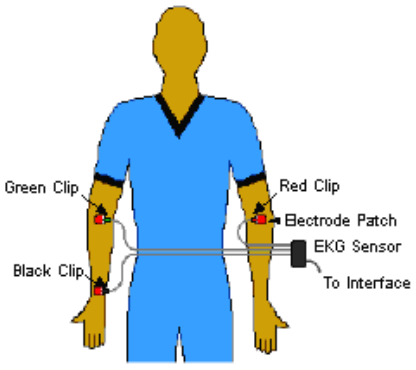
PART II: Sensor Calibration and Equipment Setup

The sensor is designed to produce a signal between 0 and five volts with 1 volt being the Isoelectric line. Deviation from the Isoelectric line indicates electrical activity. The shape and periodicity of the signal is of primary importance, so the sensor does not need to be calibrated.

Equipment Setup: Connecting the EKG Sensor to a Person

- Use three electrode patches per subject. The electrodes can be reused but they tend to absorb moisture (they are very hygroscopic), and therefore, reuse is not recommended. The electrodes should be kept in an airtight, clean, dry container for storage.
- Because the electrical signal produced by the heart and detected at the body's surface is so small, it is very important that the electrode patch makes good contact with the skin. Scrub the areas of skin where the patches will be attached with a paper towel to remove dead skin and oil.

1. Peel three electrode patches from the backing paper.
   Firmly place the first electrode on the right wrist.
   Place a second electrode on the right elbow pit.
   Place the third electrode on the left elbow pit.



- Place each electrode so it is on the inside part of the arm (closer to the body) and the tab on the edge of the electrode patch points down, so the wire of the sensor can hang freely without twisting the edge of the electrode patch.

2. Connect the micro alligator clips from the sensor to the tabs on the edges of the electrode patches.

- Connect the black (or "reference") alligator clip to the wrist electrode patch.
- This is the reference point for the "Isoelectric" line (baseline).
- Connect the green (or negative) alligator clip to the right elbow electrode patch.
- Connect the red (or positive) alligator clip to the left elbow electrode patch.

There are several different ways to connect the EKG sensor. This simple arrangement is appropriate for the classroom.

PART IIIA: Data Recording – Resting EKG

SAFETY NOTE: This activity requires the person whose EKG is being measured to perform mild exercise (e.g., jogging in place) for three minutes. Do NOT perform this activity if vigorous activity will cause discomfort or be hazardous to the health of the person.

1. When everything is ready, start recording data. The values of data will be recorded in the Graph display. Data recording stops automatically at 15 seconds.

- The person whose EKG is being measured should remain calm and relaxed. Encourage the person to breathe normally.
- Muscle activity in the arms causes electrical signals that may overwhelm the cardiac signals. Remind the person whose EKG is being measured to relax and remain as still as possible.
- If the EKG trace is very irregular, remove the electrode patches. Use rubbing alcohol to more thoroughly clean the areas of skin where the electrodes will be placed. After the alcohol evaporates, put new electrode patches on the cleaned areas of skin.

PART IIIB: Data Recording – EKG After Mild Exercise

1. Remove the micro alligator clips from all three electrode patches. Leave the electrode patches attached to the person whose EKG is being measured.
2. Have the person exercise for three minutes by jogging in place (or by doing any equivalent activity such as “stepping in place” or calisthenics).
3. At the end of three minutes of exercise, have the person who is being measured sit down in a chair or lie down on a couch. Re-attach the micro alligator clips in the same arrangement as for PART IIIA.
4. Start recording data. Data recording stops automatically at 15 seconds.

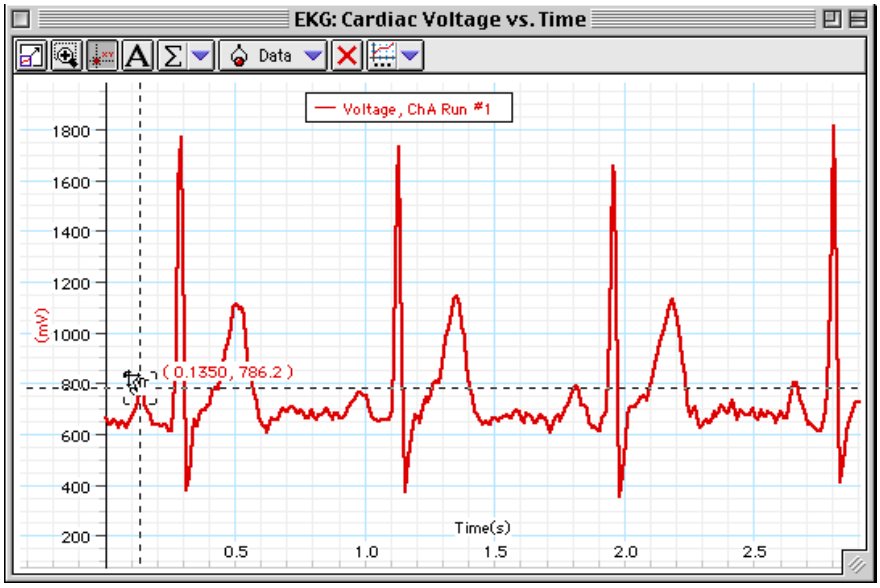
Name _____ Class _____ Date _____

Analyzing the Data

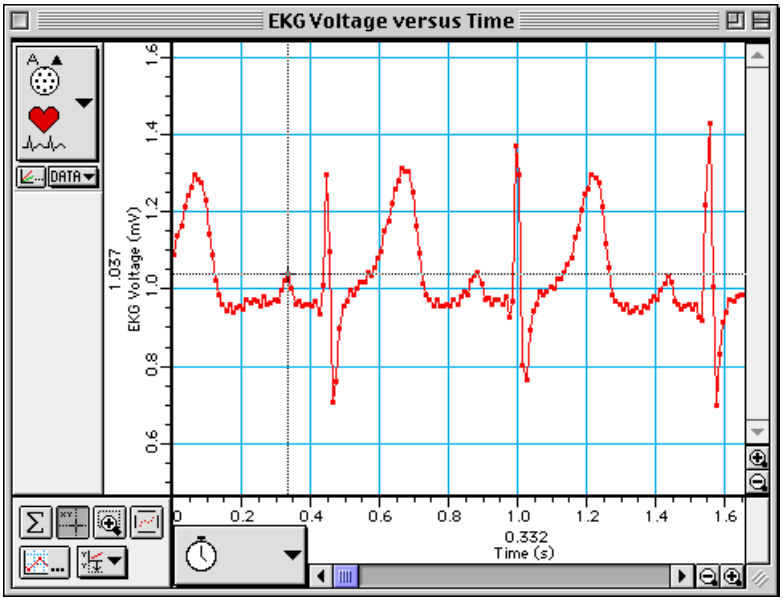
1. Set up the Graph display to show both runs of data. Zoom in on a region of the first run of data that includes three or four complete heart cycles.

2. Use the built-in analysis tools to measure the peaks of the **P**, **Q**, and **R** waves. Record the times in the Lab Report section.

- Hint: In *DataStudio*, click the 'Smart Tool' button ( ).The 'Smart Tool' displays the coordinates of its position as you move it to any position in the Graph display. When the 'Smart Tool' is on a data point, the 'x' coordinate is the time and the 'y' coordinate is the voltage value at that point.



- In *ScienceWorkshop*, click the 'Smart Cursor' button () and move the cursor into the display area. The coordinates of the cursor are displayed in the label area of the Y-axis and the X-axis.



3. Calculate the **P-R** interval and record the time.
4. Measure the peak of the **S** wave. Record the time.
5. Calculate the **Q-R-S** interval and record the time.
6. Measure the peak of the **T** wave. Record the time.
7. Calculate the overall **Q-T** interval and record the time.
8. Using the graph's built-in statistics tools, find the minimum, maximum, and mean for the Heart Rate.
9. Repeat the data analysis process for the second run of data.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B14: EKG – Rest and Exercise

What Do You Think?

How does a person's electrocardiogram (EKG) of a person at rest compare to the electrocardiogram of the same person after mild exercise?

Data Table: Interval Analysis

Item	Time (Run #1)	Time (Run #2)
P wave begins	sec	sec
Q wave begins	sec	sec
R wave begins	sec	sec
S wave begins	sec	sec
T wave begins	sec	sec

Item	Time (Run #1)	Time (Run #2)	Typical Time
P-R interval	sec	sec	sec
QRS interval	sec	sec	sec
Q-T interval	sec	sec	sec

Data Table: Heart Rate Analysis

Item	Rate (Run #1)	Rate (Run #2)
Minimum	bpm	bpm
Maximum	bpm	bpm
Mean	bpm	bpm

Questions

1. Compare your values for the P-R, Q-R-S, and Q-T intervals for the EKG at rest to the values for the P-R, Q-R-S, and Q-T intervals for the EKG after mild exercise. How do the time intervals for the EKG after mild exercise compare to the time intervals for the EKG at rest? What could explain the differences, if any?

2. How do the time intervals for the EKG after mild exercise compare to the typical time intervals given earlier?

3. What could explain the difference in the heart rate measured for the EKG at rest and the heart rate measured for the EKG after mild exercise?

Name _____ Class _____ Date _____

Activity B15: Reaction Time to Sound, Light, and Touch (Photogate)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Physiology	B15 Reaction.DS	B15A Reaction Time	B15A_RCT.SWS

Equipment Needed	**Qty**	**Consumables**	**Qty**
Photogate Head (ME-9498A)	2	Cardboard, 20 by 20 cm	1
Time-of-Flight Accessory (ME-6810)	1	Tape	1 roll
Pen, dowel or stick	1		

Note: This activity requires two people.

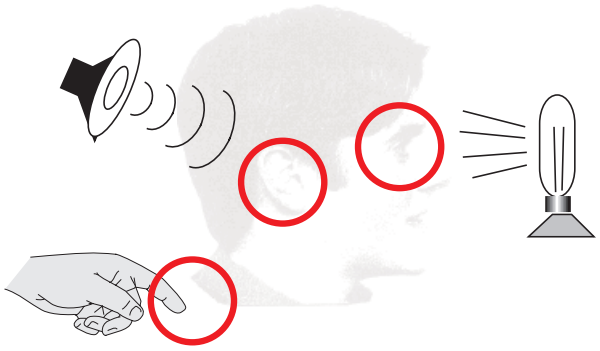
What Do You Think?

The purpose of this activity is to measure human reaction time to sound (audible stimulus), light (visual stimulus), and touch (tactile stimulus). Which reaction time will be quickest?

Take time to write an answer to this question in the Lab Report section.

Background

Reaction time in this activity is the time to make a response to a stimulus. In this activity you will measure reaction time to a sound stimulus, reaction time to a light stimulus, and reaction time to a touch stimulus. First, measure the reaction time to a sound made by striking a Time-of-Flight Accessory with a pen or dowel. Then measure the reaction time to a light emitted when a Photogate beam is blocked. Finally, measure the reaction time to a touch on the shoulder.



For You To Do

One person should be the tester while the other person is measured (the other person is the 'reactor'). Then switch roles and repeat the measurements. Use *DataStudio* or *ScienceWorkshop* to measure and display the reaction times.

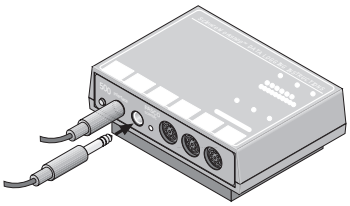
Part	Tester	Reactor
Reaction to Sound	**Strike the Time-of-Flight Accessory with a pen or dowel to make a sound.**	**Block a Photogate beam when you *hear* the sound.**
Reaction to Light	**Block a Photogate beam to turn on the light-emitting diode (LED) on the Photogate.**	**Block a Photogate beam when you *see* the LED turn on.**
Reaction to Touch	**Block a Photogate beam at the same instant that you touch the person's shoulder.**	**Block a Photogate beam when you *feel* the touch on your shoulder.**

SAFETY REMINDER	THINK SAFETY ACT SAFELY BE SAFE!
• Follow all safety instructions.	

PART IA: Computer Setup – Reaction to Sound

For this part of the activity you will need the Time-of-Flight Accessory and one Photogate.

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Time-of-Flight Accessory stereo phone plug into Digital Channel 1.
3. Connect a Photogate stereo phone plug into Digital Channel 2.
4. Open the file titled as shown:



DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B15 Reaction.DS	B15A Reaction Time	B15A_RCT.SWS

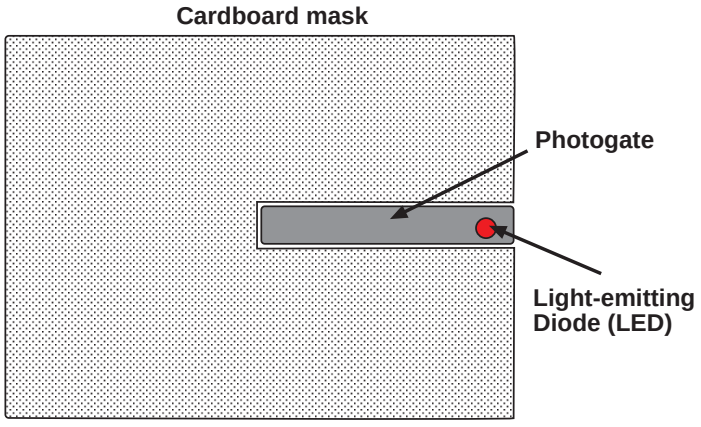
- The *DataStudio* file has a Digits display, a Table display, and a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Digits display and a Table display. The ScienceWorkshop document also has a Start condition and a Stop condition and the Experiment Setup window shows a 'Power Amplifier' plugged into Channel A.

NOTE: If you use *ScienceWorkshop* you need to modify the *ScienceWorkshop* document before you record data. See the Appendix at the end of the activity.

- Data recording is automatically set at 10,000 measurements per second (the default for a Photogate or the Time-of-Flight Accessory).

Pre-Lab

Make a mask for one of the Photogates for Part B (Reaction to Light). Cut a piece of cardboard so it can fit over the Photogate as shown in the diagram. This mask will be used to hide the hand of the Tester during data recording in Part B.



Name _____ Class _____ Date _____

PART IIA: Equipment Setup – Reaction to Sound

Reaction time is the time between the signal going into Channel 1 and the signal going into Channel 2. The timing begins when the test strikes the Time-of-Flight Accessory to make a sound (signal goes to Channel 1) and the timing ends when the Reactor blocks the Photogate beam (signal goes to Channel 2).

1. **Tester**: Hold the Time-of-Flight Accessory in your hand or place the Accessory on a table so you can sharply hit the center of it with the end of a pen or a dowel to make a sound.
2. **Reactor**: Sit or stand with your back to the Tester. Set up the Photogate in front of you so you can use a finger to 'chop down' through the Photogate's infrared beam as soon as you hear the sound from the Tester.

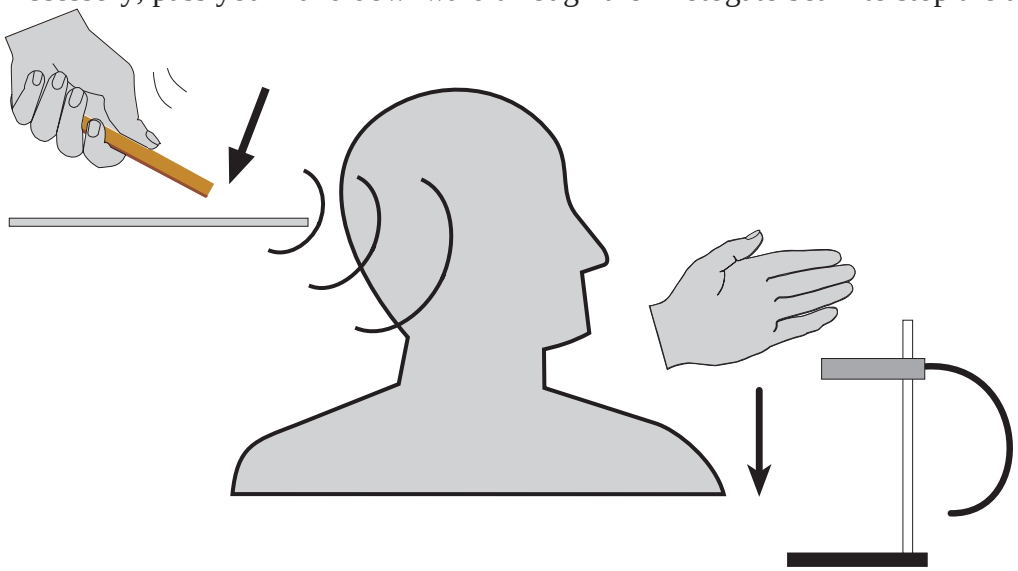
PART IIIA: Data Recording – Reaction to Sound

1. **Tester**: Get ready to record the reaction time to a sound stimulus (i.e., you will hit the Time-of-Flight Accessory to make a sound).

   Reactor: Face away from the Tester. Place your hand above the Photogate beam so you can pass your hand through the beam in a quick, downward chopping motion when you hear the sound of the Tester hitting the Time-of-Flight Accessory.

2. **Tester:** Start data recording. (Hint: Click 'Start' or click 'REC'.) Then, strike the Time-of-Flight Accessory with a pen or dowel to make a sharp sound.

- Timing begins when the Time-of-Flight Accessory is hit.
- **Reactor**: As soon as you hear the sound of the Tester hitting the Time-of-Flight Accessory, pass your hand downward through the Photogate beam to stop the timing.



- The Digits display will show the amount of time.

3. Repeat the process five times.

PART IB: Computer Setup – Reaction to Light

1. Unplug the Time-of-Flight Accessory from Digital Channel 1.
2. Connect the other Photogate stereo phone plug into Digital Channel 1.
3. Continue to use the same *DataStudio* or modified *ScienceWorkshop* file.

PART IIB: Equipment Setup – Reaction to Light

Reaction time is the time between the signal going into Channel 1 and the signal going into Channel 2. The timing begins when the Tester blocks the first Photogate (signal goes to Channel 1) and the timing ends when the Reactor blocks the second Photogate (signal goes to Channel 2).

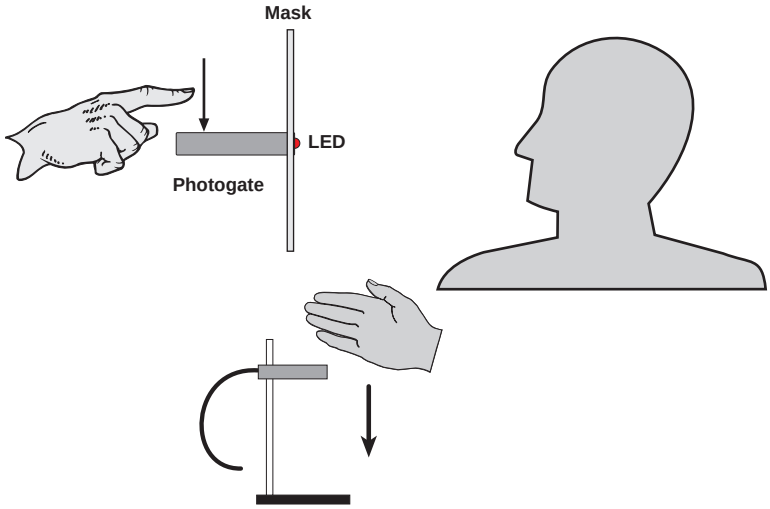
1. **Tester**: Tape the cardboard mask onto the Photogate in such a way that you can hold the Photogate in one hand and keep your other hand hidden behind the cardboard mask.
2. **Reactor**: Sit or stand facing the Tester. Set up the Photogate in front of you so you can use a finger to 'chop down' through the Photogate's infrared beam as soon as you see the light-emitting diode (LED) on the Photogate turn on.

PART IIIB: Data Recording – Reaction to Light

1. **Tester**: Get ready to record the reaction time to a light stimulus (i.e., you will block the Photogate beam and cause the LED to turn on.). Hold the Photogate with the cardboard mask in front of the Reactor in such a way that the Reactor can see the LED on the Photogate but cannot see your hand.

   Reactor: Face toward the Tester so you can see the LED on the Photogate. Place your hand above the Photogate beam so you can pass your hand through the beam in a quick, downward chopping motion when you see the LED turn on.
2. **Tester:** Start data recording. (Hint: Click 'Start' or click 'REC'.) Then, use your finger to block the Photogate beam.

- Timing begins when the Tester blocks the Photogate beam.



- **Reactor**: As soon as you see the LED turn on, pass your hand downward through the Photogate beam to stop the timing.
- The Digits display will show the amount of time.

3. Repeat the process five times.

PART IC: Computer Setup – Reaction to Touch

1. Continue to use the same *DataStudio* or modified *ScienceWorkshop* file.

PART IIC: Equipment Setup – Reaction to Touch

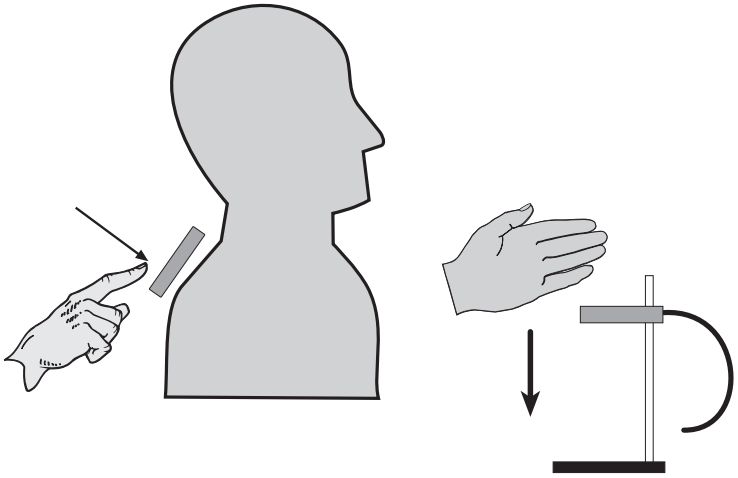
1. **Tester**: Remove the cardboard mask from the Photogate. Stand behind the Reactor so you can touch the Reactor on the back.
2. **Reactor**: Sit or stand facing away from the Tester. Set up the Photogate in front of you so you can use a finger to 'chop down' through the Photogate's infrared beam as soon as you feel the Tester touch your back.

PART IIIC: Data Recording – Reaction to Touch

1. **Tester**: Get ready to record the reaction time to a tactile stimulus (i.e., you will block the Photogate beam as you touch the Reactor on the back.). Hold the Photogate just above and slightly behind the Reactor's upper shoulder in such a way that you can bring your finger down through the Photogate beam and touch the Reactor on the back at the same time.

   Reactor: Face away from the Tester so you cannot see when the Reactor is the LED on the Photogate. Place your hand above the Photogate beam so you can pass your hand through the beam in a quick, downward chopping motion when you feel a touch on the back.

2. **Tester:** Start data recording. (Hint: Click 'Start' or click 'REC'.) Then, use your finger to touch the Reactor on the back and block the Photogate beam at the same time.



- Timing begins when the Tester blocks the Photogate beam.
- **Reactor**: As soon as you feel a touch on the back, pass your hand downward through the Photogate beam to stop the timing.
- The Digits display will show the amount of time.

3. Repeat the process five times.

Analyzing the Data

1. Set up the Table so it displays all your data. Record the reaction times for sound, light, and touch.
2. Use the built-in analysis tools in the Table display to find the mean of the reaction times to the sound, light, and touch. Record the mean for each part.

- Hint: In *DataStudio*, click the 'Statistics' menu button (). Select 'Mean'. The Minimum, Maximum, and Mean appear at the bottom of the Table.
- In *ScienceWorkshop*, click the 'Statistics' button (). The Minimum, Maximum, Mean and Standard Deviation appear at the bottom of the Table.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B15: Reaction Time to Sound, Light and Touch

What Do You Think?

The purpose of this activity is to measure human reaction time to sound (audible stimulus), light (visual stimulus), and touch (tactile stimulus). Which reaction time will be quickest?

Data Table

	Sound		Light		Touch
Trial	Time (s)	Trial	Time (s)	Trial	Time (s)
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
Mean		Mean		Mean	

Questions

1. Which reaction time is fastest on average?

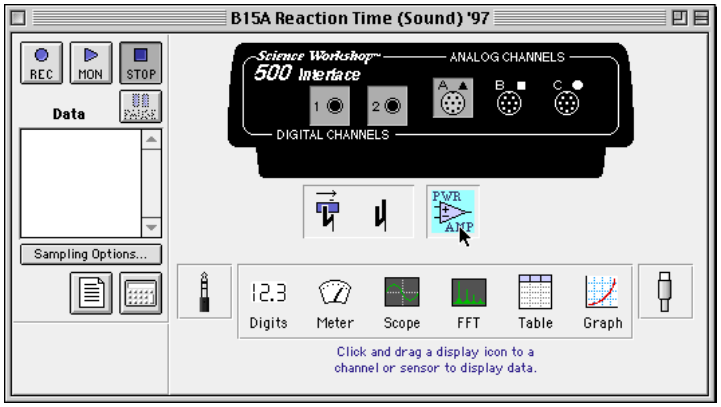
2. The reaction time to one stimulus compared to the other may be different because the person being tested had more trials to "practice". How could a test be done to determine the effect that practice has on reaction time?

Appendix: Modify the *ScienceWorkshop* Document

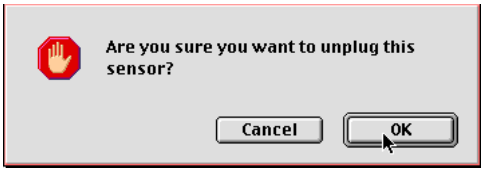
Make two modifications to the *ScienceWorkshop* file for this activity. Remove the 'Power Amplifier' from Analog Channel A and remove the Start and Stop conditions in the Sampling Options window.

Remove the 'Power Amplifier' from Analog Channel A:

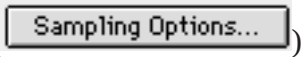
1. In the Experiment Setup window, click the Power Amplifier icon to make it active.



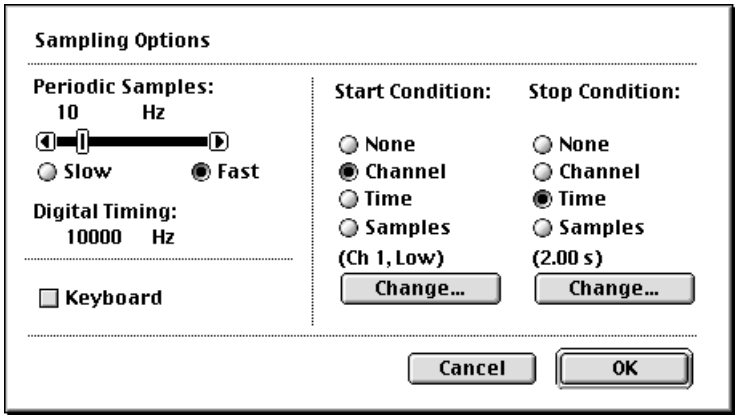
2. Press the 'delete' key on the keyboard. Click 'OK' in the alert window to return to the Experiment Setup window.



Remove the 'Start' and 'Stop' conditions:

1. Click the 'Sampling Options' button (

) or select 'Sampling Options' in the Experiment menu to open the Sampling Options window.



2. Click 'None' under Start Condition and under Stop Condition. Click OK to return to the Experiment Setup window. Save your changes.

Name _____ Class _____ Date _____

Activity B16: The Effect of Respiration on Dissolved O_2 Concentrations (Dissolved Oxygen Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Environment	B16 Dissolved O2.DS	(See Appendix)	(See Appendix)

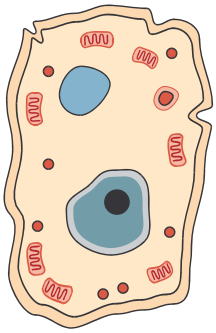
Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
Dissolved Oxygen Sensor (CI-6542)	1	Sugar	5 g
Temperature Sensor (CI-6505)	1	Water, distilled or deionized	400 mL
Balance (SE-8723)	1	Weighing paper	1
Beaker, 600 mL	1	Yeast solution	5 mL
Bottle, about 1 L, with cap	1		
Graduated cylinder	1		
Stir rod	1		
Protective gear	PS		

What Do You Think?

The purpose of this activity is to study the effect of respiration on dissolved oxygen concentrations. What effect do you think yeast will have on the dissolved oxygen concentration in water?

Take time to write an answer to this question in the Lab Report section.

Background



During cellular respiration, organisms break apart carbohydrates to release energy. There are two types of cellular respiration – anaerobic and aerobic. Both types begin with glycolysis in which glucose is converted to pyruvic acid.

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

Aerobic cellular respiration requires oxygen. If yeast in a glucose solution break down the glucose during aerobic cellular respiration, the concentration of oxygen in the solution should decrease.

Yeast are ectotherms whose metabolism is determined in part by the temperature of their surroundings. The aerobic cellular respiration in yeast is particularly sensitive to temperature.

SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

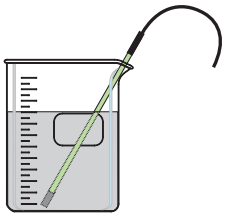
For You To Do

Use a Dissolved Oxygen Sensor to measure the concentration of dissolved oxygen in a dilute glucose solution before and after a small amount of yeast suspension is added to the solution. Use *DataStudio* or *ScienceWorkshop* to record and display the measured data.

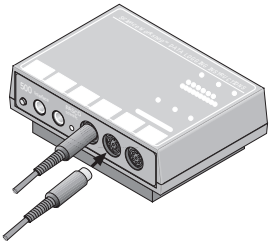
Compare the concentration of dissolved oxygen in the solution before and after the yeast are added.

Pre-Lab

Put 400 mL of room temperature deionized or distilled water into a beaker. Put the Temperature Sensor into the water.



PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Dissolved Oxygen Sensor DIN plug into Analog Channel A on the interface.
3. Connect the Temperature Sensor DIN plug into Analog Channel B.
4. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B16 Dissolved O2.DS	(See Appendix)	(See Appendix)

- The *DataStudio* file has a Digits display of temperature, a Graph display of dissolved oxygen concentration versus time, and a Workbook display. Read the instructions in the Workbook.

NOTE: If you use *ScienceWorkshop* you need to create the *ScienceWorkshop* document before you record data. See the Appendix at the end of the activity.

- Data recording is set at 10 measurements per second (10 Hz).

PART II: Sensor Calibration and Equipment Setup

Sensor Calibration

- For calibration you will need the following: one-liter bottle, Dissolved Oxygen Sensor and soaker bottle, graduated cylinder, Temperature Sensor, water, and the table of 'Concentration (mg/L) of Dissolved O_2 at Saturation by Temperature and Barometric Pressure' (see the last page of the Instruction Manual for the Dissolved Oxygen Sensor).

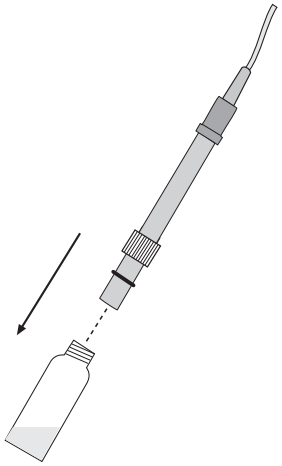
1. Use the software to measure the temperature of the water in the beaker.

- Hint: In *DataStudio*, select 'Monitor Data' from the Experiment menu. In *ScienceWorkshop*, click the 'MON' button ().

  Monitor the temperature for about thirty seconds and then record the value of the temperature. Stop measuring temperature and then remove the Temperature Sensor.

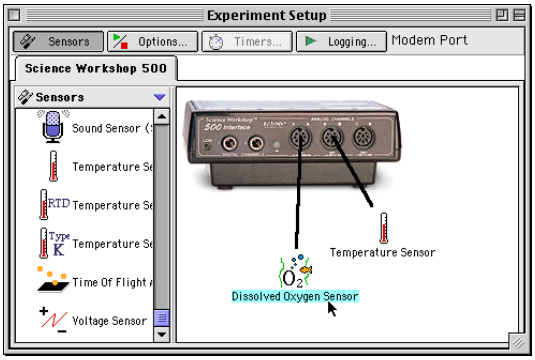
2. Pour the 400 mL of room temperature deionized or distilled water into the bottle. Cap the bottle and shake it vigorously for about 10 seconds to oxygenate the water.

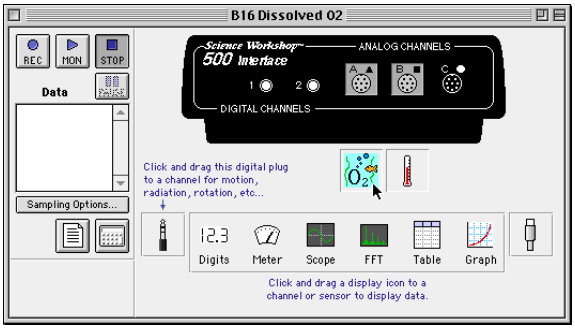
3. Put 5 mL of the oxygenated water from the bottle into the Dissolved Oxygen Sensor's soaker bottle. Insert the end of the sensor into the bottle and screw on the lid. Adjust the end of the sensor to about 2-cm above the water in the soaker bottle.



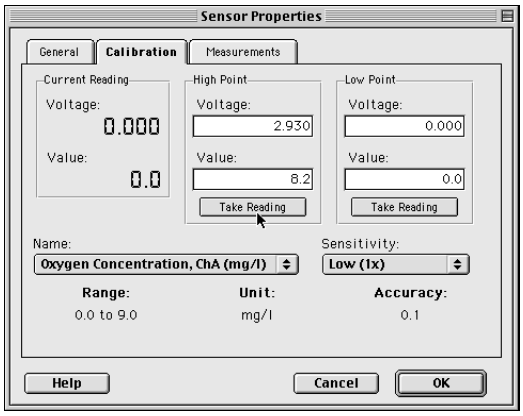
4. Use the software to calibrate the Dissolved Oxygen Sensor.

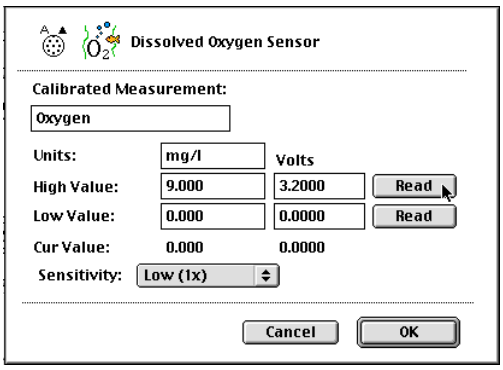
- In the Experiment Setup window, double-click the Dissolved Oxygen Sensor icon.





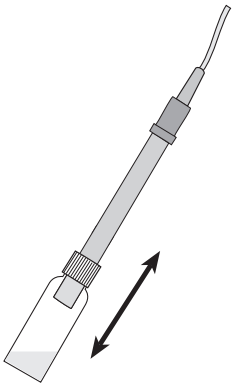
- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab.





- In *ScienceWorkshop*, the Sensor Setup window will open.

5. Shake the soaker bottle vigorously for about ten seconds. Shake off any large water drops from the membrane on the end of the sensor.

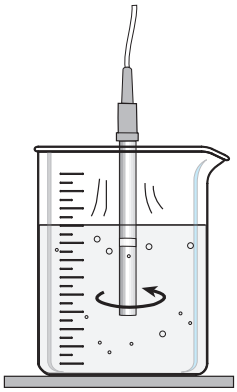


- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*.
- Refer to the table of Concentration (mg/L) of Dissolved O_2 at Saturation by Temperature and Barometric Pressure. Find the value of concentration that matches the temperature of the water. (If you know the barometric pressure, use it. Otherwise, use 760 mm Hg as the pressure). Enter the value in the Sensor Setup window under 'High Point' in *DataStudio* or in the row labeled 'High Value' in *ScienceWorkshop*.
- Click **OK** to return to the Experiment Setup window.

Equipment Setup

1. Pour the water from the bottle back into the beaker. Dissolve 5 g of sugar into the water.
2. Prepare to put 5 mL of the activated yeast suspension into the water.

PART III: Data Recording



1. Put the Dissolved Oxygen Sensor into the beaker with the sugar solution and begin stirring gently.
2. Start recording data. Hint: In *DataStudio*, click 'Start' (

). In *ScienceWorkshop*, click the 'REC' button (

).
3. After 30 seconds, add the activated yeast suspension to the beaker. Continue to stir the solution with the sensor while you are recording data.
4. Record data for ten minutes or until the dissolved oxygen level reaches a minimum value and stops changing.

Analyzing the Data

1. Use the Graph display to view your data.

- Hint: In *DataStudio*, click 'Scale to Fit' () in the Graph toolbar. In *ScienceWorkshop*, click 'Autoscale' () in the lower left corner of the display.

2. Determine the minimum and maximum values of dissolved oxygen.

- Hint: In *DataStudio*, click the 'Statistics Menu' button () in the Graph toolbar. The minimum and maximum values appear in the Graph legend. Hint: In *ScienceWorkshop*, click the 'Statistics' button () to open the statistics area. In the statistics area, click the 'Statistics Menu' button (). Select 'Minimum', open the menu again, and select 'Maximum'.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B16: The Effect of Respiration on Dissolved O_2 Concentrations

What Do You Think?

The purpose of this activity is to study the effect of respiration on dissolved oxygen concentrations. What effect do you think yeast will have on the dissolved oxygen concentration in water?

Data Table

Item	Maximum	Minimum
Dissolved O_2 Concentration	mg/L	mg/L

Questions

1. What is the evidence that the yeast cells are alive and respiring?

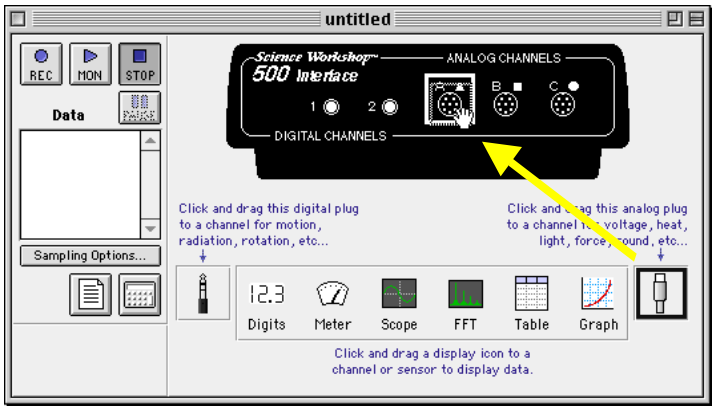
2. What happens to the yeast when the dissolved oxygen concentration reaches a minimum? Is there any evidence that the yeast cells are still alive?

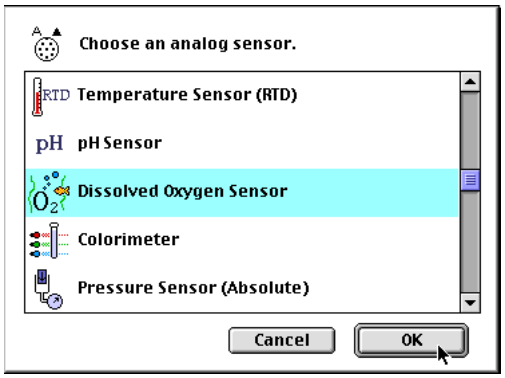
Name _____ Class _____ Date _____

Appendix: Create a *ScienceWorkshop* document for B16 Dissolved O2

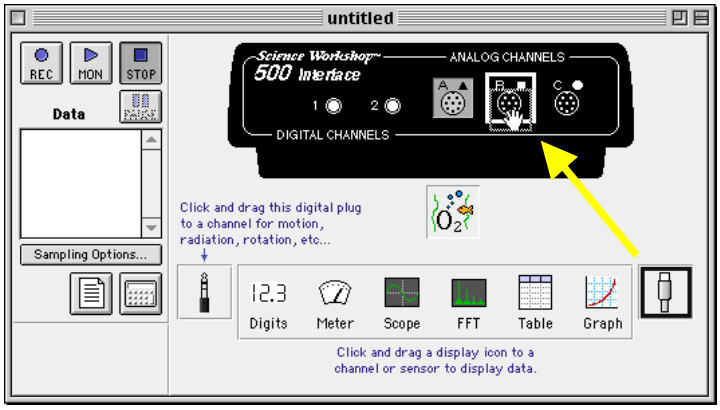
Set Up the Sensors

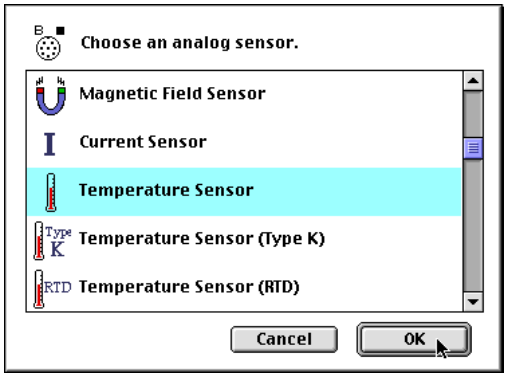
1. In the Experiment Setup window, click-and-drag the analog sensor plug icon to Analog Channel A. Select 'Dissolved Oxygen Sensor' from the list of sensors. Click 'OK' to return to the Experiment Setup window.





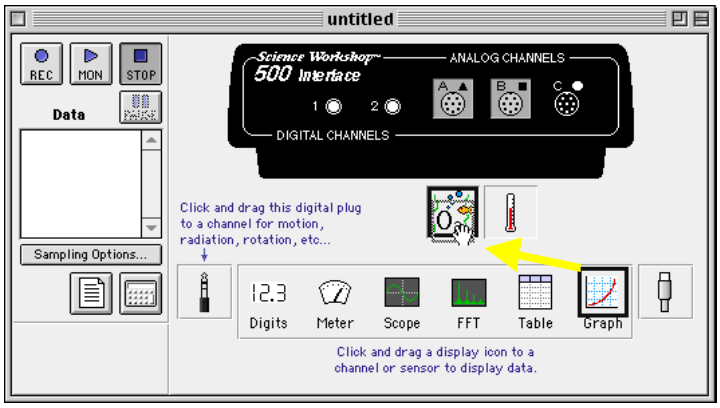
2. Click-and-drag the analog sensor plug icon to Analog Channel B and select 'Temperature Sensor' from the list of sensors. Click 'OK' to return to the Experiment Setup window.



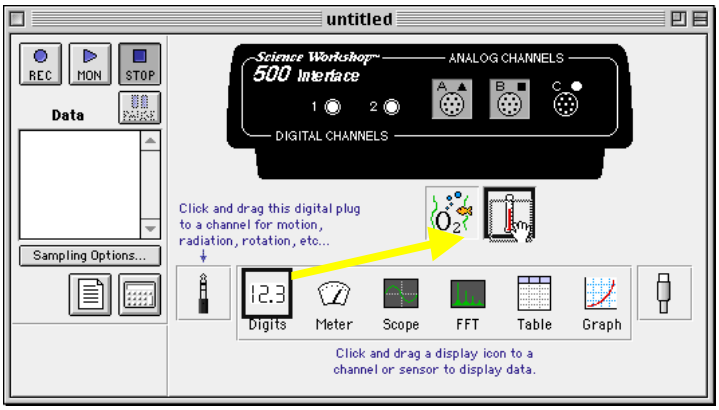


Set Up the Displays

3. In the Experiment Setup window, click-and-drag the Graph display icon to the Dissolved Oxygen Sensor icon.



4. Return to the Experiment Setup window and click-and-drag the Digits display icon to the Temperature Sensor icon.



Name _____ Class _____ Date _____

Activity B17: Acid Rain (pH Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Environment	B17 Acid Rain.DS	B17 Acid Rain	B17_RAIN.SWS

Equipment Needed	**Qty**	**Chemicals and Consumables**	**Qty**
pH Sensor (CI-6507)	1	Buffer solution: high pH	100 mL
Base and support rod (ME-9355)	1	Buffer solution: low pH	100 mL
Beaker, 250 mL	3	Sodium hydrogen carbonate, $NaHCO_3$, solid	5 g
Beaker, 100 mL	4	Sodium hydrogen sulfite, $NaHSO_3$, solid	5g
Berol-type pipette, 15 cm stem	3	Sodium nitrite, $NaNO_2$, solid	5g
Berol-type pipette, 2 cm stem	3	Water	12 mL
Berol-type pipette with 1.0 M HCl	1	Water, distilled	1 L
Clamp, buret (SE-9445)	1		
Test tube, 20 by 150 mm	1		
Wash bottle	1		
Protective gear	PS		

What Do You Think?

The purpose of this activity is to "create" acid rain. What is acid rain and what causes it? How much will the pH of water be changed by different gases such as carbon dioxide and nitrogen dioxide?

Take time to write answers to these questions in the Lab Report section.

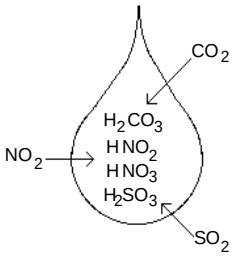
Background

Water vapor in the air can combine with other gases found in the air. You may be surprised to learn that rain water is slightly acidic. One reason is that water vapor can combine with carbon dioxide gas to form carbonic acid. The natural pH value of rainwater is usually between 6.0 and 6.9. Rainfall accumulates in rivers and streams causing a slight acidification.

Other gases found in the air can also combine with water vapor to form "acid rain". For example, gases in automobile exhaust and other gases given off by combustion of fossil fuels can combine with water vapor to form sulfurous acid, nitrous acid, and nitric acid.

You will produce four of the constituents of acid rain and monitor their effect on the pH of water samples.

- **carbonic acid, H_2CO_3**
- **nitrous acid, HNO_2**
- **nitric acid, HNO_3**
- **sulfurous acid, H_2SO_3**



Carbonic acid is formed when carbon dioxide gas dissolves in rain droplets of unpolluted air:

$$CO_{2(g)} + H_2O_{(l)} \text{ =====> } H_2CO_{3(aq)}$$

Nitrous acid and nitric acid result from a common air pollutant, nitrogen dioxide (NO_2). Most nitrogen dioxide in our atmosphere is produced from automobile exhaust. Nitrogen dioxide gas dissolves in rain drops and forms nitrous and nitric acid:

$$2\ NO_{2(g)} + H_2O_{(l)} \ =====> \ HNO_{2(aq)} + HNO_{3(aq)}$$

Sulfurous acid is produced from another air pollutant, sulfur dioxide (SO_2). Most sulfur dioxide gas in the atmosphere results from burning coal containing sulfur impurities. Sulfur dioxide dissolves in rain drops and forms sulfurous acid:

$$SO_{2(g)} + H_2O_{(l)} \ =====> \ H_2SO_{3(aq)}$$

If large amounts of these gases are in the air, the pH of rainwater can drop drastically. Rainfall of low pH values directly affects the aquatic life in the rivers and streams where this water accumulates. Acid rain can also cause damage to plant life.

SAFETY REMINDERS

- Wear protective gear while handling chemicals.
- Follow directions for using the equipment.
- Dispose of all chemicals and solutions properly.

For You To Do

First, calibrate the pH Sensor. Then build three ‘gas generators’ using Berol-type pipettes partially filled with three different compounds: sodium hydrogen carbonate, sodium hydrogen sulfite, and sodium nitrite. Each compound produces a different gas when hydrochloric acid is added (carbon dioxide from the sodium hydrogen carbonate, sulfur dioxide from the sodium hydrogen sulfite, and nitrogen dioxide from the sodium nitrite).

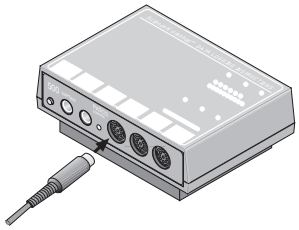
In the second part of the activity, add a small amount of hydrochloric acid to each gas generator to activate each generator.

Finally, collect the gas produced by each generator and bubble the gas through tap water. Use the pH Sensor to measure the change in pH of the water as the gas mixes with it.

Use *DataStudio* or *ScienceWorkshop* to record and display the pH. Compare the change in pH created by carbon dioxide gas to the change in pH created by sulfur dioxide gas and nitrogen dioxide gas.

Name _____ Class _____ Date _____

PART I: Computer Setup



1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the pH sensor DIN plug into Analog Channel A on the interface.
3. Open the file titled as shown:

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B17 Acid Rain.DS	B17 Acid Rain	B17_RAIN.SWS

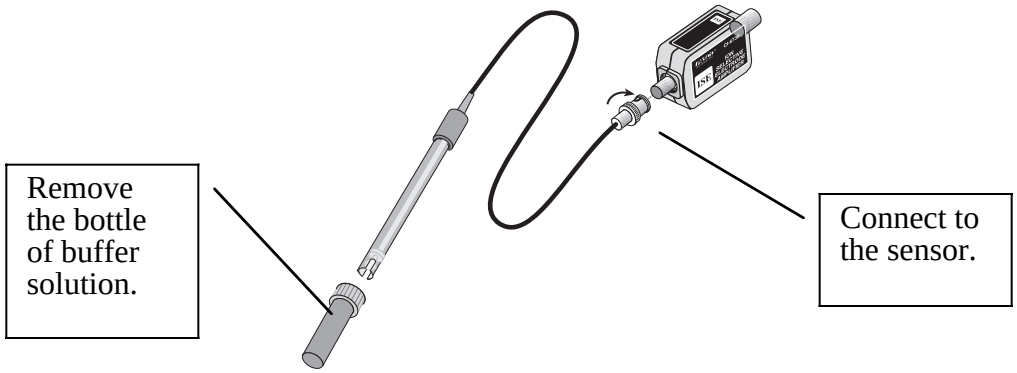
- The *DataStudio* file has a Workbook display, a Graph display, and a Table display. Read the instructions in the Workbook.
- The *ScienceWorkshop* document has a Graph of pH versus Time and a Table display of pH.
- Data recording is set at ten measurements per second (10 Hz) and a 'Stop Condition' at 100 seconds.

PART II: Sensor Calibration and Equipment Setup

Calibrate the Sensor

- To calibrate the pH Sensor you will need a wash bottle, distilled water, three beakers, and buffer solutions of high pH (e.g. pH 10) and low pH (e.g. pH 4). Put distilled water into the wash bottle and into one of the beakers. Put buffer solutions in the other two beakers.

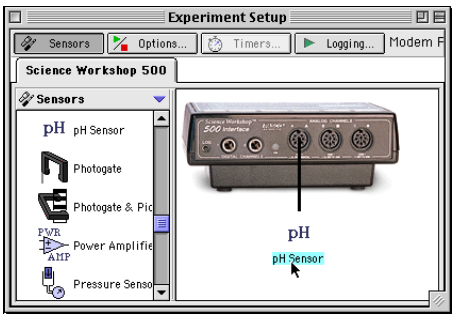
1. Remove the pH electrode from its bottle of buffer solution. Connect the electrode to the pH Sensor amplifier. To connect the electrode, push the BNC plug onto the receptacle on the Sensor amplifier and turn the BNC plug clockwise until it 'clicks' into place.

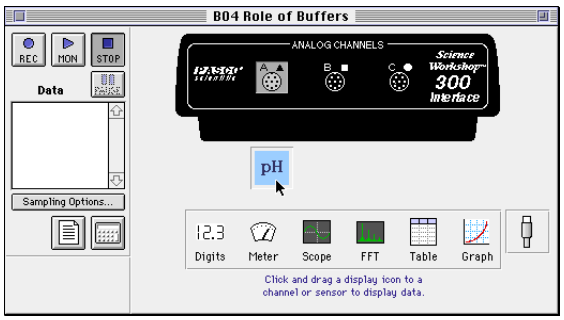


2. Use the wash bottle to rinse the end of the electrode. Soak the pH electrode in the beaker of distilled water for 10 minutes.

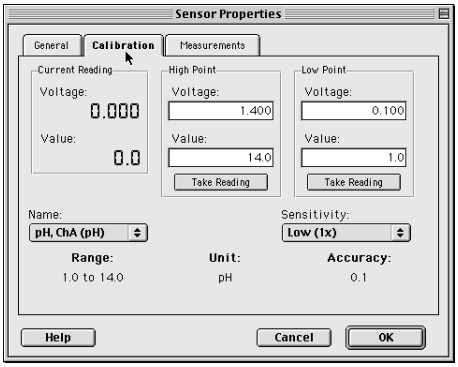
- NOTE: While the electrode is soaking you can set up the equipment.

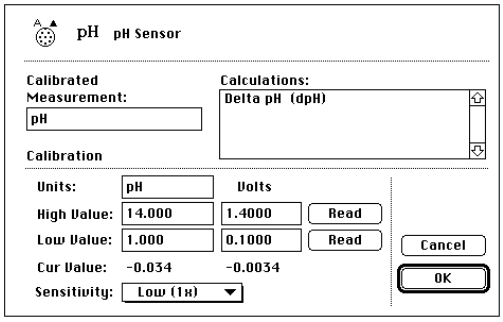
3. In the Experiment Setup window, double-click the pH Sensor icon.





- In *DataStudio*, the Sensor Properties window will open. Click the 'Calibration' tab. In *ScienceWorkshop*, the Sensor Setup window will open.





4. Calibrate with the high pH buffer solution.

- Put the end of the pH electrode into the high pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'High Point' in *DataStudio* or the 'Read' button in the row for 'High Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution.

5. Thoroughly rinse the pH electrode with distilled water and dry it with a tissue.
6. Calibrate with the low pH buffer solution.

- Put the end of the H electrode in the low pH buffer solution.
- Check the voltage under 'Current Reading' in *DataStudio* or next to 'Cur Value:' in *ScienceWorkshop*.
- When the voltage stabilizes, click the 'Take Reading' button under 'Low Point' in *DataStudio* or the 'Read' button in the row for 'Low Value:' in *ScienceWorkshop*.
- Enter the pH value of the buffer solution. Click **OK** to return to the Experiment Setup window.

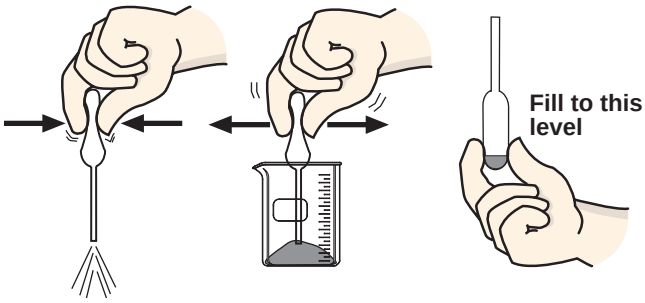
7. Thoroughly rinse the pH electrode with distilled water and dry gently.

Name _____ Class _____ Date _____

Equipment Setup

[ ] Prepare the gas generators.

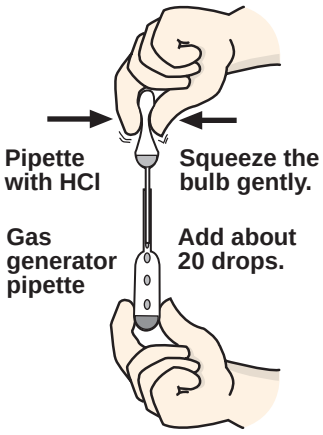
1. Label three *short-stem* Berol pipettes with the formula of the solid they will contain: "$NaHCO_3$" (for sodium hydrogen carbonate), "$NaNO_2$" (for sodium nitrite) and "$NaHSO_3$" (for sodium hydrogen sulfite).
2. Label three *long-stem* Berol pipettes with the formula of the gas they will contain: "CO_2" (for carbon dioxide), "NO_2" (for nitrogen dioxide) and "SO_2" (for sodium dioxide). Use the 100-mL beaker to support the pipettes.
3. Your teacher will supply a beaker containing powdered $NaHCO_3$ (sodium hydrogen carbonate). Squeeze the bulb of the *short-stem* pipette labeled "$NaHCO_3$" to push the air out of the bulb. Place the open end of the pipette into the powdered $NaHCO_3$. Release the bulb to draw some of the powdered $NaHCO_3$ into the pipette. Draw the powder into the pipette until there is just enough powder to fill the curved end of the bulb of the pipette when you hold the pipette with the bulb end down (see the diagram).



4. Repeat the previous step to fill the "NaNO2" and "NaHSO3" short-stem Berol pipettes with the corresponding powdered compounds.
5. Get a Berol pipette with 1.0 Molar hydrochloric acid (HCl) from your teacher.

- Caution: HCl is a strong acid. Hold the pipette gently, with the stem pointing up, so that HCl doesn't drip out.

Insert the narrow stem of the HCl pipette into the larger opening of the pipette with the $NaHCO_3$ (see the diagram.) Gently squeeze the HCl pipette to add about 20 drops of HCl solution to the powdered $NaHCO_3$.



When finished, remove the HCl pipette. Gently swirl the pipette that contains $NaHCO_3$ and HCl.

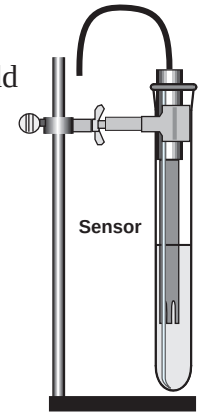
Carbon dioxide gas, CO_2, is generated in this pipette. Place the pipette *bulb down* in the 100-mL beaker to prevent spillage.

6. Repeat this same procedure to add HCl to the pipette with the powdered $NaHSO_3$ (sodium hydrogen sulfite). Sulfur dioxide, SO_2, is generated in this pipette. Place this pipette *bulb down* in the 100-mL beaker to prevent spillage

7. Repeat this procedure a third time to add HCl to the powdered $NaNO_2$ (sodium nitrite) pipette. Nitrogen dioxide, NO_2, is generated in this pipette. Return the HCl pipette to your teacher. Leave the three gas-generating pipettes in a 100-mL beaker until needed.

[ ] Set up the pH Sensor

8. Attach a 20 x 150 mm test tube to the base and support rod using a clamp. Add about 4 mL of tap water to the test tube. Rinse the pH electrode with distilled water and place the electrode into the tap water in the test tube.

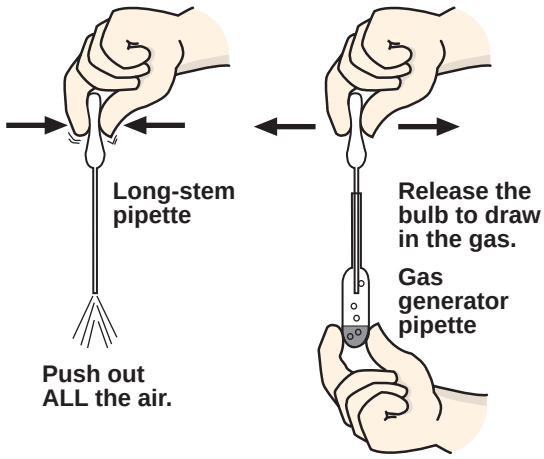


[ ] Collect the gas

9. Squeeze all of the air from the bulb of the long-stem pipette labeled "CO_2". Keep the bulb completely collapsed and insert the long stem of the pipette down into the gas-generating "$NaHCO_3$" pipette. The tip of the long-stem pipette should not touch the liquid in the "$NaHCO_3$" pipette (see the diagram). Release the pressure on the bulb so that it draws gas up into it. Store the long-stem pipette and the "$NaHCO_3$" pipette in the 100-mL beaker.

10. Repeat the 'gas collection procedure' using the "$NaNO_2$" and "NO_2" pipettes.

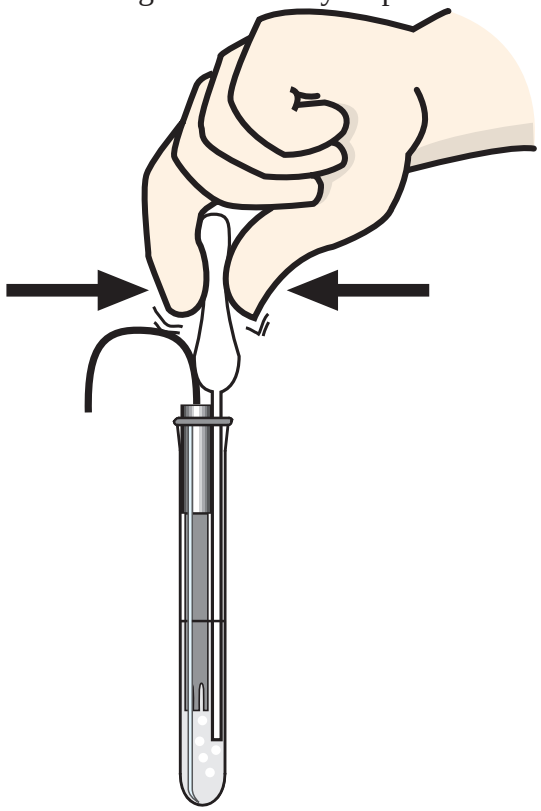
11. Repeat the 'gas collection procedure' using the "$NaHSO_3$" and "SO_2" pipettes.



Name _____ Class _____ Date _____

PART III: Data Recording

1. Insert the long-stem pipette labeled "CO_2" into the test tube, alongside the pH sensor, so that its tip extends into the water near the bottom of the test tube (see the diagram.)
2. Start recording data. After 15 seconds, gently squeeze the bulb of the pipette so that bubbles of CO_2 *slowly* bubble up through the solution. Use both hands to squeeze *all* of the gas from the bulb. Data recording automatically stops at 100 seconds.



3. Remove the pH electrode from the test tube and rinse the electrode thoroughly with distilled water and return it to the sensor storage solution.
4. Discard the contents of the test tube as directed by your teacher. Rinse the test tube *thoroughly* with tap water.
5. Add 4 mL of tap water to the test tube.
6. Repeat the data recording process using NO_2 gas.
7. Repeat the data recording process using SO_2 gas.
8. When you are finished, rinse the pH electrode with distilled water and return it to the sensor storage bottle. Dispose of the six pipettes as directed

Analyzing the Data

1. Examine each run of data in your Table display to determine the minimum pH value and maximum pH value for the water for each gas. Record the values.

- Hint: In *DataStudio*, click the 'Statistics Menu' button (). In *ScienceWorkshop*, click the 'Statistics' button ().

2. For each of the three gases, calculate the change in pH and record it.
3. Record your conclusion and answer the questions in the Lab Report.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B17: Acid Rain

What Do You Think?

The purpose of this activity is to "create" acid rain. What is acid rain and what causes it? How much will the pH of water be changed by different gases such as carbon dioxide and nitrogen dioxide?

Data Table

Gas	Initial pH	Final pH	Change in pH (ΔpH)
CO_2			
NO_2			
SO_2			

Questions

1. In this activity, which gas caused the smallest change in pH?

2. Which gas (or gases) caused the largest change in pH?

3. Coal from western states, like Montana and Wyoming, has a lower percentage of sulfur impurities than coal found in the eastern United States. How would burning low-sulfur coal decrease rainfall acidity? Use specific information about gases and acids to answer this question.

4. High temperatures in the automobile engines cause nitrogen and oxygen gases from the air to react and form nitrogen oxides. What two acids in acid rain result from the nitrogen oxides found in automobile exhaust?

5. Which gas and resulting acid in this experiment would cause rainfall in *unpolluted* air to have a pH value less than 7 (sometimes as low as 5.6)?

6. Why would acidity levels usually be lower (pH higher) in actual rainfall than the acidity levels you recorded in this experiment? Rainfall in the United States generally has a pH between 4.5 and 6.0.

Name _____ Class _____ Date _____

Activity B18: Insulating Properties of Water and Soil (Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Environment	B18 Insulation	B11 Insulation Properties	B11_SOIL.SWS

Equipment Needed	**Qty**	Insulation material	------
Temperature Sensor (CI-6505A)	2	Protective gear	PS
Base and Support Rod (ME-9355)	1	**Chemicals and Consumables**	**Qty**
Clamp, Buret (SE-9446)	2	Ice, crushed	500 mL
Beaker, 1 L	2	Soil	1 L
Freezer	1	Tape	1 roll
Heat Lamp	1	Water	1 L

What Do You Think?

Which substance is a better "insulator", water or soil? In other words, which substance would let thermal energy move through it the quickest?

Take time to write answers to these questions in the Lab Report section.

Background

Have you ever been to the beach on a hot day? Did the sand burn your bare feet? Did the water seem much cooler than the sand?

One way that temperature changes is by a process called *convection*. Convection is defined as the transfer of heat by movement of a gas or liquid. For example, cold water is denser (maximum density at 4 ˚C) and sinks while warm water is less dense and rises. So water forms a circular convection current with the cool water sinking and warm water rising.

Another way that temperature changes is by a process called *conduction*. Conduction is defined as the transfer of heat through *direct* contact of one molecule with the next.

Heat transfer occurs when thermal energy moves through a substance. A good insulator has a slow heat transfer rate. A poor insulator has a fast heat transfer rate. The rate of heat transfer for a substance depends on many factors such as what it is made of or whether it is densely packed or loosely packed.

SAFETY REMINDER

- Follow all safety instructions.

THINK SAFETY
ACT SAFELY
BE SAFE!

For You To Do

Use Temperature Sensors to measure the temperature at two different depths in water and in soil. Use *DataStudio* or *ScienceWorkshop* to record and display the data.

Start with both the water and the soil at a cold temperature, and then expose the samples to a heat source (the lamp) for equal amounts of time. Compare the change in temperature in the water to the change in temperature in the soil.

Will the lamp need to be the same height above the water sample as it is above the soil sample? Why or why not?

Pre-Lab

Prepare the soil sample.

1. Put some soil in a beaker. (Hint: Fill the beaker about half full.)

Do you need to record the amount of soil you put into the beaker?

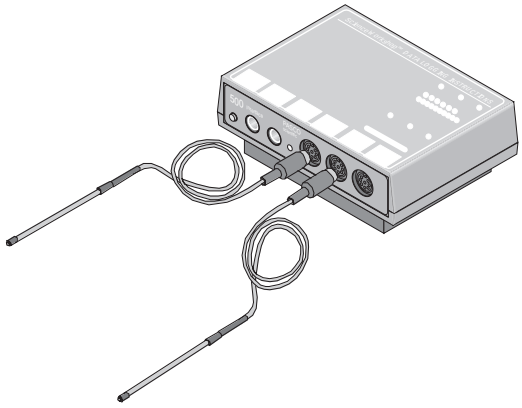
2. Set up the Channel A Temperature Sensor so the tip of the sensor is 2 cm below the surface of the soil.
3. Set up the Channel B Sensor in the same manner, but position it so the tip is 5 cm below the surface of the soil. Make sure the tip does not touch the bottom.

Hint: Place tape on the sensors at 2 cm and 5 cm from the tip. The marks will tell you when the sensors are at the correct depth.

4. Put the beaker in a freezer overnight.

PART I: Computer Setup

1. Connect the interface to the computer, turn on the interface, and turn on the computer.
2. Connect one Temperature Sensor to Analog Channel A and the other to Analog Channel B on the interface.



3. Open the file titled as shown:

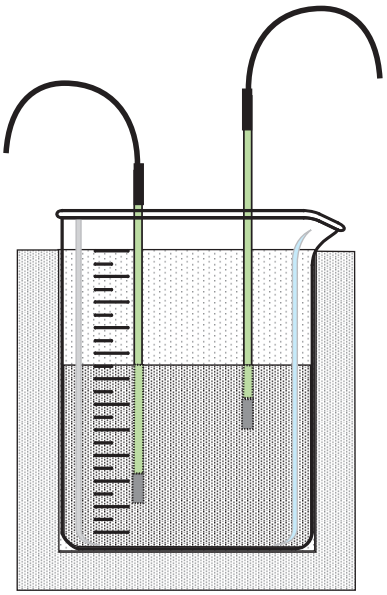
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
B18 Insulation.DS	B11 Insulation Properties	B11_SOIL.SWS

- The *DataStudio* file has a Workbook display. Read the instructions in the Workbook.
- The *ScienceWorkshop* file has Digits displays and a Graph display.
- Data recording is set at one measurement per 60 seconds and a 'Stop Condition' at 30,000 seconds (8.3 hours).

Name _____ Class _____ Date _____

PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the Temperature Sensors.



Equipment Setup A: Insulating Properties of Soil

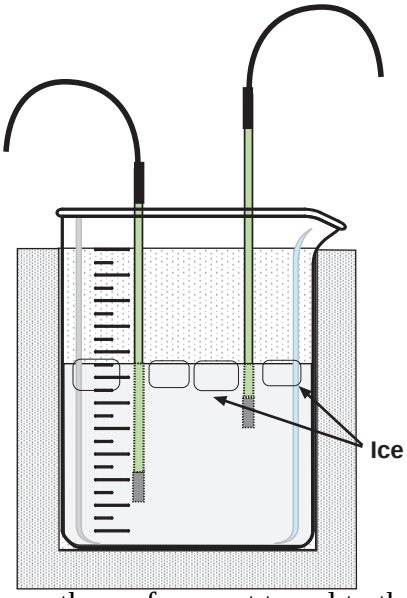
1. Retrieve the beaker of soil from the freezer. Put insulating material around the beaker.
2. Use clamps and a support rod to hold the two Temperature Sensors in place.
3. Place a heat lamp above the soil so the lamp is 10 cm above the soil.

Should you measure the exact distance between the soil and the lamp?

PART IIIA. Data Recording: Insulating Properties of Soil

1. Start recording data.
2. Leave overnight. Data recording will automatically stop after 30,000 seconds (8.3) hours.

Equipment Setup B: Insulation Properties of Water



1. Fill a beaker half full with water. Put insulating material around the beaker.

Should you use the same size of beaker as you used for the soil? Should you fill this beaker to the same level as the level of the soil in the first part?

2. Use a clamp and support rod to set up the Channel A Temperature Sensor so the tip of the sensor is 2 cm below the surface of the water. Make sure the tip does not touch the beaker.
3. Set up the Channel B Sensor in the same manner, but position its tip 5 cm below the surface of the water. Make sure the tip does not touch the bottom.

PART IIIB: Data Recording - Insulation Properties of Water

1. *Gently* place crushed ice on the surface of the water. DO NOT drop the ice in the beaker. The ice should remain on the surface, not travel to the bottom and then float back up. Note the time when you placed the ice on the surface.
2. Start recording data.

• Note: Data recording is preset to last for 30,000 seconds.

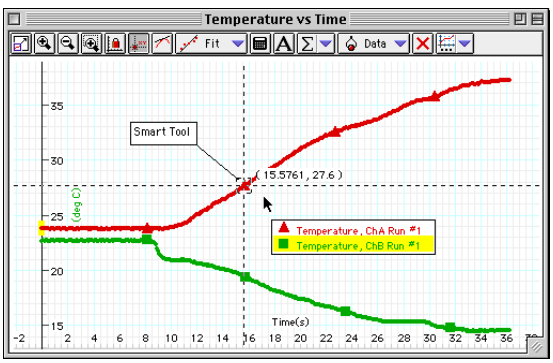
3. Place a heat lamp above the water so the lamp is 10 cm above the surface.
4. Leave overnight. Data recording will automatically stop after 30,000 seconds (8.3 hours).

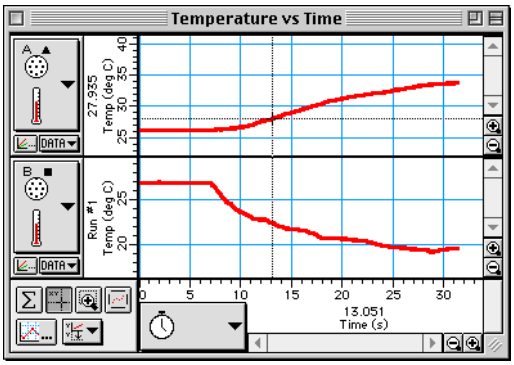
Analyzing the Data

1. Set up your Graph display so it shows your temperature data for the temperature change in the water.

2. Use the displays to find the maximum temperature of the water for the sensor near the surface and for the sensor near the bottom of the beaker. Record the time that matches the maximum temperature for each sensor.

Hint: In the Graph display, use the Smart Tool in *DataStudio* or the Smart Cursor in *ScienceWorkshop*.





3. Next, set up your display so it shows the temperature data for the temperature change in the soil.

4. Use the displays to find the maximum temperature of the soil for the two sensors. Record the time that matches the maximum temperature for each sensor.

Record your results in the Lab Report Section

Name _____ Class _____ Date _____

Lab Report - Activity B18: Insulating Properties of Water and Soil

What Do You Think?

Which substance is a better "insulator", water or soil? In other words, which substance would let thermal energy move through it the quickest?

Data Table

	Water		Soil	
Item	**Channel A**	**Channel B**	**Channel A**	**Channel B**
Minimum temperature	˚C	˚C	˚C	˚C
Maximum temperature	˚C	˚C	˚C	˚C
Time to maximum temperature	hr	hr	hr	hr

Questions

1. Using the graphs, describe the temperature changes for both beakers? Were the changes gradual or quick? How long did it take for significant temperature changes to take place?

Insulation Properties of Water

2. Was there a temperature difference between the two sensors? Why? Use the concept of convection to explain.

3. Ice is less dense than water. How does this fact benefit the aquatic life that lives in lakes and ponds?

Insulating Properties of Soil

4. Were there temperature differences between the two sensors?

5. Which took longer to warm up when placed under a lamp: the ice water or the frozen soil? Why?

6. Does the density of soil affect the rate of temperature change? Form a hypothesis? How would you test it?

7. Why do you burn your hand if pick a hot pot, but do not if you use a pot holder? Explain in terms of conduction.