



Experiments in Biology

for MultiLab™



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Pressure (150 –1150 mbar)

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Preface

This book contains 28 Biology experiments for students, designed for use with MultiLab4™, an einstein™ LabMate and einstein™ Sensors. The most recent version of MultiLab4 can be downloaded from the FOURIER Education website (<http://fourieredu.com>).

The experiments are divided into five subject groups: Plant Physiology, Cell Processes, Microorganisms, Human Physiology, and Environment.

For your convenience we have added an index in which the experiments are sorted according to sensor.

einstein™ LabMate Devices

The einstein™ LabMate includes the following:

6 built-in sensors:

- Heart Rate
- Temperature
- Humidity
- Pressure
- UV
- Light

+ 4 ports for external sensors

External sensors can be connected to the einstein™ LabMate by inserting the sensor cable into one of the sensor ports.

Connecting the einstein™ LabMate


Press the Power button on the top of the device to turn it on

When the einstein™ LabMate powers up, it will display either a green, blue or red and green flashing light.

- A blue flashing light indicates that the einstein™ LabMate is on and paired with a computer
- A green flashing light indicates that the einstein™ LabMate is on but not paired with a computer
- A red and green flashing light indicated the einstein™ LabMate is low on battery and should be plugged into the USB charging cable.

Note: The einstein™ LabMate can also be connected to the computer via a USB cable.

To pair the einstein™LabMate+ with your Windows 7 computer's Bluetooth adaptor:


1. First, verify that a Bluetooth adaptor is installed on your computer. If you are not sure how to do this, please consult the Microsoft Support web pages. Then, pair the einstein™LabMate to your computer, Here's how:
2. Open Devices and Printers by clicking the Start button (), and then, on the Start menu, clicking Devices and Printers.
3. Click Add a device, and then follow the instructions.
4. Click the einstein™LabMate you want to add to your computer, then click Next.
Your einstein™LabMate should appear in the list of available devices under the name "LabMate" with 3 or four digits directly after. These digits will match the last 3 or four digits of the serial number of your einstein™LabMate, located on the back of your device. If you don't see the einstein™LabMate you want to add, make sure the device is turned on. If you just turned on the device, it may take Windows several seconds to detect it.

Pairing einstein™LabMate with your Mac via Bluetooth:

1. Make sure that your computer has Bluetooth
Make sure that your computer has Bluetooth built-in or that a compatible Bluetooth adapter is connected. Open System Preferences (from the Apple menu, choose System Preferences), then choose Bluetooth from the View menu.
Turn on Bluetooth
In Bluetooth preferences, select the "On" checkbox (for earlier Mac OS X versions, click the Settings tab, then click Bluetooth Power: On). Make sure to also turn on your einstein™LabMate
2. Set up a new device
Click "Set Up New Device" (in earlier Mac OS X versions, click the Devices tab in Bluetooth, then click "Set Up New Device"). Your einstein™LabMate should appear in the list of available devices under the name "LabMate" with 3 or four digits directly after. These digits will match the last 3 or four digits of the serial number of your einstein™LabMate, located on the back of your device. If you don't see the einstein™LabMate you want to add, make sure the device is turned on. Follow the onscreen instructions to finish setting up your einstein™LabMate.

Note: If you are using a Windows version other than Windows 7, please consult the Microsoft Support pages on how to pair a Bluetooth device to your computer.

MultiLab4 setup

When using the einstein™ Labmate, select the MultiLab4 icon () on the application desktop.

If you are in a room where others are using einstein™ LabMates, make sure you are paired with your einstein™ LabMate. The serial number appearing in the lower right of the MultiLab4™ screen should match that on the underside of your einstein™ LabMate device.

Working with Graphs in MultiLab4

The experiments in this book require the use of the MultiLab4 program to analyze the results.

Understanding Graphs

In general, graphs in MultiLab4 represent the data from one or more sensors along the y (horizontal) axis vs. time along the x (vertical) axis.

It is also possible to display data from one sensor along the x axis. To change what is displayed along the x axis, click on the arrow key (▼) below the x axis. Choose any data set from the drop down menu.

By default, graphs in MultiLab4 auto scale, which means you can see the entire graph displayed. Graph Toolbar:





To zoom in on one part of the graph, use the Zoom tool (🔍) from the graph toolbar at the bottom of the graph window. Drag the cursor over the region of the graph you want to expand. Click the Zoom tool again to disable the zoom feature. Click on the Autoscale tool (↕) to return to the original auto scale graph. You can also move the graph using the Pan tool (🖱️).

Analyzing a Graph

Analyzing the information contained in a graph is one of MultiLab4's most important and powerful functions.

To analyze a graph:

- Run an Experiment.
- In order to use most of MultiLab4's analysis functions, you must select at least one point on the graph – this is known as a cursor. Many functions require two cursors. Use the cursor tools to display first one  and then two  cursors.

Note: If you are using more than one sensor, both points will appear on the same plot line.

Working with Cursors

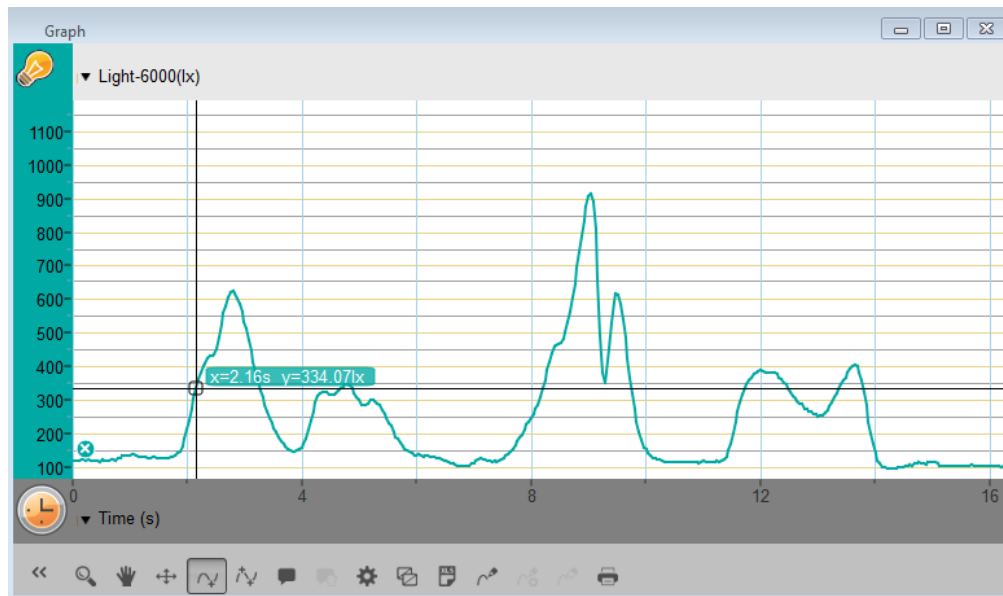
You can display up to two cursors on the graph simultaneously.

Use one cursor to display individual data recording values or to select a curve.

Use two cursors to analyze the data in the graph.

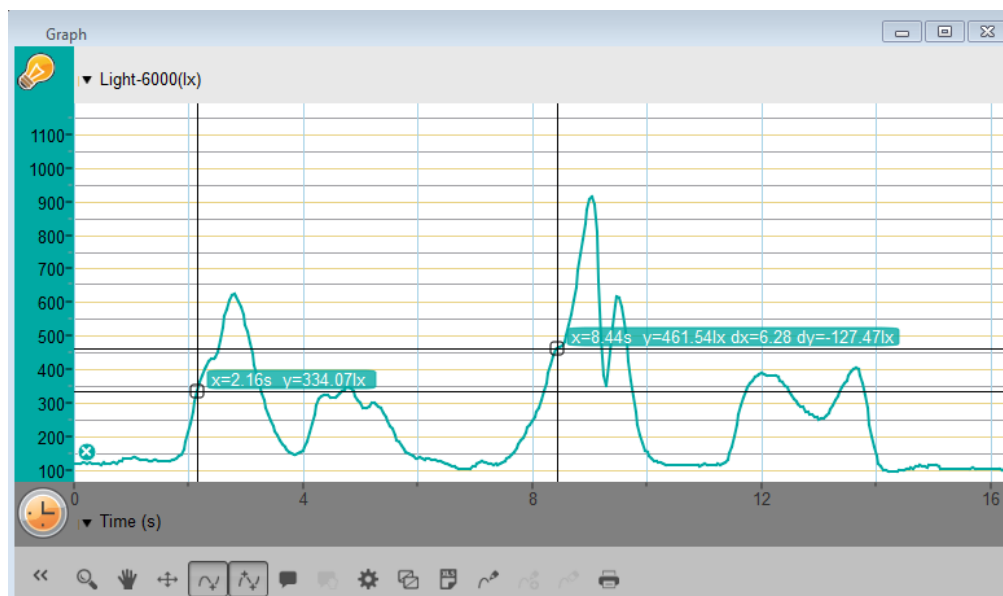
1. To display the first cursor:

In the graph window, click on any point on a plot line. MultiLab4 will now display the coordinate values.



2. To display the second cursor:

Once the first cursor is placed, click the second cursor tool (Δ) on the graph toolbar.

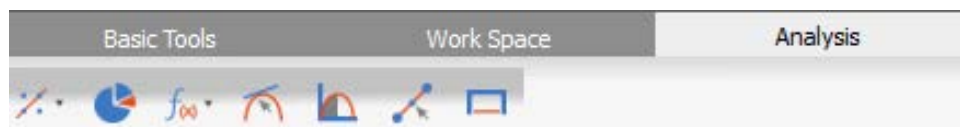


When there are two data points selected; the differences between the x and y values of the two points will appear above the second point on the graph.

- dx refers to the difference between the x values of the 2 points.
 - dy refers to the difference between the y values of the 2 points.
3. [Moving a cursor](#)
- Click and hold a cursor then drag it left and right along a single plot line.
 - Drag the cursor up and down to move the cursor from one plot line to another on a single graph.
4. [To remove a cursor:](#)
- Click on the second and then the first cursor tool on the graph toolbar.
The cursors will disappear from the plot line


Working with Functions

Once you have selected a cursor, many powerful analysis tools are available.
Select the Analysis toolbar to access the list of tools available to you.



Select one of the analysis tools to apply it to your data.

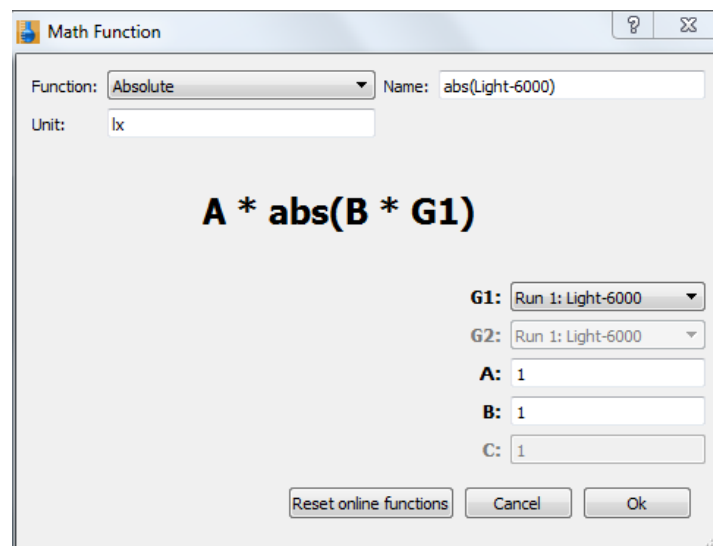
Some of the analysis tools will draw a new plot line on the graph, displaying the results.

The Math Functions tool () will allow you to perform mathematical operations on your data.

Select this tool to open the Math Function window and choose the mathematical operation from the dropdown Function menu.

You can choose your data set from the dropdown menu G1.

An equation representing the mathematical operation will appear in bold in the Math Function window.



Some functions, such as Subtract, require you to compare 2 plot lines. To compare two plot lines:

- Use the G1 and G2 dropdown menus to select the plot lines you would like to compare.
- Select Ok.
- A new plot line will appear on the graph, displaying the results.

Experimental Layout

Each experiment includes the following parts:

- **Introduction:** A brief description of the concept and theory
- **Equipment:** The equipment needed for the experiment
- **Equipment Setup:** Illustrated guide to assembling the experiment
- **Current Setup Summary:** Recommended setup
- **Procedure:** Step-by-step guide to executing the experiment
- **Data Analysis**
- **Questions**
- **Further Suggestions**


Sealing

Many of the experiments in this book, especially those involving pressure measurements, are dependent on the flasks or test tubes being tightly sealed. Following is a guide to ensure that these experiments run smoothly.

Note: To ensure a tight seal you may need to use a material such as modeling clay to seal any openings.

Note: You may want to consider purchasing the *einstein™* Pressure Kit which is specifically designed for these types of experiments.

Once you have sealed the flask or test tube, you can test the seal.

1. Select Run () to begin recording data.
2. (If your setup includes three-way valves) Turn the three-way valves to enable free air flow from the surrounding air (Position A – see Figure 1).

The readings should now indicate the atmospheric pressure.

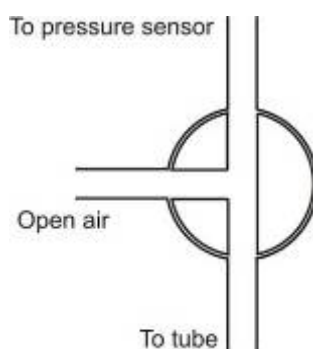


Figure 1: Three-way valve – Position A

(If your setup includes three-way valves) Turn the three-way valves to seal the system from the surrounding air (Position B – see Figure 2)

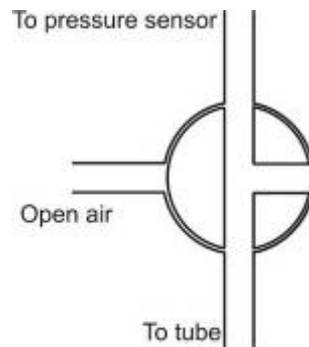


Figure 2: Three-way valve – Position B

3. Press the stoppers. The pressure should rise a little and then remain constant (see Figure 3).

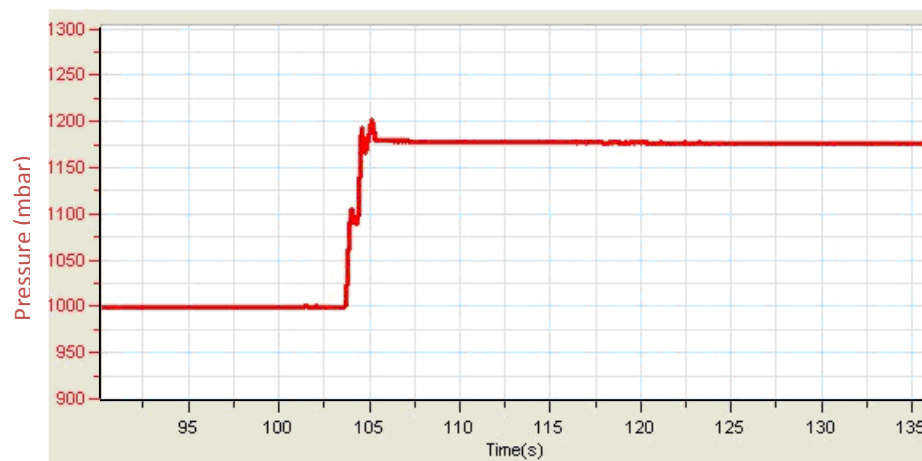


Figure 3

4. If the pressure drops (see Figure 4), there is a leak. Check your seals carefully and use a material such as modeling clay to seal off any possible openings. Repeat step 4. If that doesn't help, replace the stopper.

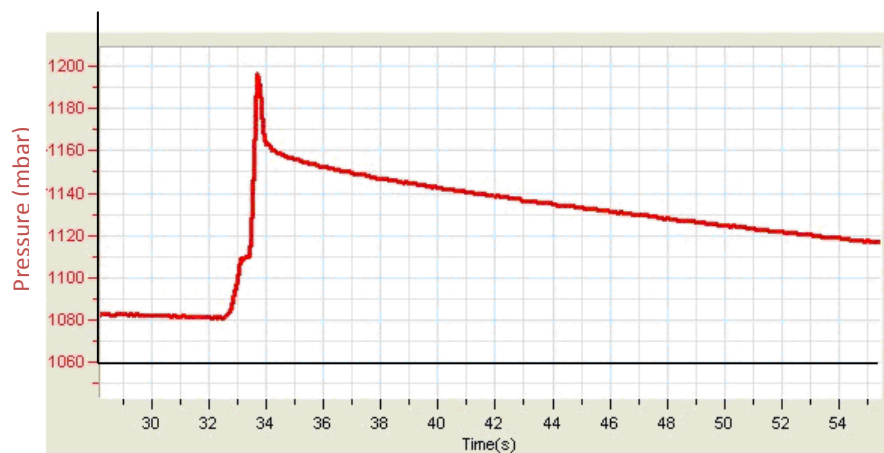



Figure 4

After you are satisfied that the containers are sealed, select Stop ().

Safety Precautions

- Follow standard safety procedures for laboratory activities in a science classroom.
- Proper safety precautions must be taken to protect teachers and students during the experiments described in this book.
- It is not possible to include every safety precaution or warning!
- Fourier assumes no responsibility or liability for use of the equipment, materials, or descriptions in this book.

Transpiration: Evaporation of Water from Terrestrial Plants

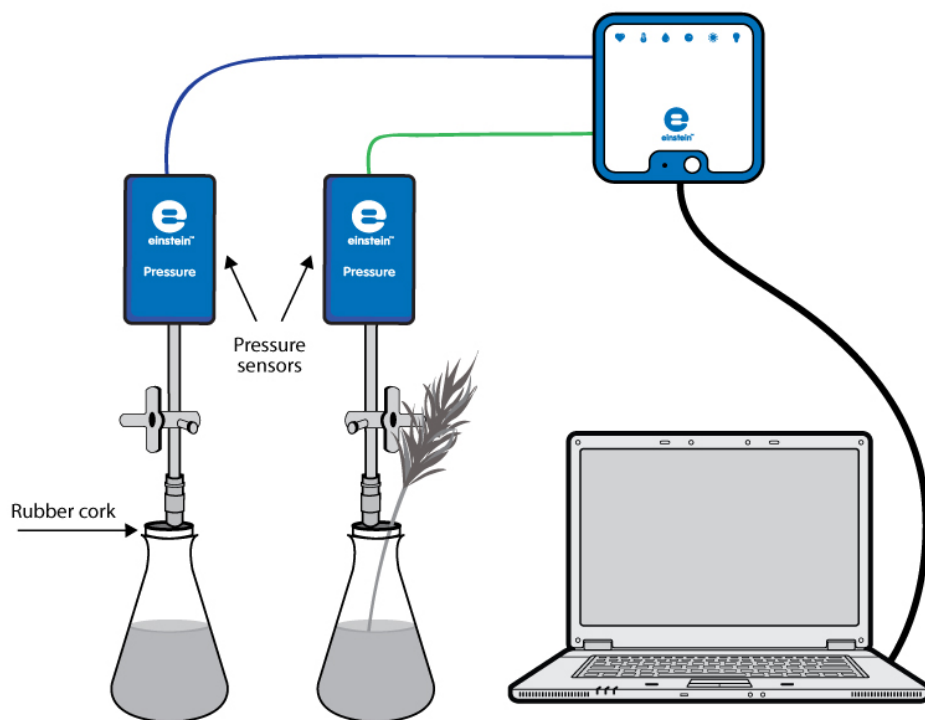


Figure 1



Introduction

More than 90% of the water absorbed by a plant's roots is ultimately lost to the atmosphere. Most of the water is lost through evaporation via the stomata in the leaves. This process is called transpiration. Because of its unique cohesive properties, this water is continuously replenished by an unbroken chain, starting from the roots and reaching the leaves, through the xylem, the principal water-conducting tissue in plants.

In this experiment we use a plant shoot inserted into a flask to measure transpiration. As water is drawn up the stem and evaporates from the leaves the volume of air in the flask will increase, leading to a reduction in pressure (in accordance with Boyle's Law). This reduction will be recorded by the Pressure Sensor.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Two Pressure Sensors (150 – 1150 mbar)
- Two 250 ml glass flasks
- One stopper with a hole for a syringe extender
- One rubber stopper with two holes
- Piece of modeling clay (optional)
- Two syringe extenders*
- Two three-way valves*

* contained in the einstein™ Pressure Kit



Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Pressure Sensors to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
4. Perform the experiment in an aerated and well-lit room. If possible, place the experiment close to a window.
5. Choose a shoot of a tree or a bush whose leaves have a large surface area (either many small leaves or several big leaves). The surface of the shoot should be smooth and cylindrical, to ensure a tight fit in the stopper.
6. Fill two 250 ml flasks with water. Make sure the flasks are filled with water leaving only a 1mm gap at the top.
7. Insert the shoot of a tree or bush into the flask with the two-holed stopper until it almost touches the flask's bottom. (Seal with clay or other material if necessary.)
8. Close the second flask with the other stopper.
9. Insert a syringe extender into both stoppers (Figure 2).
10. Attach three-way valves to each of the syringe extenders.
11. Make sure the flasks are completely sealed; you may need to use modeling clay or other materials to complete the seal.
12. Connect a Pressure Sensor to each three way valve.
13. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Pressure Sensors are selected under Measurements.

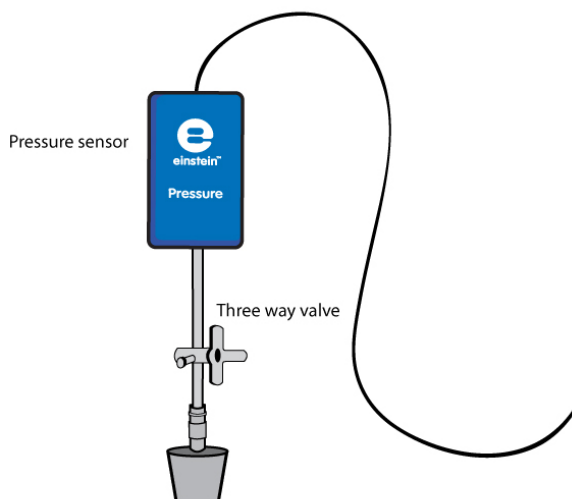


Figure 2



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Rate:	Every second
Samples:	2000
Duration:	33 minutes 20 seconds



Note: Ensure that only the external Pressure Sensors (150– 1150 mbar) are selected and not the internal Pressure Sensor (0– 400 kPa).



Procedure



Checking the experimental setup: Before starting the experiment, make sure that the flasks are tightly sealed. For more details see Sealing.

Performing the experiment:

1. Make sure that the experiment begins with both flasks at atmospheric pressure. Turn the three-way valves to position A (see Sealing), and then return to position B. The pressure in both the flasks should now equal atmospheric pressure.
2. Select **Run** () to begin recording data.
3. Follow the pressure in the Graph window of MultiLab4.
4. Allow the experiment to run at least 25 min.
5. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. To calculate the transpiration rate you'll need to create a graph in which you've subtracted the control data from the experimental data.
 - a. Select **Math functions** () from the Analysis window on the upper menu bar.
 - b. In the Math function window which opens, choose Subtract from the Function drop down menu.
 - c. In the G1 drop-down menu, select Pressure (from the flask with the branch). In the G2 drop-down menu select Pressure (from the control flask).
 - d. In the Name edit box enter a name (e.g. Subtraction).
 - e. Click OK.
2. Apply a linear fit to the graph:
 - a. Select the new plot line.
 - b. Select **Curve fit** () from the Analysis window on the upper menu bar.
 - c. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
 - d. The slope of the fit line is the measured rate of water loss in the experiment.

An example of graphs obtained in this experiment is shown below:

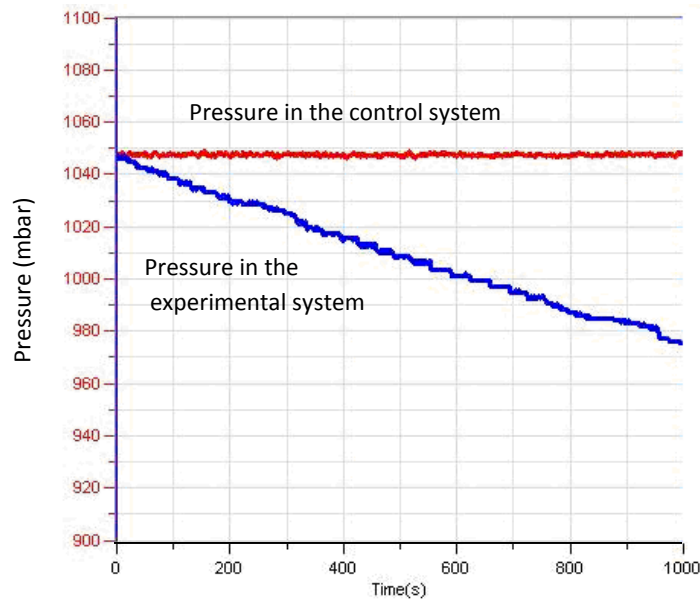


Figure 3



Questions

1. What is the control used in this experiment?
2. Why is a control flask necessary in the experiment?
3. What is the effect of light on the rate of transpiration during the experiment?
Would you expect similar changes in the dark?
4. What would be the effect of an increase in humidity on the rate of water suction? Explain your answer.
5. Why is a shoot with a large surface area of leaves necessary for this experiment?
6. What is the source of water loss in this experiment?
7. What would be the effect of covering the underside of the leaves with Vaseline?



Further Suggestions

1. Design an experiment to examine the effect of light on the rate of water loss.
2. Examine the effect of wind and humidity on the rate of water loss.
3. Examine the effect of covering the leaves with Vaseline on rate of water suction.
4. Examine the effect of surface area on the rate of water loss: Use shoots of different sizes and with different numbers of leaves.

Water Transport in Shoots and Leaves of Terrestrial Plants



Figure 1



Introduction

Water is absorbed from the soil by the plant root and transported to all parts of the plant. This passage of water is called the transpiration stream.

Several factors play a role in pushing water up the transpiration stream against the force of gravity:

Root Pressure and Osmosis – Water penetrates root cells through osmosis, a force created by unequal concentrations of water inside the root cells and the surrounding soil. Osmosis continues to push water upward due to unequal osmotic pressure across the plant.

Capillary action or capillarity is the ability of narrow tubes to draw liquid upwards against the force of gravity. The flow of water in a plant's thin xylem tubes is influenced by two opposite forces: adhesive forces of water molecules to the surface of the tube walls and cohesive forces that attract water molecules to each other. When the adhesive forces between the water and the tube walls are stronger than the cohesive forces between the water molecules, a capillary action is generated.

Transpiration Pull is the major force driving water circulation in plants and trees. Water evaporates through the stomata located in the leaves: This process is called Transpiration. As water evaporates from leaves, more water is pulled up from the root system by osmosis – a process that causes water to flow from an area where it is plentiful to an area where it is scarce.

The gas carbon dioxide or CO_2 is needed for photosynthesis. During the day, the stomata open allowing the plant to “breathe in” CO_2 . This also greatly increases the amount of water lost through evaporation. Ultimately, 90% of water taken in by plants is lost through transpiration.

In this experiment water rising through the xylem is observed in a celery stalk (*Apium graveolens*) as it absorbs water colored with methylene blue dye.

The extent of water loss in transpiration is followed by measuring water intake by a shoot inserted into a flask full of water. Evaporation of water from the leaves leads to suction of the water from the flask. The suction of the water continuously increases the volume of air in the flask, thus causing a reduction in pressure (in accordance with Boyle's Law) that can be recorded by the Pressure Sensor.



Equipment

- einstein™ LabMate and a computer with MultiLab4
- Two Pressure Sensors (150 – 1150 mbar)
- Five 250 ml glass flasks
- Two rubber stoppers with 2 holes each
- Piece of modeling clay
- Two syringe extenders*
- Two three-way valves*
- Magnifying glass
- Plastic knife
- 20 cm ruler
- Celery stalk
- Shoot of a tree or bush (*Nerium oleander* works well)
- 1% methylene blue dye

*contained in einstein™ Pressure Kit

Part 1: Water circulation in celery leaves



Procedure

1. Pour 100 ml of 1% methylene blue solution into three 250 ml flasks. Number them: 1-3.
2. Divide the celery stalk along its length into 3 strips. Each strip should include an equal number and type of leaves - preferably the younger inner leaves, and the stalk.
3. Observe the cross section under a magnifying glass. Try to identify the xylem tubes (see Figure 1).
4. Place one strip in each flask.
5. Wait five minutes, and then take one stalk out of the solution. Wipe off excess color.
6. Cut a 1 cm piece from the lower edge of the stalk. Observe the cross section under the magnifying glass to see if the xylem bundles are blue. Count the number of colored xylem bundles you observe in the section.
7. Keep cutting off 1 cm pieces from the bottom of the celery stalk until you reach a section without colored bundles (see Figure 2).
8. Wait 10 minutes; take out the second stalk. Cut cross sections and check them under the magnifying glass as performed in steps 6 and 7. Count the number of xylem bundles you observe in the section.
9. After 20 minutes take out the third stalk and repeat steps 6 and 7.

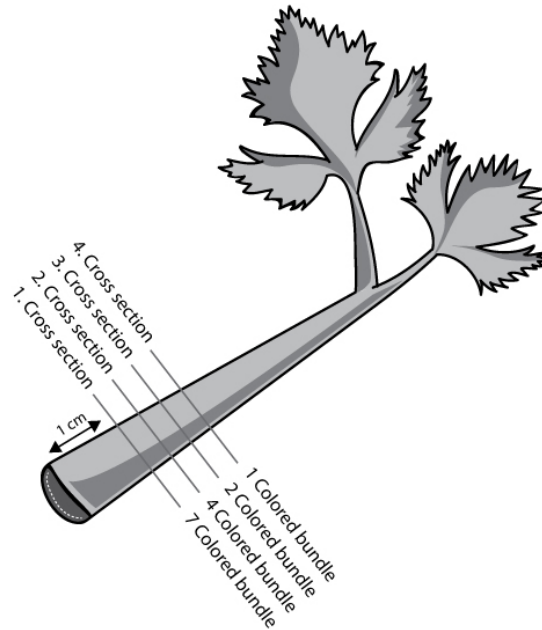


Figure 2


10. Prepare a table to display your results:

Height (cm)					
No. of colored tubes in the section					

11. Calculate the average height the color has reached in each stalk.
12. Multiply the height by the number of colored bundles. For example:
 - a. In one bundle the height was 5 cm: 5 cm X one bundle = 5
 - b. In three bundles the height was 4 cm: 4 cm X three bundles = 12
 - c. In five bundles the height was 3 cm: 3 cm X five bundles = 15
 - d. Sum up the total height in all the sections: 32 cm
 - e. Divide it by the total number of bundles: 9
 - f. The average height reached by the water after 5 minutes was 3.5 cm.
13. Calculate the average rate of water rise in the three leaves in cm per minute.

Part 2: Measuring the rate of water suction from the flask by the Shoot

123 Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Pressure Sensors to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 3.
4. Perform the experiment in an aerated and well-lit room. If possible, place the experimental systems close to the window.
5. Choose a shoot of a tree or a bush whose leaves have a large surface area (either many small leaves or several big leaves). The surface of the shoot should be smooth and cylindrical, to ensure a tight fit in the stopper.

6. Fill the two 250 ml flasks with water. Make sure the flasks are filled with water leaving only a 1mm gap at the top.
7. Insert the shoot of a tree or bush into the flask with the two-holed stopper until it almost touches the flask's bottom. (Seal with clay or other material if necessary.)
8. Close the second flask with the other stopper.
9. Insert a syringe extender into both stoppers (Figure 4).
10. Attach three-way valves to each of the syringe extenders.
11. Make sure the flasks are completely sealed; you may need to use clay or other material to complete the seal.
12. Connect a Pressure Sensor to each three way valve.
13. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Pressure Sensors are selected under Measurements.

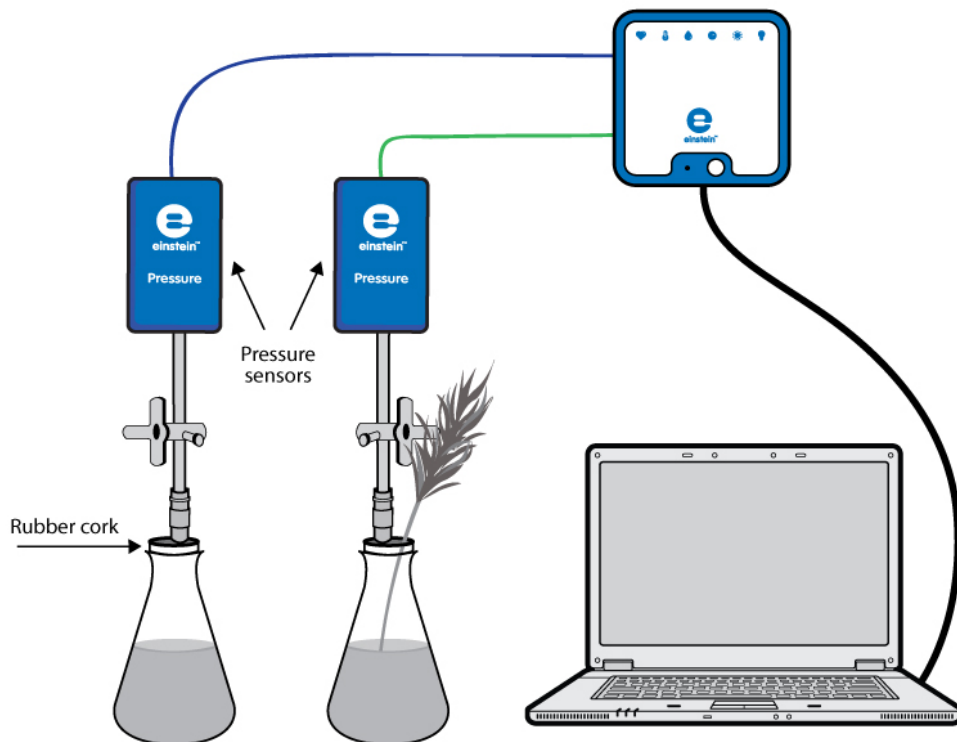


Figure 3

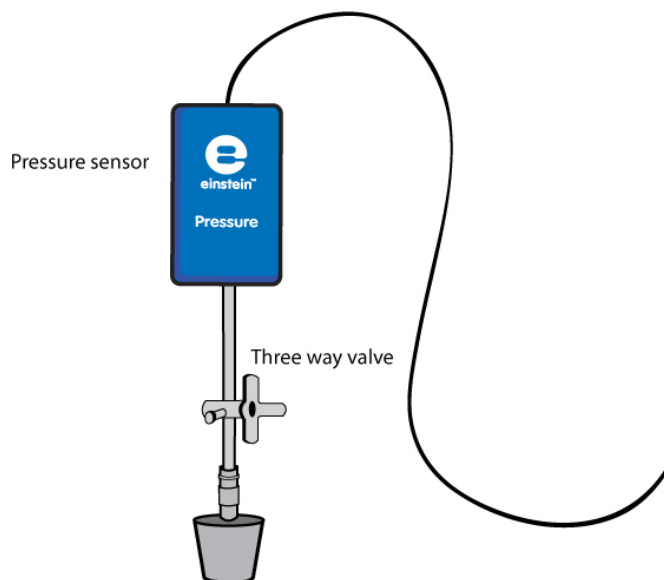


Figure 4



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Rate:	Every second
Samples:	2000
Duration:	33 minutes 20 seconds

Note: Ensure that only the external Pressure Sensors (150– 1150 mbar) are selected and not the internal Pressure Sensor (0– 400 kPa).





Procedure

Checking the experimental setup:



Before starting the experiment, make sure that the flasks are tightly sealed. For more details see Sealing.

Performing the experiment:

1. Make sure that the experiment begins with both flasks at atmospheric pressure. Turn the three-way valves to position A (see Sealing), and then return to position B. The pressure in both the flasks should now equal atmospheric pressure.
2. Select **Run** () to begin recording data.
3. Follow the pressure in the Graph window of MultiLab4.
4. Allow the experiment to run at least 25 min.
5. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. To calculate the transpiration rate you'll need to create a graph in which you've subtracted the control data from the experimental data.
 - a. Select **Math functions** () from the Analysis window on the upper menu bar.
 - b. In the Math function window which opens, choose Subtract from the Function drop down menu.
 - c. In the G1 drop-down menu, select Pressure (from the flask with the branch). In the G2 drop-down menu select Pressure (from the control flask).
 - d. In the Name edit box enter a name (e.g. Subtraction).
 - e. Click OK.
2. Apply a linear fit to the graph:
 - a. Select the new plot line.
 - b. Select **Curve fit** () from the Analysis window on the upper menu bar.
 - c. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph
 - d. The slope of the fit line is the measured rate of water loss in the experiment.

An example of the graphs obtained in this experiment is shown below:

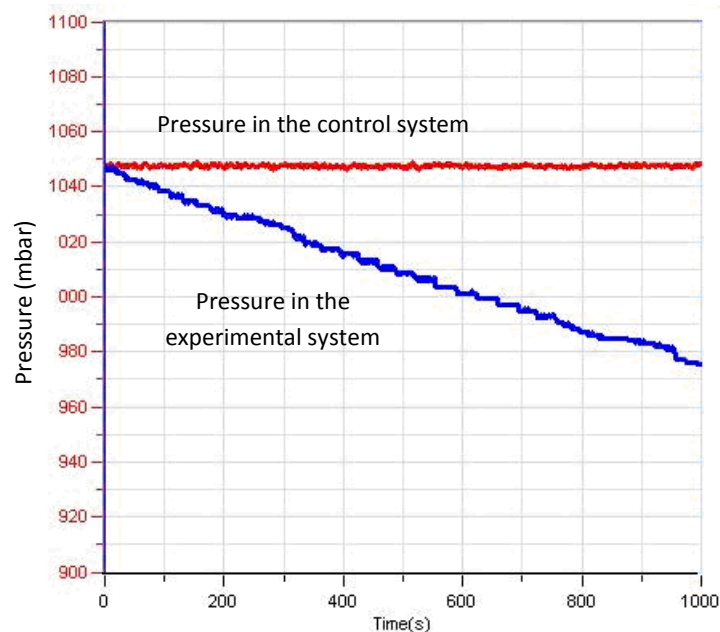


Figure 4



Questions

1. What is the control used in this experiment?
2. Why is a control flask necessary in the experiment?
3. What is the effect of light on the rate of transpiration during the experiment?
Would you expect similar changes in the dark?
4. What would be the effect of an increase in humidity on the rate of water suction?
Explain your answer.
5. Why is a shoot with a large surface area of leaves necessary for this experiment?
6. What is the source of water loss in this experiment?
7. What would be the effect of covering the underside of the leaves with Vaseline?



Further Suggestions

1. Design an experiment to investigate the effect of light on the rate of water loss.
2. Explore the effect of wind and humidity on the rate of water loss.
3. Explore the effect of covering the leaves with Vaseline on the rate of water suction.
4. Explore the effect of surface area of leaves on the rate of water loss: Use shoots of different sizes and numbers of leaves.
5. Cut the shoot and compare the number of xylem bundles with what you observed in the celery stalk.
6. Compare the evaporation rate in another plant. Choose a plant with a high rate of respiration, *Ceratonia siliqua* for example.

Measuring the Photosynthesis Rate in Aquatic Plants - *Elodea*

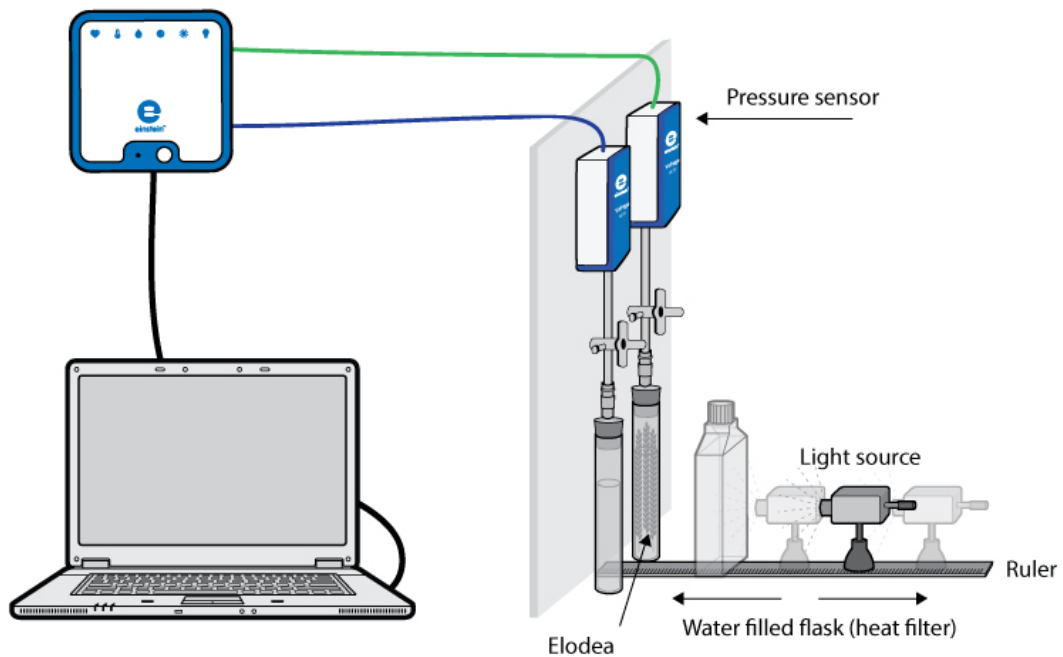


Figure 1



Introduction

Most plant life is dependent on photosynthesis to survive. This process uses the energy from light to turn carbon dioxide (CO_2) and water into carbohydrates. In this process molecular oxygen is generated. The light is absorbed by pigments in photosynthetic organisms such as chlorophyll in green plants. Under optimal conditions of light intensity, carbon dioxide concentrations and temperature, photosynthesis rates depend on the surface area or mass of the plant exposed to light.

In this experiment we follow the photosynthesis rate in the aquatic plant *Elodea ernstiae* using Pressure Sensors to measure the rate of oxygen release.



Equipment

- einstein™ LabMate and a computer with MultiLab4
- Two 50 ml glass test tubes
- Two stoppers with a hole for syringe extenders
- Two syringe extenders*
- Two three-way valves*
- Perspex stand to support tubes and sensors
- One liter flat water bottle (glass or plastic) or tissue culture bottle (heat filter)
- Two Pressure Sensors (150-1150 mbar)
- 2 g of fresh Elodea
- Plastic knife
- Bright light source (e.g. 150 W Halogen lamp)
- 0.5% bicarbonate solution

*contained in einstein™ Pressure Kit

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Equipment Setup

1. Assemble the equipment as shown in Figure 1.
 - a. Fill each glass test tube with 0.5% bicarbonate solution. Leave a small volume of air between the solution surface and the stopper.
 - b. Slice the *Elodea* branch into segments that fit the test tube.
 - c. Place the *Elodea* segments into one test tube.
The other test tube will serve as the experimental control.
 - d. Seal the test tubes tightly with the stoppers.
 - e. Insert syringe extenders into the stoppers (Figure 2).

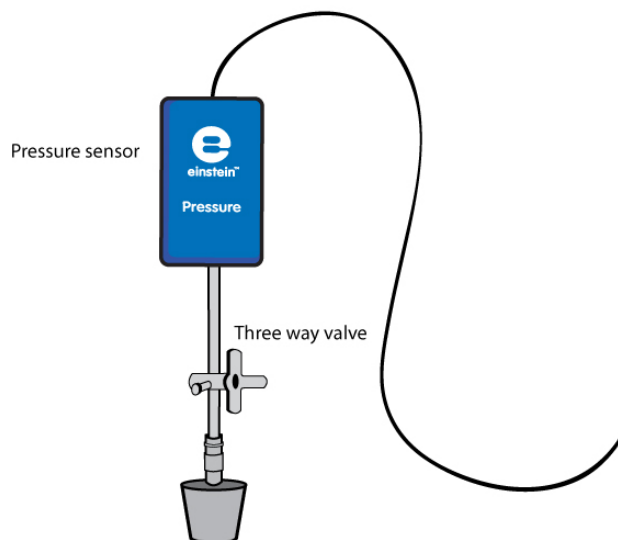



Figure 2

- f. Attach three-way valve to the other end of the syringe extenders.
- g. Connect Pressure Sensors to the valves.

- h. Position the light source 25 cm from the glass test tubes (see Figure 1).
- i. Fill the flat plastic bottle with water and place it between the light source and the test tubes.
The water absorbs the heat that radiates from the light source.
2. Launch MultiLab4 ().
3. Connect the Pressure Sensors to ports on the einstein™ LabMate.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment.
Make sure that only the Pressure Sensors are selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Rate:	Every second
Samples:	5000
Duration:	1 hour23 minutes 20 seconds




Note: Ensure that only the external Pressure Sensors (150– 1150 mbar) are selected and not the internal Pressure Sensor (0– 400 kPa).



Procedure



Checking the experimental setup: Before starting the experiment, make sure that the test tubes are tightly sealed. For more details see Sealing.

Performing the experiment

1. Make sure that the experiment begins with both test tubes at atmospheric pressure. Turn the three-way valves to position A (see Sealing), and then return to position B. The pressure in both test tubes should now equal atmospheric pressure.
2. Turn on the light source.
3. Select **Run** () to begin recording data.
4. Monitor the photosynthesis rate until the pressure in the test tube with the *Elodea* reaches about 1100 mbar.
5. Select **Stop** () to stop collecting data.
6. Save your data by selecting Save () from the Basic Tools window on the upper menu bar.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. To calculate the rate of photosynthesis you'll need to create a graph in which you've subtracted the control data from the experimental data.
 - a. Select Math **functions** () from the Analysis window on the upper menu bar.
 - b. In the Math function window which opens, choose Subtract from the Function drop down menu.
 - c. In the G1 drop-down menu, select Pressure (from the test tube with the *Elodea*) . In the G2 drop-down menu select Pressure (from the control test tube).
 - d. In the Name edit box enter a name (e.g. Subtraction).
 - e. Click OK.
2. Apply a linear fit to the graph:
 - a. Select the desired range of the new plot line.
 - b. Select **Curve fit** () from the Analysis window on the upper menu bar.
 - c. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
 - d. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
 - e. The slope of the fit line is the measured rate of oxygen production as a result of photosynthesis.

An example of the graph, obtained in this experiment is shown below:

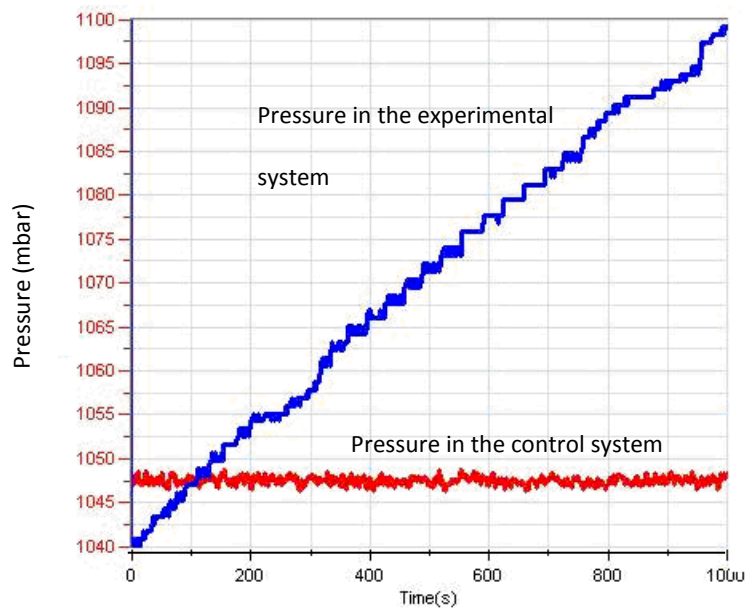


Figure 3

In the following graph, the result of the subtraction and the linear fit to this data are shown:

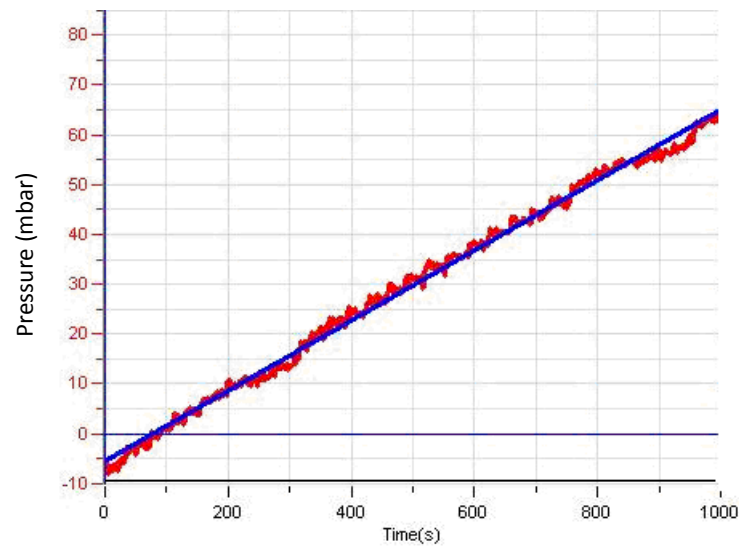


Figure 4

Questions

1. How is the pressure generated in the experiment related to photosynthesis?
2. Why is a control system necessary in this experiment?
3. Two types of controls can be set: one containing bicarbonate solution only, the other containing bicarbonate solution plus boiled *Elodea* segments. What is the difference between these two controls?
4. How might an increase in the test tubes' temperature during the experiment affect the photosynthesis rate?

Further Suggestions

1. Photosynthesis rates depend on several factors: mass of *Elodea*, concentration of bicarbonate, and light intensity. How does each of these factors affect the reaction rate?
2. Using the system described in this experiment, design new experiments to measure the effect of each of these factors. Try repeating the experiment with a double mass of *Elodea*, stronger light intensity, etc.

Measuring the Photosynthesis Rate: Using an Oxygen Sensor

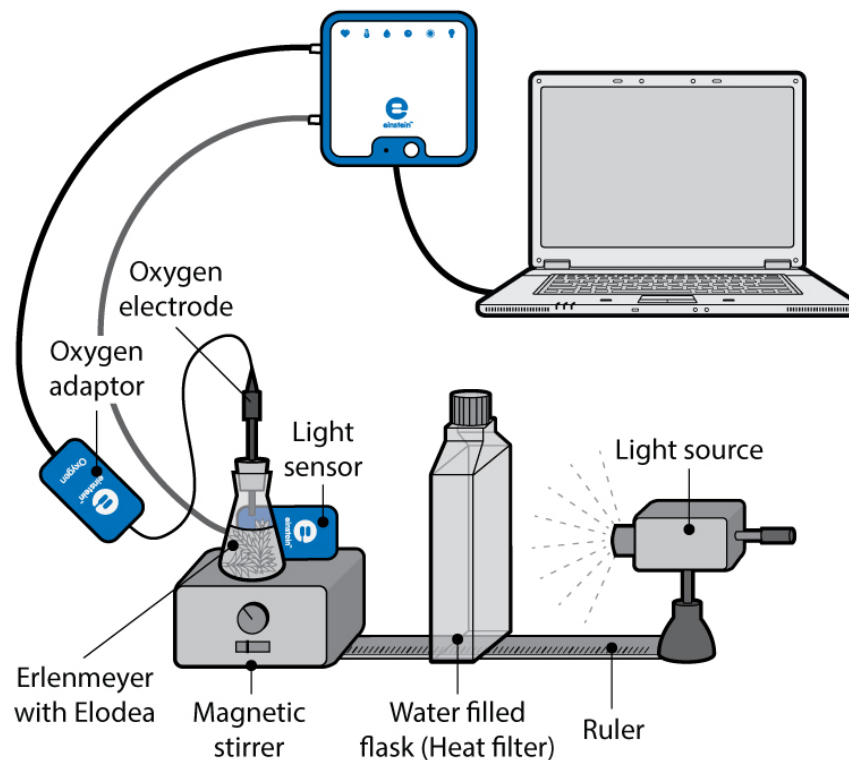


Figure 1



Introduction

Photosynthesis provides food for most plant life on earth. This process uses the energy from light to turn carbon dioxide (CO_2) and water into carbohydrates and generates oxygen which is released into the atmosphere. Light, the energy source for this process, is absorbed by pigments in photosynthetic organisms. Under optimal conditions of light intensity, carbon dioxide concentrations and temperature, photosynthesis rates depend on the surface area or mass of the plant exposed to light.

In this experiment we follow the photosynthesis rate in *Elodea* by measuring the rate of oxygen production.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Oxygen Sensor
- Light Sensor (triple range)
- 20 g of fresh *Elodea*
- Bright light source (e.g. 150 W Halogen lamp)
- 250 ml transparent glass Erlenmeyer flask
- Stopper with a hole in it that fits the Oxygen Sensor or a stopper with a hole and modeling clay (Optional – two holes, one for a Temperature Sensor).
- About 1 liter of tap water
- Magnetic stirrer and stir bar
- One liter flat water bottle (glass or plastic) or tissue culture bottle (heat filter)
- Optional Temperature Sensor (-40 °C to 140 °C)



Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Oxygen (DO₂) Sensor, the Light Sensor and the Temperature Sensor to ports on the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
 - a. The system consists of a 250 ml transparent glass Erlenmeyer flask, containing tap water and fresh *Elodea* (about 20 g) with a stir bar in the flask.
 - b. The flask is placed on a magnetic stirrer. Using the stand, carefully place the Oxygen Sensor electrode in the flask, near to the stir bar at the bottom. (Optional – a Temperature Sensor can be placed in the flask).
 - c. The Erlenmeyer flask must be totally sealed to prevent oxygen leakage. For more information on sealing see: Sealing
 - d. The Light Sensor is placed near the flask to measure the level of light to which the *Elodea* is exposed.
 - e. Use a 150 Watt reflection lamp as a light source. Place it 25 cm from the flasks.
 - f. In order to prevent heating the flask, a flat 1 liter water bottle is placed between the light source and the flask.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Oxygen, Light and Temperature Sensors are selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Oxygen DO ₂
Measurements:	Oxygen DO ₂ (mg/L)
Sensor:	Light-600
Range	0-600 lx
Measurements:	Light-600 (lx)
Sensor:	Temperature (-40°C to 140°C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	5000
Duration:	1 hour 23 minutes 20 seconds

Note: Ensure that only the external Light Sensor and Temperature Sensor (-40°C to 140°C) are selected and not the internal Light Sensor and internal Temperature Sensor (-30°C to 50°C).



Procedure

1. Select **Run** () to begin recording data.
2. Switch on the light and begin stirring and observe the oxygen (DO₂) concentration level.

Note: Follow temperature levels in the flat water bottle throughout the experiment. If water temperature rises sharply (more than 5°C in 5 minutes), stop the measurements and change the water in the bottle. After about half hour, turn the light off and cover the flask, so that the *Elodea* is not exposed to light.

3. Select **Stop** () to stop collecting data.
4. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Determine the rate of oxygen production:
 - a. Use **two cursors** () to select one point at the beginning of the graph and one point at the end of the graph of dissolved oxygen vs. time.
 - b. Select **Curve fit** () from the Analysis window on the upper menu bar.
 - c. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
 - d. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.

An example of the graph obtained in this experiment is shown below:

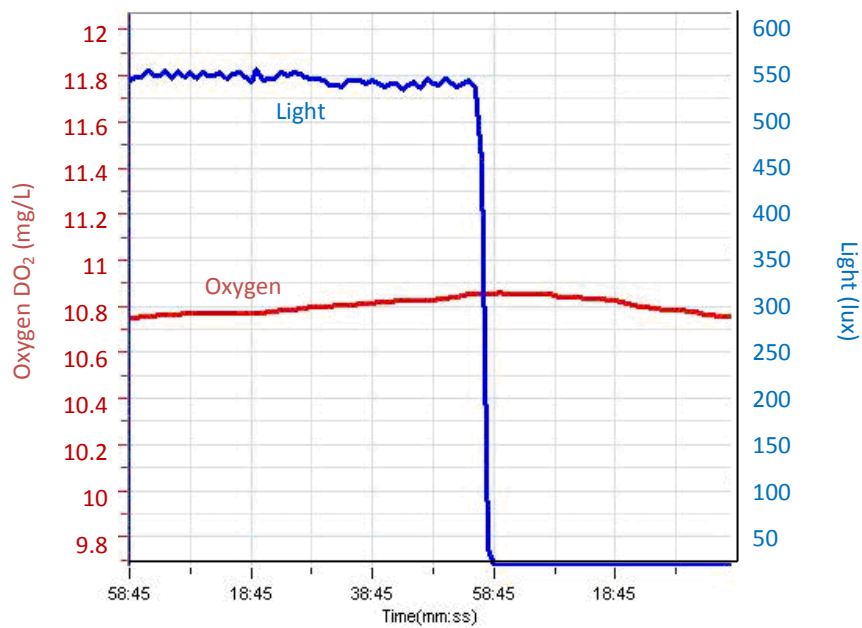


Figure 2



Questions

How would the addition of bicarbonate influence photosynthesis?

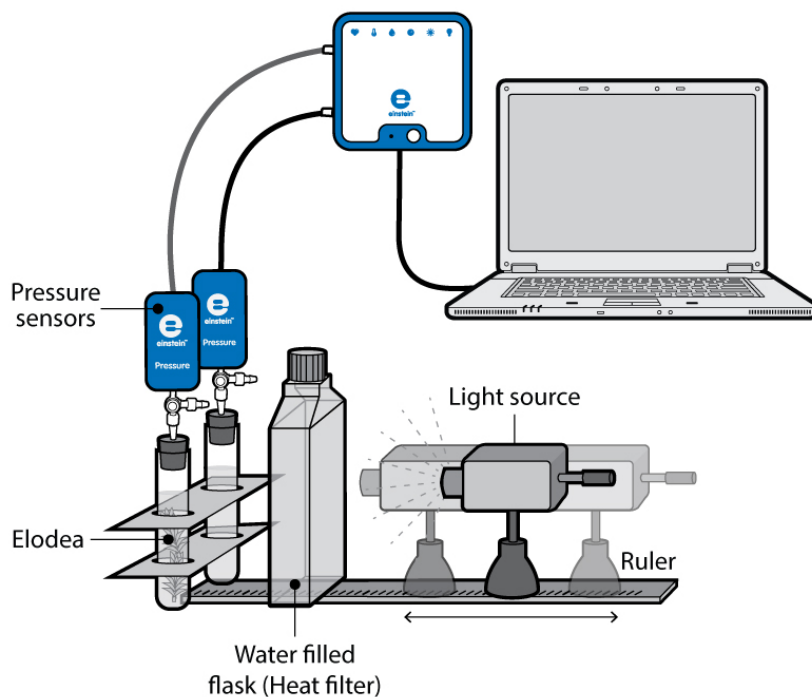


Further Suggestions

1. Photosynthesis rates depend on several factors: the mass of *Elodea*, light intensity etc. How does each of these factors affect the reaction rate?
2. Using the system described in this experiment, design new experiments to measure the effect of each of these factors. Try repeating the experiment with a double mass of *Elodea*, stronger light intensity, adding bicarbonate etc.

Effect of Light on the Photosynthesis Rate

Figure 1



Introduction

The photosynthesis rate depends on light intensity. Under optimal conditions, a saturation curve is obtained. Light intensity at different distances from a light source is inversely proportional to the square of the distance.

$$(1) \quad I = \frac{1}{r^2}$$

Where:

I = The light intensity.

r = The distance from the light source.

In this experiment the light intensity is modified by placing the light source at different distances from the experimental system.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Two Pressure Sensors (150 - 1150 mbar)
- Light Sensor (triple range)
- 2 g of fresh *Elodea*
- 150 W reflector lamp
- Two 50 ml glass test tubes
- Two stoppers with a hole for syringe extenders
- Two syringe extenders*
- Latex tube*
- Two three-way valves*
- Stand to support the sensors
- Two one liter flat water bottles (glass or plastic) or tissue culture bottles (heat filter)
- Bright light source (e.g. 150 W Halogen lamp)
- Optional: Temperature Sensor (-40°C to 140°C)
- Meter stick

*contained in einstein™ Pressure Kit

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Pressure Sensors and the Temperature Sensor to ports on the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
 - a. Slice 2 g of the *Elodea* branch into segments that fit the size of the test tube.
 - b. Place the *Elodea* segments into one test tube. The other test tube will serve as the experimental control.
 - c. Fill the test tubes with tap water. The tap water should reach 1 cm below the stopper.
 - d. Seal the test tubes tightly with the stoppers.
 - e. Insert syringe extenders into the stoppers (Figure 2).
 - f. Attach three-way valves to the other end of the syringe extenders.
 - g. Connect the Pressure Sensors to the valves.

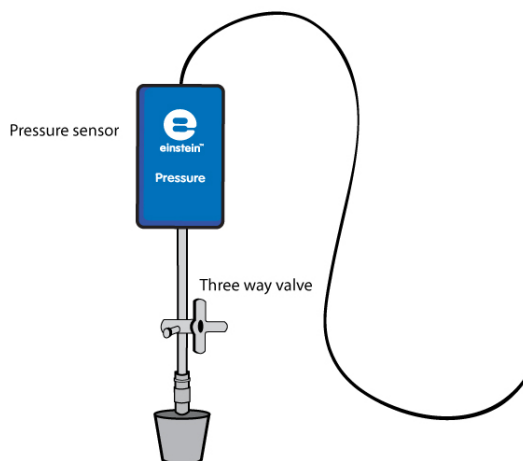


Figure 2

- Fill the flat plastic bottles with tap water and place them between the light source and the test tubes. The water absorbs the heat radiating from the light source.
- In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Pressure and Temperature Sensors are selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Sensor:	Temperature (-40°C to 140°C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	5000
Duration:	1 hour 23 minutes 20 seconds

Note: Ensure that only the external Pressure Sensor (150– 1150 mbar) and external Temperature Sensor (-40°C to 140°C) are selected and not the internal Pressure Sensor (0– 400 kPa) or internal Temperature Sensor (-30°C to 50°C).




Procedure

Checking the experimental setup: Sealing.

Performing the experiment:

- In this experiment, the photosynthesis rate is measured at five different times, each time with a different light intensity. Light intensity is changed by moving the lamp farther and farther from the plant. The recommended range is 20 to 45 cm.
- Since the duration of this experiment is relatively long (about 45 minutes), place two flat bottles between the light source and the experimental test tubes.
- Follow temperature levels in the flat water bottles throughout the experiment. If the water temperature rises sharply (more than 5°C in five minutes), stop the measurements and change the water in the bottles. Water temperature can be monitored using a Temperature Sensor.
- The experiment uses two test tubes, with one serving as a control. Add 2 g of fresh *Elodea* to one of the test tubes.
- Place the test tubes side by side, opposite the light source. Make sure the test tubes are equally illuminated. It is recommended that you illuminate the test tube containing the *Elodea* for five minutes before the experiment is started. This will saturate the solution, and oxygen release can be measured immediately at the beginning of the experiment. Otherwise, a lag period of about six minutes is observed.
- Draw a straight line from the center of the light source up to the contact line of the two test tubes. Put a ruler along this line, in order to measure the distance of the light source from the test tubes (see Figure 1).
- Use the Temperature Sensor to measure the temperature in the test tubes when you start the experiment. Repeat the measurement at the end of the experiment. The temperature should not rise by



more than 2°C.

8. Make sure that the experiment begins with both test tubes at atmospheric pressure. Turn the three-way valves to position A (see Sealing), and then return to position B. The pressure in both test tubes should now equal atmospheric pressure.
9. Select **Run** () to begin recording data.
10. Follow the pressure in the Graph window of MultiLab4.
11. Let the experiment run for at least 8 minutes.
12. After eight minutes, turn the light off, move the light source to the second distance and turn the light on again.

CAUTION! The light source warms up during the experiment. Be cautious when moving it.

13. Repeat the experiment for 2-3 additional distances.

Note: To avoid disturbing the pressure levels do not touch the test tubes during the experiment.




14. Select **Stop** () to stop collecting data.
15. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.

Measurement of light intensity at different distances

1. Place the Light Sensor at the contact line of the two test tubes.
2. Place the sensor's opening exactly opposite the center of the light source.
3. Make sure the Light Sensor is immobile.
4. Connect the Light Sensor to one of the ports on the einstein™ LabMate.
5. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Light Sensor is selected under Measurements.



Program the sensors to log data according to the following setup:

Sensor:	Light-150K
Range:	0-150klx
Measurements:	Light-150K (klx)
Rate:	10 samples per second
Samples:	20000
Duration:	33 minutes 20 seconds

8. Select **Run** () to begin recording data.
9. Prepare a table and record the light intensity at different distances from the test tubes.
10. Select **Stop** () to stop collecting data.
11. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. To calculate the net reaction rate, you will need to create a graph in which you subtract the Pressure graph obtained for the control system from that of the experimental system:
 - a. Select Math functions () from the Analysis window on the upper menu bar.
 - b. In the Math function window which opens, choose Subtract from the Function drop down menu.
 - c. In the G1 drop-down menu, select Pressure (from the test tube with the *Elodea*) . In the G2 drop-down menu select Pressure (from the control test tube).
 - d. In the Name edit box enter a name (e.g. Subtraction).
 - e. Click OK.
2. In this experiment, a set of linear segments are obtained, each representing a different distance of the light source from the test tubes.
3. The linear segments are isolated by selecting one point on the graph when the light was moved to a certain distance and another point when the plant was moved from the distance.
4. Apply a linear fit to the selected segment of the graph:
 - a. Select the desired range of the new plot line.
 - b. Select Curve fit () from the Analysis window on the upper menu bar.
 - c. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
 - d. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
 - e. The slope of the fit line is the net reaction rate.
 - f. Repeat for each linear segment of the graph.

An example of the graph and linear fits obtained in this experiment is shown below (the black lines are the linear fits):

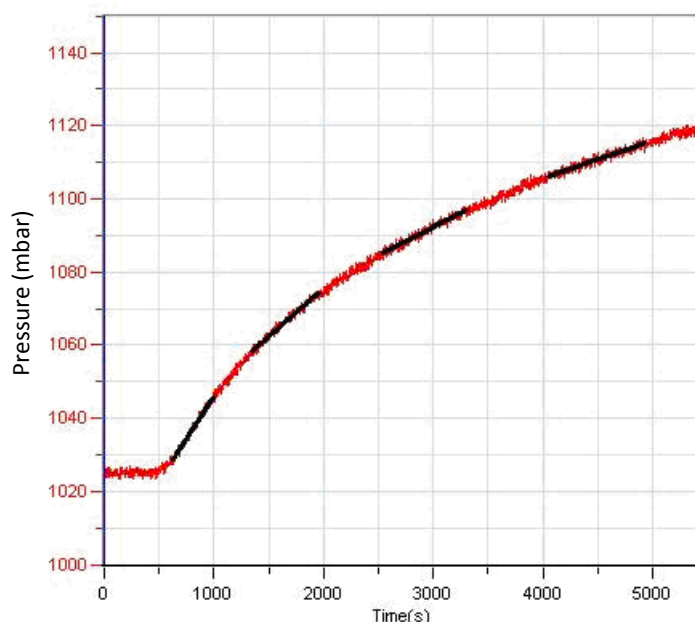


Figure 2

Fill in the following table:

Exp. no	Distance from Light Source (cm)	Slope	Light Intensity (klux)
1			
2			
3			
4			
5			



Questions

1. How is light intensity modified in this experiment?
2. Why is a control system necessary in this experiment?
3. Describe the effect of light intensity on the rate of photosynthesis:
 - Does the rate depend on light intensity over the whole range of intensities examined?
 - Define the range of intensities in which light is a limiting factor.
4. How could an increase in temperature in the test tubes affect the outcome of the experiment?



Further Suggestions

1. Examine the effect of light wavelength on photosynthesis. Place blue, green, and red filters between the test tubes and the light source.
2. At limited light intensities, how does an increase in the mass of *Elodea* affect the rate of photosynthesis?
3. Design an experiment to test your hypothesis.

Effect of Light on the Photosynthesis Rate: Using an Oxygen Sensor

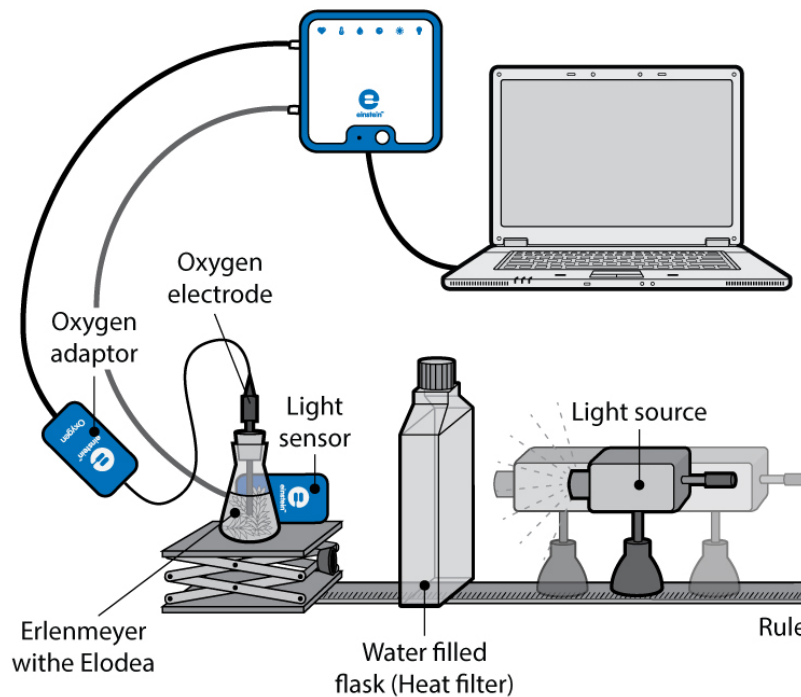


Figure 1

Introduction

Photosynthesis provides food for most plant life on earth. This process uses the energy from light to turn carbon dioxide (CO_2) and water into carbohydrates and generates oxygen which is released into the atmosphere. Light, the energy source for this process is absorbed by pigments in photosynthetic organisms.

Under optimal conditions of carbon dioxide concentrations and temperature, the rate of photosynthesis depends on the light intensity absorbed by the photosynthetic parts of the organism. Light intensity at different distances from a light source is inversely proportional to the square of the distance.

$$I = \frac{1}{r^2} \quad (1)$$

Where:

I = The light intensity.

r = The distance from the light source.

In this experiment the light intensity is modified by placing the light source at different distances from the experimental system.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Oxygen Sensor
- Light Sensor (triple range)
- Optional Temperature Sensor (-40°C to 140°C)
- 9 g of fresh *Elodea*
- Bright light source (e.g. 150 W halogen lamp)
- 250 ml glass Erlenmeyer
- Stopper with a hole that fits the Oxygen Sensor or a stopper with a hole and modeling clay
- Laboratory jack
- Two one liter flat water bottles (glass or plastic) or tissue culture bottles (heat filter)
- 0 - 2% bicarbonate solution



Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Oxygen Sensor and the Light Sensor to ports on the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
 - a. The rate of photosynthesis may vary with the species of plant available and the season of the year. Therefore, it is recommended you conduct one experiment under optimal conditions of light (about 20 cm distance between the light source and the Erlenmeyer flask) and a bicarbonate concentration of 0.5% - 1.0%, before measuring the effect of light intensity on photosynthesis rate.
 - b. Set up a 250 ml transparent glass Erlenmeyer flask filled with bicarbonate solution and about 9 g. of fresh *Elodea*:
 - i. Mark a line about 5 cm below the top of the Erlenmeyer flask.
 - ii. Cut the *Elodea* into short pieces and arrange them so that they are parallel to each other to ensure maximal exposure to the light. Place the plants inside the Erlenmeyer flask.
 - iii. Fill the Erlenmeyer flask with bicarbonate solution up to the line marked.
 - iv. Insert the oxygen electrode. It should be immersed into the solution and tightly close the Erlenmeyer flask.
 - c. The concentration of oxygen released to the water with the bicarbonate solution and the plant is followed using the Oxygen Sensor.
 - d. In order to produce a reasonable rate of photosynthesis, about 5 ml of free air should be kept in the Erlenmeyer.
 - e. The Erlenmeyer flask should be tightly closed to prevent leakage of oxygen, either by a stopper with a hole that fits the oxygen electrode or by covering the Erlenmeyer flask's opening with modeling clay.
 - f. The Light Sensor is mounted behind the Erlenmeyer flask to measure the light intensity to which the *Elodea* is exposed.
 - g. Because heat can affect the reaction rate, two flat water bottles are placed between the light source and the Erlenmeyer flask to prevent heating of the bicarbonate solution.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Oxygen, Light and Temperature Sensors are selected under Measurements.



Current Setup Summary




Program the sensors to log data according to the following setup:

Sensor:	Oxygen DO ₂ mg/L
Measurements:	Oxygen DO ₂ mg/L
Sensor:	Light-150K
Range:	0-150klux
Measurements:	Light-150K (klux)
Sensor:	Temperature (-40°C to 140°C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	5000
Duration:	1 hour 23 minutes 20 seconds

Note: Ensure that only the external Light Sensor and external Temperature Sensor (-40°C to 140°C) are selected and not the internal Light Sensor and internal Temperature Sensor (-30°C to 50°C).




Procedure

1. In this experiment the rate of photosynthesis is measured for various concentrations of bicarbonate solution. Choose four to five concentrations of bicarbonate in the range of 0% - 2%. Start the experiment with 0.5% bicarbonate solution.
2. Follow temperature levels in the flat water bottle throughout the experiment. If water temperature rises sharply (more than 5 °C in five minutes), stop the measurements and change the water in the bottles.
3. It is recommended that you illuminate the Erlenmeyer flask containing the *Elodea* for five minutes before the experiment is started. In this way, the solution becomes saturated with oxygen and oxygen release can be measured immediately when the experiment starts. Otherwise, a lag period of about six minutes is observed.
4. Select **Run** () to begin recording data.
5. Start the experiment with the light source at the maximal distance chosen. Make sure the light is directed at the Erlenmeyer flask.
6. Switch on the light and follow the oxygen percentage level.
7. Follow photosynthesis rate for 5-8 minutes, until a straight line is observed. At large distances from the light source the rate may be very low.
8. After 5-8 minutes, turn off the light.
9. Select **Stop** () to stop collecting data.
10. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.
11. Move the light source to the second distance and turn the light on again.
12. Repeat steps 4 - 10 at three to four additional distances.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. When the experiment is carried out with a 0.5% bicarbonate solution, a set of graphs, each with a linear segment, is obtained. Each graph represents a different distance of the light source from the Erlenmeyer flask.
2. Use the cursors to select a range of data points within this linear segment.
3. Apply a linear fit to the selected segment of the graph:
 - e. Select Curve fit () from the Analysis window on the upper menu bar.
 - f. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
 - g. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
 - g. The slope of the fit line is the net reaction rate.
 - h. Repeat for each graph.

An example of the graph obtained in this experiment, is shown below:

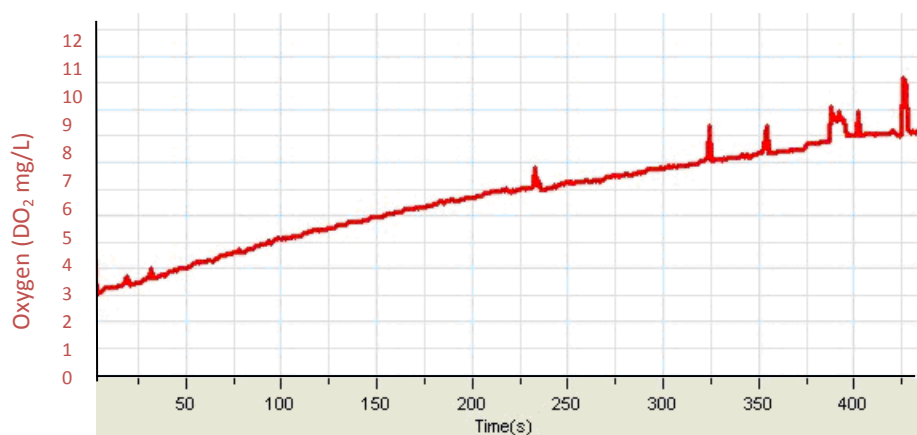


Figure 2

4. Use the cursor to read from the light intensity from the graph and fill in the following table:

Exp. no	Distance from Light Source (cm)	Slope	Light Intensity (Klux)
1			
2			
3			
4			
5			

5. Use Excel to draw a graph describing the relationship between the light intensity and the rate of photosynthesis (slope).
6. Repeat steps 1-5 for each bicarbonate solution ranging in concentration from 0% - 2%.



Questions

1. How is light intensity modified in this experiment?
2. Describe the effect of light intensity on the rate of photosynthesis.
3. Does the rate depend on light intensity in the whole range of intensities examined?
4. Define the range of intensities in which light is a limiting factor.
5. What can be the effect of a temperature rise in the Erlenmeyer flask during the experiment?



Further Suggestions

1. The rate of photosynthesis can be followed by measuring oxygen release into the solution. The Oxygen Sensor should be defined as DO_2 (Dissolved Oxygen) and a magnetic stirrer should be used to ensure an even distribution of oxygen in the solution. If DO_2 is measured, a successive measurement at different distances is impossible. The solution must be replaced and a different measurement for each distance should be performed.
2. Examine the effect of light wavelength on photosynthesis. Place blue, red, and green filters between the test tubes and the light source. Cover the test tubes with cardboard to prevent penetration of light from sources other than the light source.
3. At limiting light intensities, how will an increase in the mass of *Elodea* affect the rate of photosynthesis?
4. Design an experiment to test your hypothesis.

Effect of Bicarbonate on the Photosynthesis Rate – Using Pressure Sensors

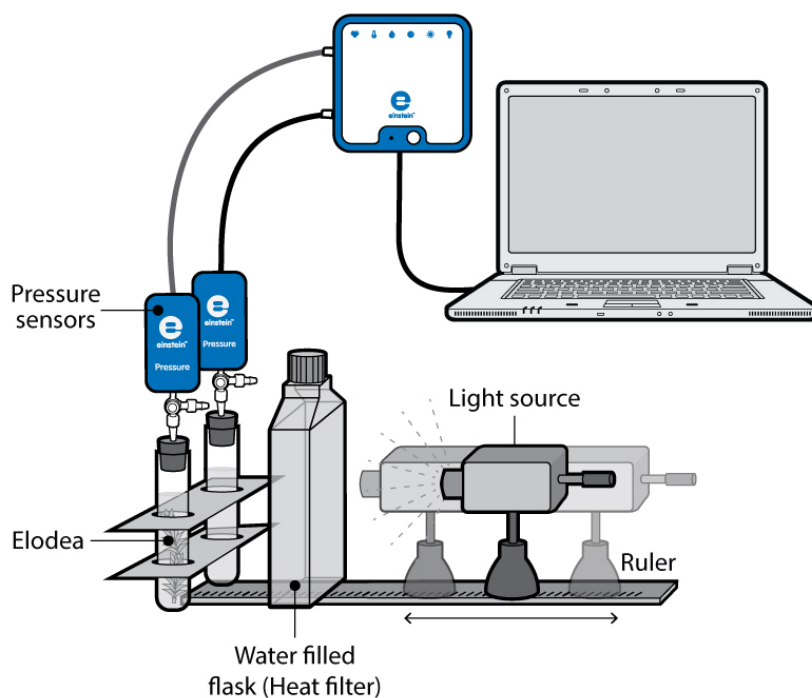


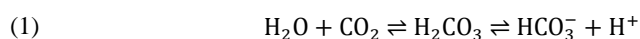
Figure 1



Introduction

Photosynthesis, the process by which most plants and trees produce carbohydrates, has both light reactions, which need light in order to occur and dark reactions which are independent of light. During these dark reactions CO_2 is broken down, or fixed and used to create carbohydrates.

The main source for the CO_2 consumed in photosynthesis is the atmosphere, consisting of about 0.03% CO_2 . Dissolution of CO_2 in water leads to the following reaction:



The bicarbonate ions produced in this reaction serve as a source of CO_2 for the dark reactions of photosynthesis.

In this experiment we measure the rate of photosynthesis at different CO_2 concentrations.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Two Pressure Sensors (150 – 1150 mbar)
- Two 50 ml glass test tubes
- Two stoppers with a hole for syringe extenders
- Two syringe extenders*
- Two three-way valves*
- Perspex stand to support the tubes and sensors
- Two one-liter flat water bottles (glass or plastic) or tissue culture bottles (heat filter)
- 2 g of fresh *Elodea*
- Plastic knife
- Bright light source (e.g. 150 W Halogen lamp)
- Optional Temperature Sensor (-40°C to 140°C)
- 0 - 2% bicarbonate solution

*contained in einstein™ Pressure Kit



Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Pressure Sensors to ports on the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
 - a. The experiment uses two 50 ml test tubes, with one serving as the control.
 - b. The concentrations of the bicarbonate solution used in this experiment are varied in the range of 0-2%.
 - c. Use a very fresh branch of *Elodea*, weighing 2 g, and slice it into segments suitable in length to the test tube size. Arrange the segments parallel to each other to ensure maximal exposure to light.
 - d. Add 2 g of fresh *Elodea* to one of the test tubes.
 - e. The tubes must be completely sealed by the rubber stoppers. A very small volume of air should remain between the stopper and the solution surface.
 - f. Place the test tubes side by side in front of the light source. Make sure the test tubes are equally illuminated.
 - g. A 150 W reflection lamp serves as the light source. Placed it at a distance of 25 cm from the test tubes.
 - h. In order to prevent heating of the test tubes, place two 1 liter flat bottles filled with water between the light source and the test tubes.
 - i. Follow the temperature of the water in the bottles throughout the experiment (you can use a Temperature Sensor).
 - j. Insert a syringe extender into each stopper (Figure 2).
 - k. Attach a three-way valve to the other end of each syringe extender.
 - l. Connect a Pressure Sensor to each valve.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Pressure and Temperature Sensors are selected under Measurements.

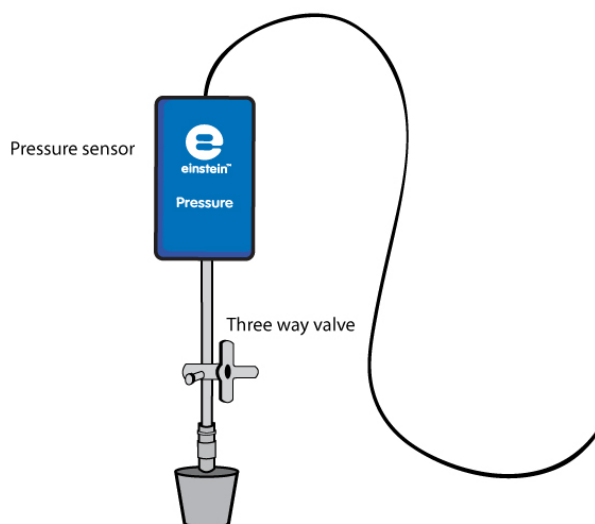


Figure 3: Three-way valve – Position A



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Sensor:	Temperature (-40°C to 140°C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	5000
Duration:	1 hour 23 minutes 20 seconds

Note: Ensure that only the external Pressure Sensor (150– 1150 mbar) and external Temperature Sensor (-40°C to 140°C) are selected and not the internal Pressure Sensor (0– 400 kPa) or internal Temperature Sensor (-30°C to 50°C).




Procedure

Checking the experimental setup: Before starting the experiment, make sure that the test tubes are tightly sealed. For more details see Sealing.


Performing the experiment:

1. In this experiment the rate of photosynthesis is measured at various concentrations of bicarbonate solution. Choose four to five concentrations of bicarbonate in the range of 0-2%. Start the experiment with 0.5% bicarbonate solution.
2. Make sure that the experiment begins with both test tubes at atmospheric pressure. Turn the three-way valves to position A (see Sealing), and then return to position B. The pressure in both test tubes should now equal atmospheric pressure.
3. It is recommended that you illuminate the test tube containing the *Elodea* for five minutes before the

experiment is started. In this way the solution becomes saturated with oxygen and oxygen release can be measured immediately at the start of the experiment. Otherwise, a lag period of about six minutes is observed.

4. Since the duration of this experiment is relatively long (about 45 minutes), place two 1 liter flat water bottles between the light source and the experimental test tubes.
5. Follow temperature levels in the flat water bottles throughout the experiment. If water temperature rises sharply (more than 5°C in 5 minutes), stop the measurements and change the water in the bottles.
6. Select **Run** () to begin recording data.
7. Measure the temperature in each experimental test tube at the start and at the end of the experiment. The temperature should not rise by more than 2°C.
8. Follow the pressure in the Graph window of MultiLab4.
9. Track the rate of photosynthesis for at least eight minutes.
10. Pour out the bicarbonate solution from both test tubes and add a bicarbonate solution of a different concentration.
11. Measure the reaction rate for an additional six minutes.



Note: Keep the same Elodea segments throughout the whole experiment.

12. Repeat steps 8-11, three more times, each time adding a bicarbonate solution of a different concentration.
13. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. To calculate the net reaction rate, you will need to create a graph in which you subtract the Pressure graph obtained for the control system from that of the experimental system:
 - a. Select **Math functions** () from the Analysis window on the upper menu bar.
 - b. In the Math function window which opens, choose Subtract from the Function drop down menu.
 - c. In the G1 drop-down menu, select Pressure (from the test tube with the *Elodea*). In the G2 drop-down menu select Pressure (from the control test tube).
 - d. In the Name edit box enter a name (e.g. Subtraction).
 - e. Click **OK**.
2. Apply a linear fit to the selected segment of the graph:
 - a. Select the desired range of the new plot line.
 - b. Select **Curve fit** () from the Analysis window on the upper menu bar.
 - c. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
 - d. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
 - e. The slope of the fit line is the net reaction rate.
3. Repeat step 2 for each linear segment of the graph (each segment refers to a different concentration of the bicarbonate solution).

An example of the graph obtained in this experiment is shown below:

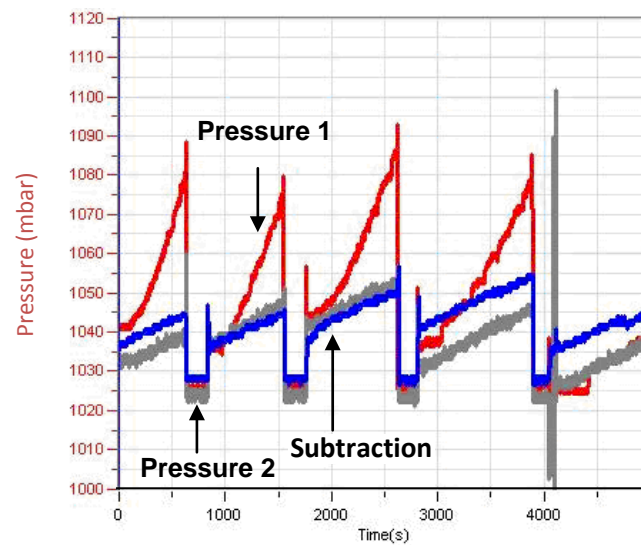


Figure 2

Fill in the following table:

Experiment Number	Bicarbonate Concentration (%)	Slope

- Use Excel to draw a graph describing the relationship between bicarbonate concentration and the rate of photosynthesis (slope).

Questions

- What did you *control* in this experiment? Explain in detail.
- How is the rate of photosynthesis influenced by the bicarbonate concentration?
- How might an increase in the temperature of the test tubes affect the measured rate of photosynthesis?
- Predict the effect of adding *Elodea* segments:
 - At low bicarbonate concentration?
 - At saturated bicarbonate levels?

Further Suggestions

Predict the effect of reducing light intensity below saturation levels? Design an experiment to test your hypothesis.

Measurement of Glucose Synthesis during Photosynthesis

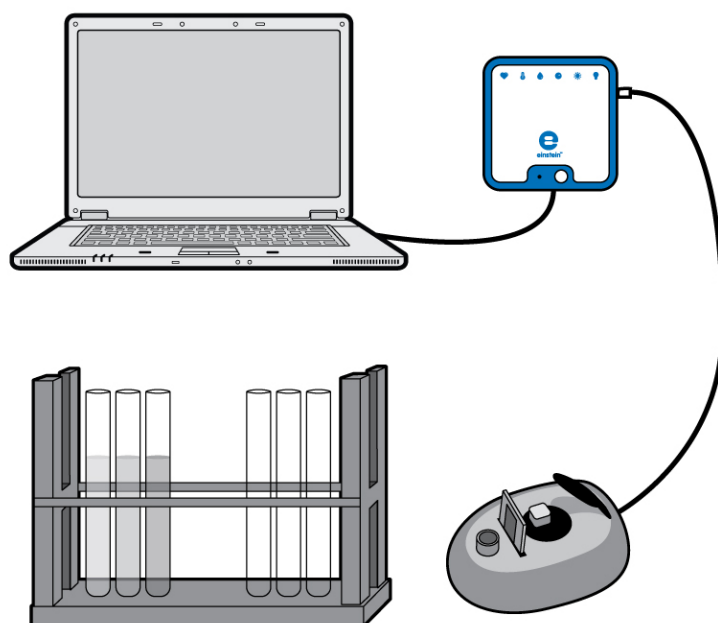


Figure 1



Introduction

Photosynthesis is the fundamental process by which plants and other organisms use light energy to produce organic compounds, such as sugars (form of carbohydrate), from carbon dioxide and water. One of the most important of these sugars is glucose.

Glucose synthesis depends upon abiotic factors such as light intensity and temperature, and upon biotic factors, such as chlorophyll levels in the plant's leaves and the surface area of the plant which is exposed to light.

In this experiment we use a Colorimeter to follow the levels of glucose synthesized in terrestrial plants.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Colorimeter
- Plant with at least 20 - 40 leaves (*Coleus*, *Pelargonium* or *Jasminum fruticans* are good choices)
- 150 W reflector lamp
- Rack with test tubes
- Mortar and pestle

- 1% glucose solution in water
- Acetone
- n-Hexane*
- 40% potassium sodium tartrate solution
- % DNS solution:
- 10 g DNS (dinitrosalicylic acid)
- 2 g/L phenol (optional, it intensifies the color)
- 0.5 g sodium sulfite
- 10 g NaOH
- Add water to 1 liter
- Cuvettes
- Gauze
- Safety goggles

*When working with n-Hexane, make sure to work under a Chemical Hood

123 Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Colorimeter to one of the ports on the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
4. The first setup is for calibration and the second is for taking measurements.
5. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Colorimeter Sensor is selected under Measurements.

Current Setup Summary

1. For the calibration of the Colorimeter, the setup is:

Sensor:	Colorimeter
Measurements:	Absorbance (%)
Rate:	Every second
Samples	100
Duration:	1 minute 40 seconds

2. Use the green filter for chlorophyll extracts and the red filter for glucose determination.
3. For the measurements of color with the Colorimeter, the setup is:

Sensor:	Colorimeter
Measurements:	Absorbance (%)
Sampling:	Manual
Samples:	5



Procedure



1. Illuminate the plant you choose or place it outside in full daylight.
2. Over intervals of one hour take off 8 leaves.
3. Preparation of chlorophyll and glucose extracts:
 - a. Weigh the leaves.
 - b. Crush the leaves with a mortar and pestle.
 - c. Add 10 ml acetone and continue to crush.
 - d. Filter the extract through gauze and collect the fluid in a test tube.
 - e. Add 10 ml n-Hexane. Mix well.
 - f. Add 10 ml tap water. Mix well. The n-Hexane is lighter than water and does not dissolve in water. A separate green layer of n-Hexane with the chlorophyll extract will form above the water.
 - g. Collect the upper layer into a test tube, and mark it, "One hour."
 - h. Collect 3 ml from the tap water layer and add it to a test tube for glucose determination. Mark it, "Glucose one hour."
 - i. Repeat stages a-h after two, three and four hours.

Measure chlorophyll concentration in your samples:




Dilute the samples with tap water (the extent of dilution depends on color intensity, but should be at least 1:3 to enable color reading in the colorimeter).

Note: You can omit the measurement of chlorophyll concentration and rely on your weighing data alone.

Calibrate the Colorimeter:

1. Use the green filter.
2. n-Hexane diluted 1:3 in tap water will serve as a blank solution.
3. Pour the blank into a cuvette and insert it into the Colorimeter.
Cover the cuvette to avoid n-Hexane evaporation.
4. Close the Colorimeter cover tightly.
5. Select **Run** () to begin recording data.
6. Turn the knob on the Colorimeter until you receive 100% transmission.
7. Select **Stop** () to stop collecting data.

Measure the color in each sample:

1. Pour each sample into a cuvette and insert it into the Colorimeter.
2. Close the Colorimeter cover tightly.
3. Select **Run** () to enable recording data.
4. Collect the data manually: Select **Manual Sampling** () each time you wish to record a data sample.
5. Select **Stop** () to stop collecting data.

Measure glucose levels in your samples:

1. Prepare a standard curve by making up five test tubes with 3 ml of the following glucose concentrations:
1%, 0.5%, 0.1%, 0.05%, 0 (blank solution).
2. Add 3 ml of 1% DNS solution to each 3 ml sample of glucose solution.
3. Cover the test tubes with glass caps or other covers to avoid evaporation.
4. Heat the mixtures to 90°C for 10 minutes until a red-brown color is obtained.

5. Add 1 ml of 40% potassium sodium tartrate solution. It stabilizes the color.
6. Cool to room temperature in cold water.

Calibrate the Colorimeter:

1. Use the red filter.
2. Pour the blank solution into a cuvette and insert it into the Colorimeter.
3. Close the Colorimeter cover tightly.
4. Select **Run** (▶) to begin recording data.
5. Turn the knob on the Colorimeter until you receive 100% transmission.
6. Select **Stop** (■) to stop collecting data.

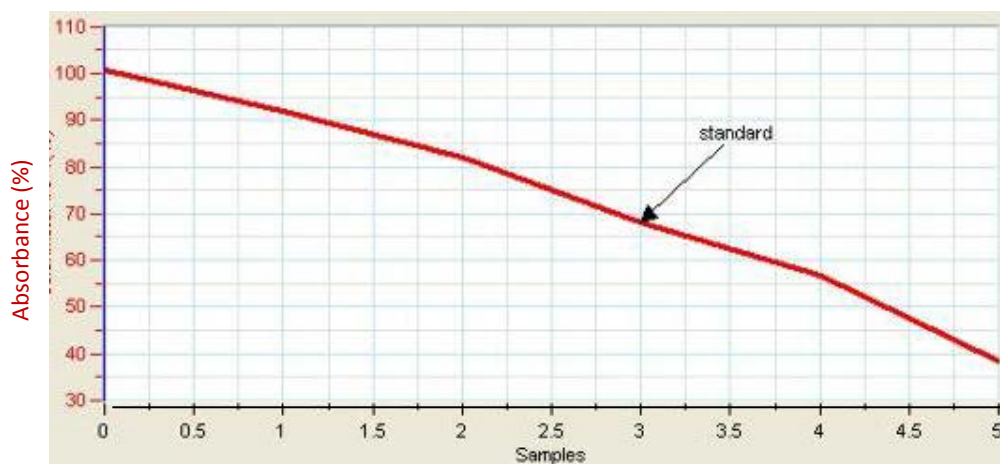
Measure the color in each sample:

1. Pour each sample into a cuvette and insert it into the Colorimeter.
2. Close the Colorimeter cover tightly.
3. Select **Run** (▶) to begin recording data.
4. Collect the data manually: Select **Manual Sampling** (⌚) each time you wish to record a data sample.
5. Select **Stop** (■) to stop collecting data.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Prepare a standard curve of glucose: light transmittance versus glucose concentration.
An example of the graph obtained in this experiment, is shown below:



2. Use the calibration curve to determine the glucose concentration which corresponds to the transmittance that you measured for each leaf sample. Use the concentrations you have determined for the time points you measured to prepare a table as shown below:

Time (Hours)	% Absorbance	Glucose Concentration	Glucose Concentration per g Leaf Weight (%/g)

3. Use Excel to prepare a graph presenting the changes in glucose concentration per g leaf with time.



Questions

1. Describe the graph showing glucose synthesis with time. Is the graph linear?
2. Why is it important to calculate glucose concentration per gram leaf weight or chlorophyll concentration?
3. Which of the parameters is more accurate: leaf weight or chlorophyll concentration? Explain.
4. What are the relationships between glucose synthesis and O_2 released during photosynthesis?
5. What is the effect of temperature on glucose synthesis rate in photosynthesis? Design an experiment to test your hypothesis.



Further Suggestions

1. Keep plants in different light intensities and measure the effect on glucose synthesis.
2. Keep the plants in closed transparent chambers: In one add KOH grains (KOH reacts with CO_2 and removes it from the free air). Compare glucose synthesis in the chambers.
3. Compare glucose synthesis in different plants.

Chapter 9

Effect of Light on Chlorophyll Levels in Plant Leaves

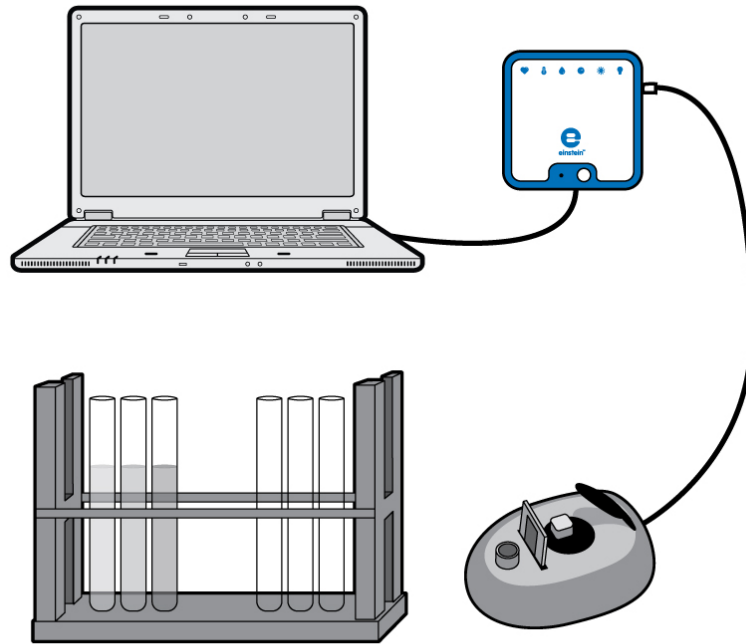


Figure 1



Introduction

Chlorophyll is a green photosynthetic pigment found in plants, algae and cyanobacteria. Chlorophyll absorbs sunlight and uses its energy to synthesize carbohydrates from CO_2 and water.

There are actually five types of photosynthetic pigments; each absorbs light most efficiently in a different part of the spectrum:

Chlorophyll a - green pigment, absorbs well at a wavelength of about 400-450 nm (blue) and at 650-700 nm (red). It is the most common pigment, present in every plant that performs photosynthesis.

Chlorophyll b - green pigment, absorbs at 450-500 nm (blue)

Carotene - orange pigment, absorbs well at 450-500 nm (blue).

Xanthophyll - yellow pigment, absorbs well at 400-530 nm (blue-violet)

Phaeophytin - grey pigment. Carotene, xanthophyll and phaeophytin are called accessory pigments, since they absorb light and transfer the energy to chlorophyll.

None of the pigments absorbs well in the green-yellow region, which explains why most of what we see in nature is green, i.e. is reflecting green light. Light intensity affects the level of chlorophyll found in plants.

In this experiment, chlorophyll is extracted from the leaves of plants exposed to different levels of lighting.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Colorimeter
- Cuvettes
- Mortar and pestle
- 95% ethanol
- Rack with test tubes
- Plants (at least 2 of each species)
- Safety goggles

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Colorimeter to one of the ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1 above.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Colorimeter Sensor is selected under Measurements.



Current Setup Summary

For the *calibration* of the Colorimeter use the green filter. The setup is:

Sensor:	Colorimeter
Measurements:	Absorbance(%)
Rate:	Every second
Samples	100
Duration:	1 minute 40 seconds







Use the green filter for chlorophyll extracts.

For the *measurements* of color with the Colorimeter, the setup is:

Sensor:	Colorimeter
Measurements:	Absorbance (%)
Sampling:	Manual
Samples:	10



Procedure

1. Grow plants (at least two of each species) under different light intensities for a week (or more),
Light intensities:
 - a. Total darkness (in a closed box or cupboard).
 - b. Weak light (in a shadowed corner or under a shadowing net).
 - c. Full daylight (close to the window in the classroom).
2. Fast growing plants such as *Ruscus sp.*, *Coleus*, *Geranium* and Purple Heart (*Setcreasea pallida*) are most suitable. Sprouts will do as well if their leaves are sufficiently large.
3. Preparation of chlorophyll extract:
 - a. Weigh 3 g of leaves.
 - b. Crush the leaves with a mortar and pestle.
 - c. Add 10 ml ethanol and continue to crush.
 - d. Collect the colored ethanol solution and pour it into a test tube. If the color is strong, dilute it with ethanol. Cover the test tube to avoid ethanol evaporation.
4. Calibrate the Colorimeter:
 - a. Use the green filter.
 - b. Ethanol will serve as a blank solution.
 - c. Pour the blank into a cuvette and insert it into the Colorimeter. Cover the cuvette to avoid ethanol evaporation.
 - d. Close the Colorimeter and cover tightly.
 - e. Select **Run** () to begin recording data.
 - f. Turn the knob on the Colorimeter until it records 100% transmission.
 - g. Select **Stop** () to stop collecting data.
5. Measure the color in each sample:
 - a. Select **Run** () to enable collecting data.
 - b. Collect the data manually: Select **Manual Sampling** () each time you wish to record a data sample.
 - c. Run a separate measurement for each species of plant.
 - d. Select **Stop** () to stop collecting data.
 - e. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.
6. Run a separate measurement for each species of plant.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Select any point on the graph to obtain the chlorophyll level in each plant species you examined under each light intensity regime.
2. Prepare a graph showing the effect of light on chlorophyll level in each plant species you examined.
3. Compare the results obtained with different plant species.

An example of a graph obtained with Purple Heart leaves taken from plants grown under four different light regimes is shown below (the first result is the blank):

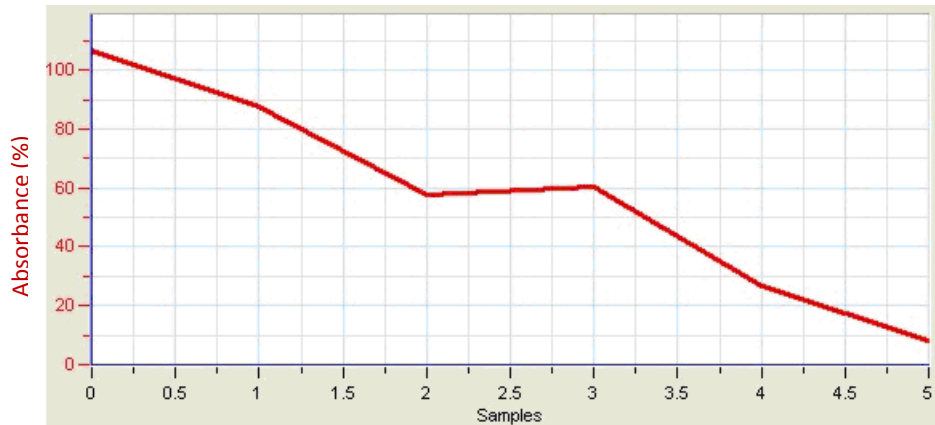


Figure 2



Questions

1. Why should you grow at least 2 plants of each plant species in each light regime?
2. Why is it necessary to grow all the plants under identical temperature and watering conditions?
3. What are the independent and dependent variables in this experiment?
4. What is the effect of light intensity on chlorophyll levels in the plant leaves you examined? Explain.
5. What kind of changes in chlorophyll levels would you expect at different seasons of the year?



Further Suggestions

1. Grow plants for different periods of time and observe chlorophyll levels, changes in the number and size of leaves, and the outcomes for plants grown in total darkness.
2. Change light conditions: Move plants grown in full daylight to weak light and vice versa. Follow changes in chlorophyll level with time.
3. Change exposure to light in the same plant: cover different parts with shadowing nets and measure their effect on the chlorophyll level in the plant.
4. Examine the effect of temperature on chlorophyll levels in the leaves.

Respiration Rate of Germinating Seeds

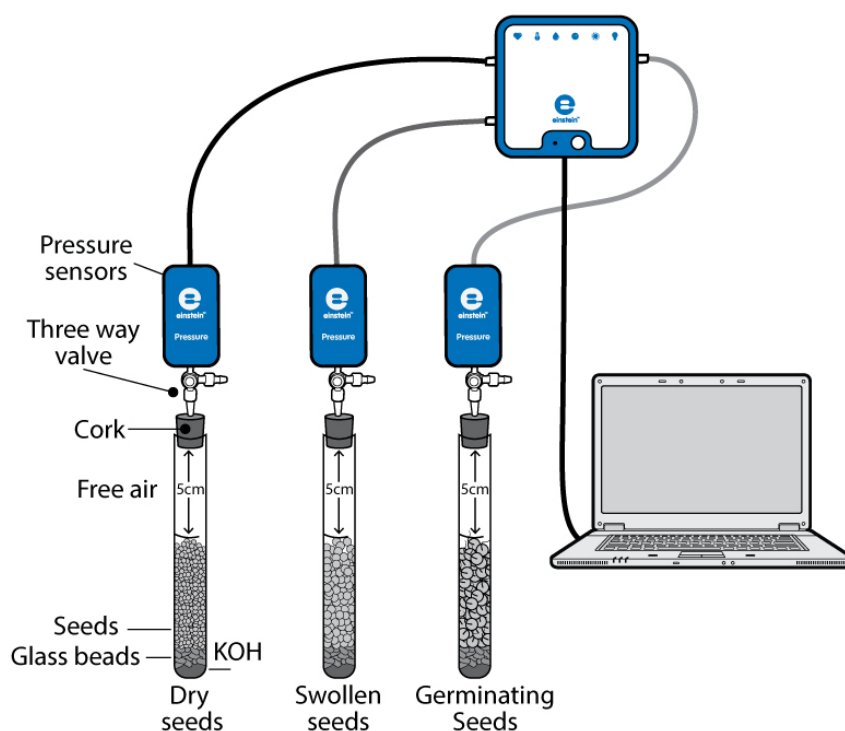


Figure 1



Introduction

Germination is the process in which seeds, spores and buds develop into trees, plants fungi etc. This process requires a large amount of energy. Carbohydrates, lipids, and other organic molecules are stored in the seed. These compounds are broken down into glucose, and then, through cellular respiration, glucose is further broken down, releasing the necessary energy. During respiration, oxygen is consumed while CO_2 is produced.

Dry seeds respire at a very low rate. Addition of water to dry seeds first releases gases retained in the seeds, a physical process completely unrelated to respiration. But as water content in the seeds increases, the respiration rate is hugely accelerated.

By following the consumption of oxygen throughout germination, several stages can be observed. First, the seeds swell as water enters them. At this stage, oxygen consumption increases at a very fast rate.

When the seeds are swollen, roots and shoots start to develop. At this stage the rate of oxygen consumption stabilizes. It increases again as the young sprout continues to grow, and the roots and shoots elongate.

Finally, the sprout starts to develop leaves. At this stage most of its storage materials are exhausted and the rate of oxygen consumption decreases.

The rate of the germination process and the rate of respiration depend on abiotic factors including temperature, oxygen and CO₂ levels and exposure to light.

In this experiment we will use Pressure Sensors to compare rates of oxygen consumption in germinating seeds, swollen seeds, and dry seeds.

KOH is used to remove CO₂ released in the respiration process. CO₂ is heavier than air. It falls to the bottom of the test tube and reacts with KOH. In this manner CO₂ accumulation in the test tube is prevented. Thus the change in air pressure in the test tube measured during respiration results solely from changes in oxygen concentration.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Three Pressure Sensors (150 – 1150 mbar)
- Three 50 ml test tubes
- Three stoppers with a hole for syringe extenders
- Three syringe extenders*
- Three three-way valves*
- 9 g dry KOH
- Glass beads
- Seeds (pea or bean): 60 dry seeds, 45 swollen seeds, 35 germinating seeds

*contained in the einstein™ Pressure Kit

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the pressure sensors to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
 - a. Insert a syringe extender into each stopper (Figure 2).
 - b. Attach a three-way valve to the other end of the syringe extenders.
 - c. Connect a Pressure Sensor to each valve.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Pressure Sensors are selected under Measurements.

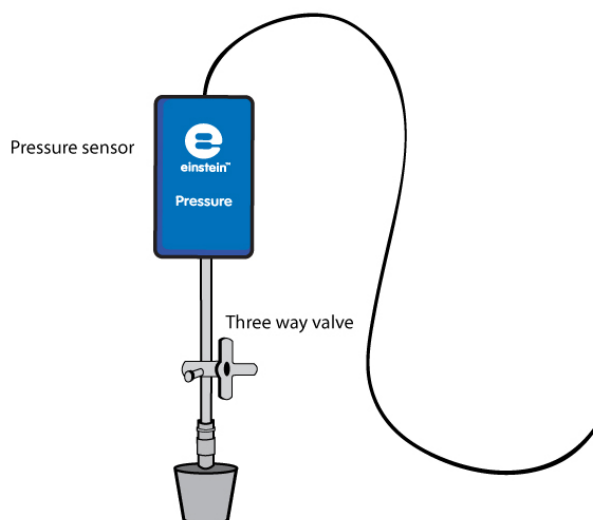


Figure 2



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Rate:	Every second
Samples	2000
Duration:	33 minutes 20 seconds

Note: Ensure that only the external Pressure Sensors (150– 1150 mbar) are selected and not the internal Pressure Sensor (0– 400 kPa).






Procedure

Checking the experimental setup: Before starting the experiment, make sure that the test tubes are tightly sealed. For more details see Sealing.

Performing the experiment:


1. Number the test tubes 1-3. Mark a line on each test tube 5 cm from the top.
2. Make sure that the experiment begins with all test tubes at atmospheric pressure. Turn the three-way valves to position A (see Sealing), and then return to position B. The pressure in all test tubes should now equal atmospheric pressure.
2. Add 3 g KOH to the bottom of each test tube. Cover it well with glass beads to ensure total separation between the KOH and the seeds.
3. Weigh the test tube with the KOH and glass beads.
4. Add dry seeds to the first test tube, swollen seeds to the second, and germinating seeds to the third, in each one, up until the line previously marked. Count the number of seeds added and weigh the test tubes together with the seeds.

5. Seal each test tube with a stopper that has a syringe extender, three way valve and Pressure Sensor connected to it.
6. Select **Run** () to begin recording data.
7. Follow the pressure in the Graph window of MultiLab4.
8. Select **Stop** () to stop collecting data.
9. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Apply a linear fit to each curve:
2. Select two points on the graph to select a range of data points.
 - b. Select Curve fit () from the Analysis window on the upper menu bar.
 - c. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
 - d. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
 - e. The slope of the fit line is the measured rate of pressure changes due to oxygen consumption in the experiment.
 - f. The units used are mbar per second.
 - g. Multiply the slope by 60 to calculate the change in pressure (mbar) per minute.
2. Compare the slopes from the three test tubes.
3. Calculate the weight of seeds in each test tube.
4. Calculate the rate of change in pressure per gram of seed weight.



Questions

1. Describe the curves observed for the three test tubes. Are they stable throughout the experiment? Are they similar in all test tubes?
2. In which test tube was oxygen consumption the fastest? The slowest?
3. Explain the differences in the rate of oxygen consumption in the different test tubes.
4. Compare the calculated rates per gram weight for each tube. Which is fastest? Is this different than your comparison of the absolute rates?
5. Explain why we express the change in oxygen consumption in terms of rate per gram weight.
6. Predict the effect of an increase in temperature on the rate of oxygen consumption in each test tube.
7. Predict the effect of a decrease in temperature on the rate of oxygen consumption in each test tube.
8. What other factors can affect oxygen consumption?
9. Design an experiment similar to this one to measure these effects.



Further Suggestions

1. Use an Oxygen Sensor to follow the rate of oxygen consumption by seeds during germination.
2. Use seeds of different plants to follow oxygen consumption during germination.
3. Measure the effect of temperature on seed germination.

Measurement of CO₂ Released during Respiration of Germinating Seeds

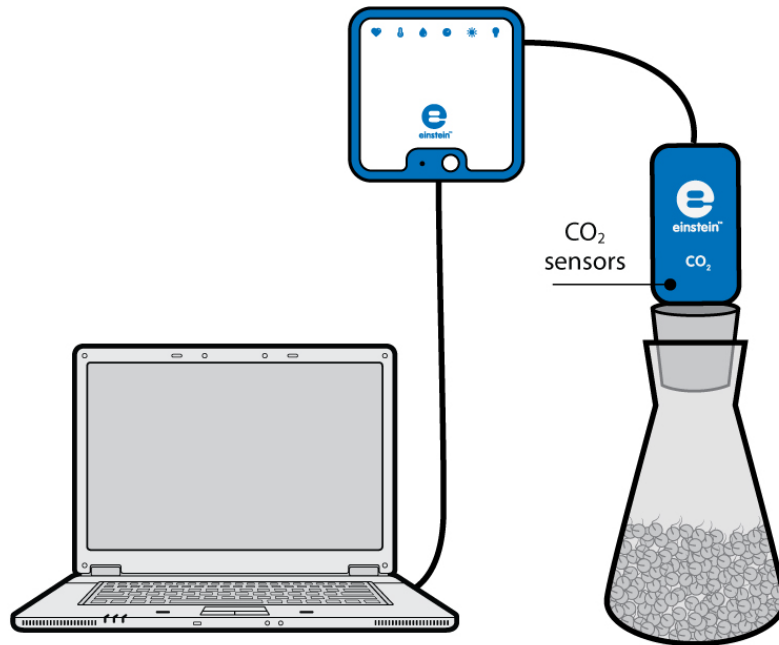


Figure 1

Introduction

Germination is the process in which seeds, spores and buds develop into trees, plants fungi etc. This process requires a large amount of energy. Carbohydrates, lipids, and other organic molecules are stored in the seed. These compounds are broken down into glucose, and then, through cellular respiration, glucose is further broken down, releasing the necessary energy. During respiration, oxygen is consumed while CO₂ is produced.

Respiration rates of dry seeds are very low. Addition of water to dry seeds increases their water content. In swollen seeds respiration accelerates, thereby increasing the rate of CO₂ release as well.

When roots and shoots start to develop, the rate of oxygen consumption stabilizes. It increases again as the young sprout continues to grow and the root and shoot elongate.

In this experiment we use a CO₂ Sensor to compare amounts of CO₂ released during respiration in swollen, dry, and germinating pea seeds.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- CO₂ Sensor
- Rubber stopper designed for CO₂ Sensor
- Flask for CO₂ Sensor and stopper assembly
- Seeds (pea or bean): 100 dry seeds, 50 swollen seeds, 35 germinating seeds
- Scale

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the CO₂ Sensor to one of the ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the CO₂ Sensor is selected under Measurements.






Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	CO ₂ (350-10000 ppm)
Measurements:	CO ₂ (ppm)
Rate:	Every second
Samples	2000
Duration:	33 minutes 20 seconds




Procedure

1. Weigh 50 swollen seeds.
2. Add 50 swollen seeds to the flask.
3. Insert the stopper into the flask and the CO₂ Sensor in the hole of the stopper. Make sure the flask is tightly sealed.
4. Select **Run** () to begin recording data.
5. Follow the changes in CO₂ levels in the flask in the Graph window of MultiLab4.
6. Repeat steps 1-5 with dry and then germinating seeds.
7. Select **Stop** () to stop collecting data.
8. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

3. Apply a linear fit to each curve:
4. Select two points on the graph to select a range of data points.
5. Select **Curve fit** () from the Analysis window on the upper menu bar.
6. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
7. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
8. The slope of the fit line is rate of the increase in CO₂ concentration during the experiment.
9. The units used are ppm per second.
2. Compare the slopes for the three different types of seeds.
3. Calculate the rate of change in CO₂ concentration per gram of seed weight.

An example of a graph obtained in this experiment is shown below:

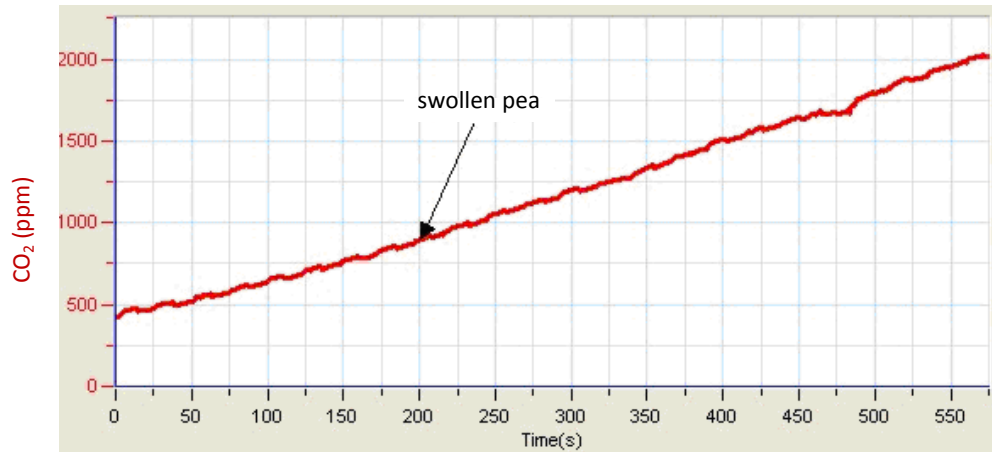


Figure 2



Questions

1. Describe the curve obtained with swollen seeds compared to dry and germinating seeds.
2. In which group of seeds was the rate of CO₂ release the fastest? The slowest?
3. Explain the differences in the rate of CO₂ release in the three groups of seeds.
4. Compare the calculated rates per gram weight for each group of seeds. Which is fastest? Is this different than your comparison of the absolute rates?
5. Explain why the change in CO₂ released is expressed in terms of rate per gram weight.
6. Predict the effect of an increase in temperature on the rate of CO₂ released in each group of seeds.
7. Predict the effect of a decrease in temperature on the rate of CO₂ released in each test tube.
8. What other factors can affect CO₂ release?
9. Design an experiment similar to this one to measure these effects.



Further Suggestions

1. Use an Oxygen Sensor to follow the rate of oxygen consumption by seeds during germination in parallel to CO₂ production.
2. Use seeds of different plants to follow CO₂ released during germination.
3. Measure the effect of temperature on CO₂ released during seed germination.

Biological Catalysis: Disproportionation of H_2O_2 in the Presence of the Enzyme Catalase

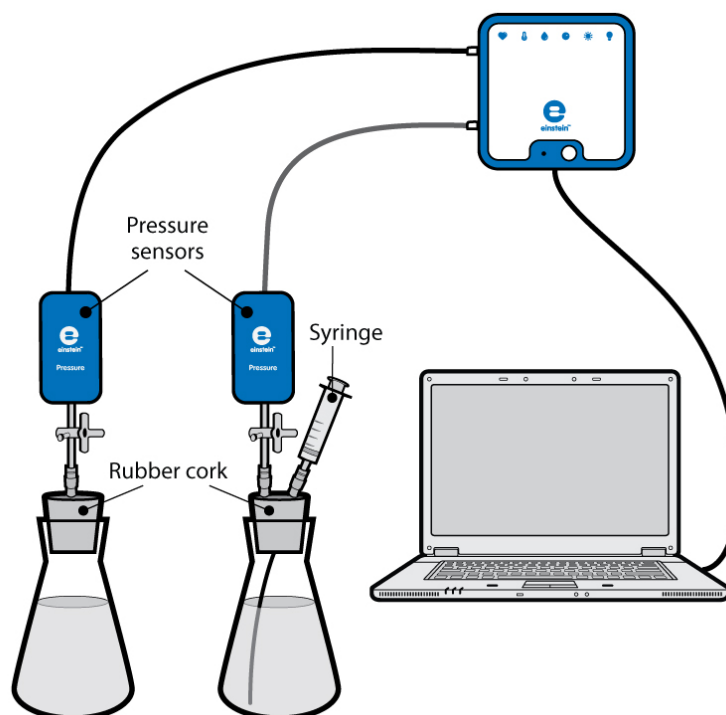


Figure 1



Introduction

When hydrogen peroxide or H_2O_2 (3%) solution is poured on a skin wound to cleanse it, the hydrogen peroxide disproportionates to water and oxygen gas. As a result, the solution bubbles vigorously. What is responsible for this vigorous reaction is the enzyme called catalase that serves as a biological catalyst. The natural function of this enzyme is to prevent the accumulation of hydrogen peroxide in the body of living organisms, since an excessive build up can damage body tissues. Hydrogen peroxide is formed in the body during oxidation reactions involving O_2 .

Catalase is abundant in the tissues of many organisms including microorganisms, animals and plants.

In this experiment we use Pressure Sensors to observe and measure the release of O_2 from a H_2O_2 solution within yeast.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Two Pressure Sensors (150 – 1150 mbar)
- Two 50 ml glass flasks
- Two stoppers with a hole for syringe extenders
- 2 ml plastic syringe*
- Three syringe extenders*
- 3% H_2O_2 solution
- 1 g dried yeast

*contained in the einstein™ Pressure Kit

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Pressure Sensors to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
 - a. Insert a syringe extender into each stopper (Figure 2).
 - b. Attach a three-way valve to the other end of the syringe extender.
 - c. Connect a Pressure Sensor to each valve.
 - d. In one of the stoppers, insert an additional syringe extender. A syringe filled with 3% H_2O_2 solution will be attached to this syringe extender later.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Pressure sensors are selected under Measurements.

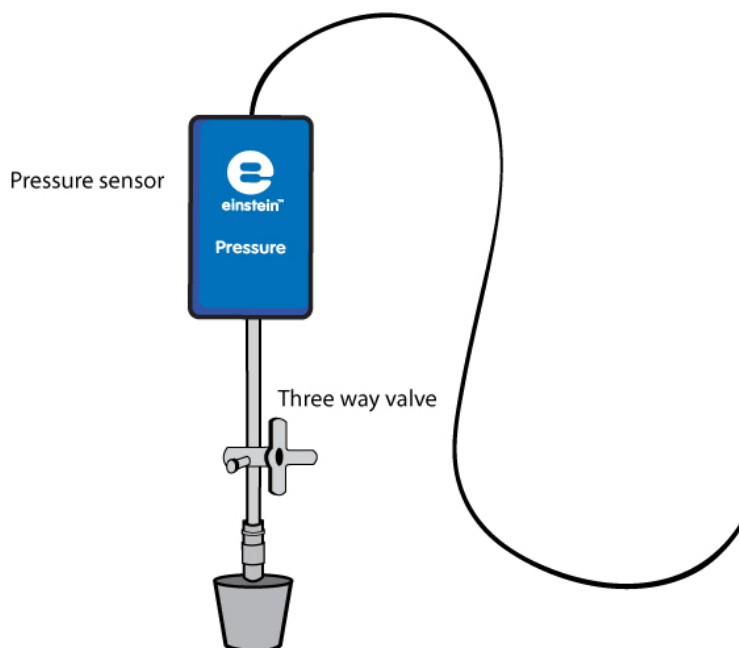


Figure 2



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Pressure 150 - 1150 mbar
Measurements:	Pressure (mbar)
Rate:	Every second
Samples	500
Duration:	8 minutes 20 seconds

Note: Ensure that only the external Pressure Sensors (150– 1150 mbar) are selected and not the internal Pressure Sensor (0– 400 kPa).






Procedure

Checking the experimental setup:

Before starting the experiment, make sure that the flasks are tightly sealed. For more details see Sealing.

Performing the experiment:

1. Weigh 1 g dried yeast. Dissolve it in 50 ml water. Mix it well to obtain a homogenous solution.
2. Fill the plastic syringe with 2 ml of 3% H_2O_2 solution.
3. Number two flasks 1 and 2.
4. Add to flask #1: 8 ml water and 2 ml 3% H_2O_2 solution.
5. Add to flask #2: 4 ml water and 4 ml of the yeast solution. Mix the solution gently.
6. Seal the flasks tightly with the stoppers.
7. Flask #2: Attach the syringe filled with 3% H_2O_2 solution through the additional syringe extender inserted into the stopper.
8. Make sure that the experiment begins with both flasks at atmospheric pressure. Turn the three-way valves to position A (see Sealing). The pressure in both the flasks should now equal atmospheric pressure.
9. Select **Run** () to begin recording data.
10. Inject the H_2O_2 solution into flask #2, and immediately turn the valves of the two flasks to stop air from flowing into them (position B, Sealing).
11. Follow changes in pressure in the Graph window of MultiLab4.
12. Select **Stop** () to stop collecting data.
13. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Calculate the change in pressure in each of the flasks: What was the initial pressure value, the final value, the difference between the two values?
Use the cursors to find the appropriate values.

2. To calculate the net reaction rate you'll need to create a graph in which you've subtracted the control data from the experimental data.
 - a. Select **Math functions** (f_{xy}) from the Analysis window on the upper menu bar.
 - b. In the Math function window which opens, choose Subtract from the Function drop down menu.
 - c. In the G1 drop-down menu, select Pressure (from the flask with the yeast) . In the G2 drop-down menu select Pressure (from the control flask).
 - d. In the Name edit box enter a name (e.g. Subtraction).
 - e. Click OK.
3. Apply a linear fit to the graph:
 - a. Use the cursors to select the desired range.
 - b. Select **Curve fit** ($y = mx + b$) from the Analysis window on the upper menu bar.
 - c. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
 - d. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
 - e. The slope of the fit line is the net reaction rate.

An example of the graphs obtained in this experiment, is shown below:

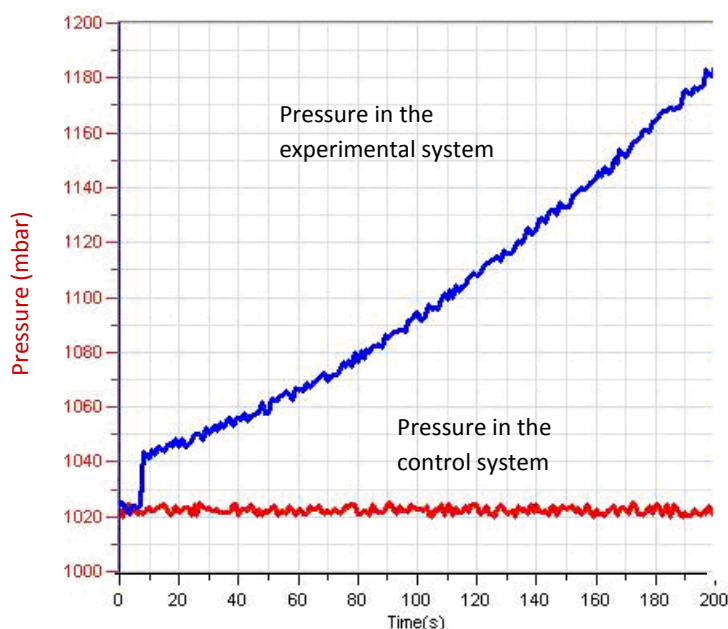


Figure 3

Questions

1. How does the pressure generated in this experiment relate to the disproportionation of H_2O_2 ?
2. Compare the changes in pressure in the two flasks. Did you observe a change in flask #1, in flask #2? Explain the differences.
3. Which of the flasks serves as a control? Explain.
4. Why is a control system necessary in this experiment?
5. What is the effect of adding yeast solution to the experimental flask?
6. Which component of yeast is responsible for the observed effect? How can you prove it?
7. Predict the effect of adding increasing amounts of yeast on the reaction rate.
8. Predict the effect of a temperature rise in the flasks during the experiment on the H_2O_2 disproportionation rate.



Further Suggestions

1. Add increasing amounts of yeast to the reaction mixture and observe the reaction produced in each case.
2. Calculate the reaction rate obtained in each experiment.
3. Compare the effect of yeast catalase with that of other organisms: chicken or beef liver and mashed potatoes.
4. Change the concentration of H_2O_2 added to the reaction mixture to see how it affects the reaction rate.
5. Observe temperature changes occurring during the reaction. Evaluate the effect of temperature on the disproportionation rate of H_2O_2 .
6. Run three systems in parallel: a control system, one with a tissue containing catalase and one with a chemical catalyst.
7. Estimate the amount of catalase in different tissues by comparing their effect to that of commercial catalase.

Effect of Enzymes on Food: Degradation of Egg White Proteins in the Presence of Pepsin

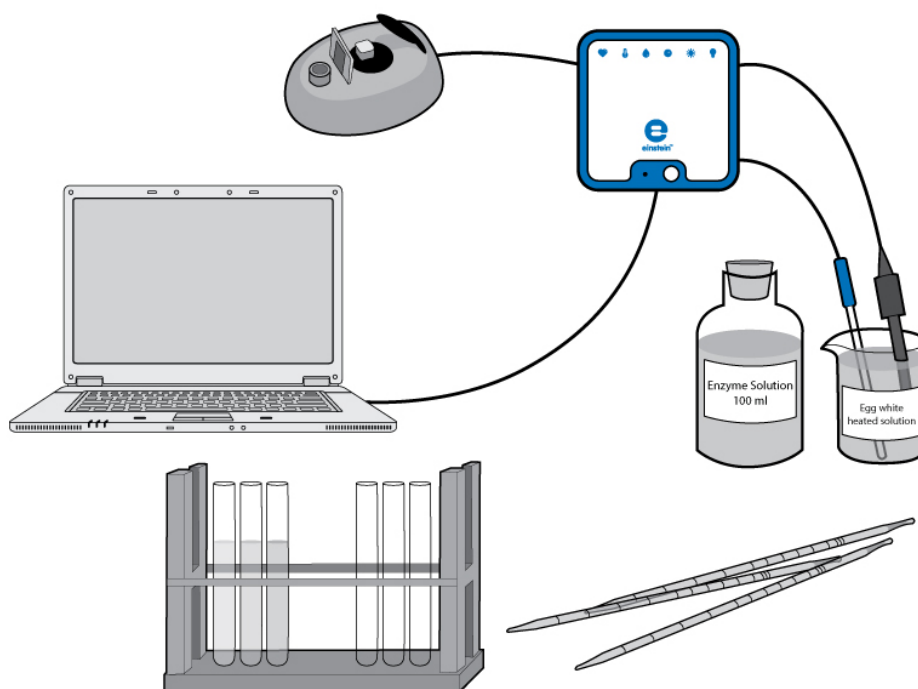


Figure 1



Introduction

Pepsin, trypsin and chymotrypsin are three enzymes that degrade proteins found in our food. Each of the three enzymes helps break the protein bonds and together they degrade the proteins into the basic building blocks - amino acids and peptides, which are readily absorbed by the intestinal lining.

Pepsin is produced in the mucosal lining of the stomach. It is initially secreted in the inactive form, trypsinogen and then, at very low pH (pH of 1.0 - 3.0), is converted to the active form, pepsin. The optimal activity for pepsin is found at this pH range.

Pepsin is used in the preparation of cheese and other protein-containing foods.

In this experiment we will observe the degradation of egg white proteins exposed to pepsin. Egg white proteins are first heated to create a turbid or cloudy solution. Then, as the proteins degrade, the solution becomes clear. This process can be measured using a Colorimeter.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Colorimeter
- pH Sensor
- Temperature Sensor (-40°C to 140°C)
- 1 egg white
- 100 ml 0.2N HCl solution
- 20 ml pepsin solution (Use a pepsin powder of about 525 units/mg solid, 4770 units/mg protein. Dissolve the powder in distilled water. For optimal activity the concentration of enzyme may vary between 0.1% and 0.5%. It should be checked in advance).
- Bunsen burner
- 400-600 ml flask
- 5 ml and 1 ml pipettes
- Rack with 10 test tubes
- Cuvettes
- Fork
- Gauze
- Wooden stick
- Safety goggles

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Colorimeter, pH Sensor and Temperature Sensor to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1 above.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Colorimeter, pH Sensor and Temperature Sensor are selected under Measurements.



Current Setup Summary




Program the sensors to log data according to the following setup:








Sensor:	Colorimeter (0-100%)
Measurements:	Absorbance(%)
Sensor:	pH
Measurements:	pH (0-14)
Sensor:	Temperature (-40°C to 140°C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	500
Duration:	8 minutes 20 seconds



Note: Ensure that only the external Temperature Sensor (-40°C to 140°C) is selected and not the internal Temperature Sensor (-30°C to 50°C).



Procedure


1. Prepare the egg white solution:
 - a. For this step of the experiment, make sure only the Temperature Sensor is selected.
 - b. In a flask, add 40 ml distilled water to 10 ml egg white.
 - c. Mix it rapidly with a fork and filter it through four layers of gauze.
 - d. Select **Run** () to begin recording data.
 - e. Follow changes in temperature in the Graph window of MultiLab4.
 - f. Heat the solution up to 55°C – 60°C (and not above this temperature) with constant stirring until a turbid solution is obtained. At this stage the solution should resemble diluted milk.
 - g. Select **Stop** () to stop collecting data.
 - h. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.

This solution is the substrate used in the experiment. Keep it in a small flask.
2. Calibrate the Colorimeter:
 - a. For this step of the experiment, make sure only the Colorimeter is selected.
 - b. Use the red filter.
 - c. Prepare a blank solution: Add 1 ml enzyme solution to 3 ml distilled water.
 - d. Pour the blank solution into a cuvette and insert it into the Colorimeter. Close the cover well.
 - e. Select **Run** () to begin recording data.
 - f. Follow the Colorimeter graph and turn the knob until you receive 100% transmission.
 - g. Select **Stop** () to stop collecting data.
 - h. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.
3. Prepare a test tube as follows:
 - a. 2.4 ml egg white solution
 - b. 0.6 ml 0.2N HCl
 - c. 1.0 ml of water
4. Measure the pH of the solution using the pH Sensor:
 - a. For this step of the experiment, make sure only the pH Sensor and Temperature Sensor are selected.
 - b. Use the Temperature Sensor for temperature compensation.
 - c. Select **Run** () to begin recording data.
 - d. The pH of the solution should be in the range of 2.0 - 3.0 pH. If necessary, adjust the pH by changing the volume of 0.2N HCl that you add.
 - e. Select **Stop** () to stop collecting data.
 - f. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.
5. Measure the rate of protein degradation:
 - a. For this step of the experiment, make sure only the Colorimeter is selected.
 - b. Add the egg white solution prepared above to a cuvette.
 - c. Select **Run** () to begin recording data.
 - d. Add 1 ml pepsin solution to the cuvette.
 - e. Mix well with a wooden stick and insert the cuvette immediately into the Colorimeter.
 - f. Close the cover well.
 - g. Follow changes in light transmittance in the Graph window of MultiLab4.

- h. Select **Stop** () to stop collecting data.
 - i. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.
6. Repeat steps 3-5 with at least 2-4 different enzyme concentrations.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. The rate of protein degradation is calculated from the rate of change in light transmission.
2. Apply a linear fit to each graph of transmittance vs. time:
 - a. Use one cursor to select the beginning of a plot line and another to select the end of the plot line.
 - b. Select **Curve fit** () from the Analysis window on the upper menu bar.
 - c. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
 - d. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
 - e. The slope of the fit line is the rate of protein degradation.

An example of the graphs obtained in this experiment is shown below:

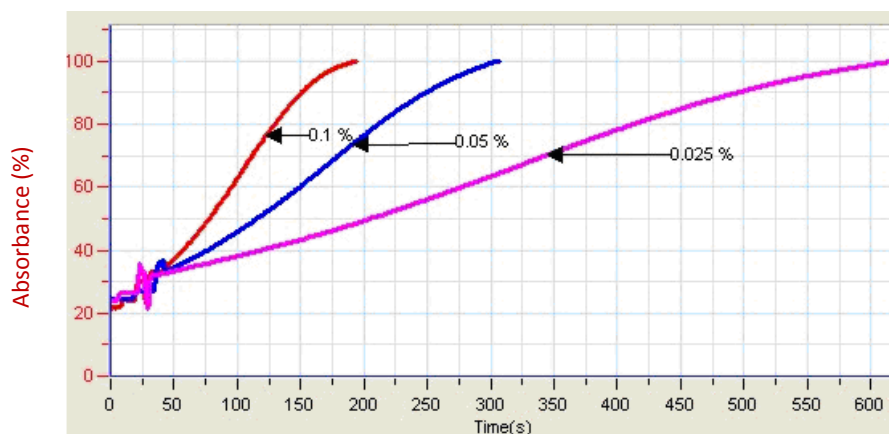


Figure 2

Prepare a graph describing the relationship between enzyme (or substrate) concentrations and the rate of protein degradation.



Questions

1. Describe the graph you prepared showing the relationship between enzyme (or substrate) concentration and rate of protein degradation.
2. What is the effect of an increase in enzyme concentration on the rate of protein degradation?
3. What is the effect of an increase in substrate concentration on the rate of protein degradation?
4. Predict the rate of degradation of another protein by pepsin.
5. How will a change in pH affect the rate of degradation of egg white proteins by pepsin?



Further Suggestions

1. Measure the effect of pH on pepsin activity in the range of 1-10 pH. Use either buffer solutions or add different volumes of 0.2 N HCl or 0.2 N Na_2CO_3 .
2. Measure the effect of temperature on pepsin activity. Incubate the substrate and enzyme mixture (at concentrations giving optimal activity) at different temperatures. Every 1-2 minutes extract samples and measure their transmittance using a Colorimeter.

Alcoholic Fermentation in Yeast

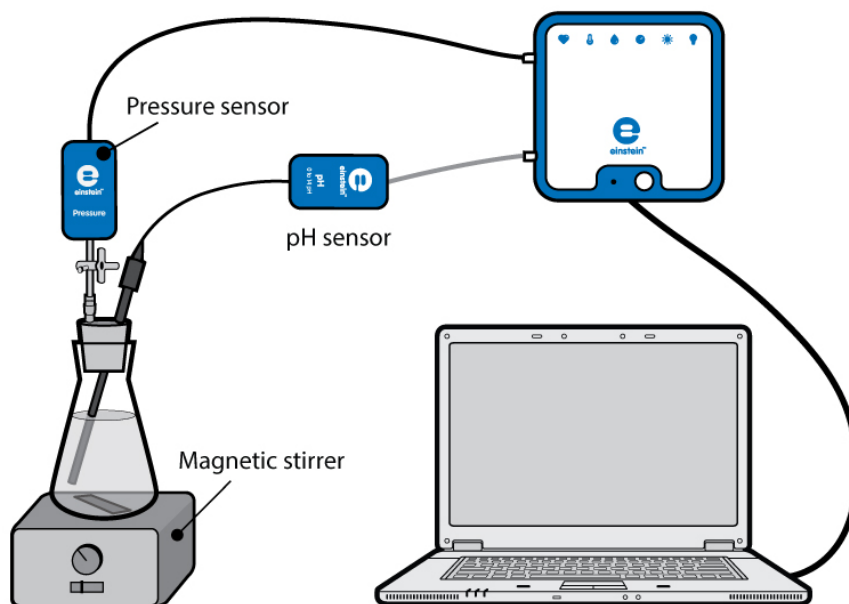
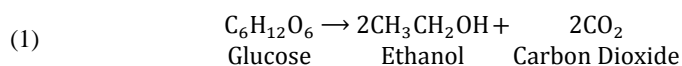


Figure 1

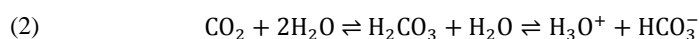


Introduction

All living organisms obtain the energy necessary to sustain life through cellular respiration, a process in which energy is released by breaking the chemical bonds in organic molecules. In aerobic organisms this happens through the oxidation of the 6-carbon sugar, glucose, by molecular oxygen, and in anaerobic organisms other oxidation agents play a role. Under anaerobic conditions (low oxygen concentrations), many organisms, including yeast, obtain their energy from the process of fermentation. In alcoholic fermentation, characteristic of many yeast species, the fermentation process starts with one molecule of glucose, and produces two molecules of the 2-carbon alcohol, ethanol, and two molecules of CO_2 :



The CO_2 released in the process dissolves in water and forms carbonic acid. This acid dissociates to form hydrogen carbonate and hydronium ions:



In acidic solutions, the solubility of CO_2 in water decreases, and it is released into the air. In this experiment we observe changes in pH and CO_2 release during yeast fermentation.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Pressure Sensor (150 – 1150 mbar)
- pH Sensor
- 50 ml glass flask
- Stopper with a hole to insert the pH Sensor
- Syringe extender*
- Three-way valve*
- 1.25 g dried yeast
- 50 ml of 2% glucose solution
- Magnetic stirrer and stir bar
- Scale
- Modeling clay

*contained in the einstein™ Pressure Kit

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Pressure Sensor and the pH Sensor to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
 - a. Insert a syringe extender into the stopper (Figure 2).
 - b. Attach a three-way valve to the other end of the syringe extender.
 - c. Connect a Pressure Sensor to the valve.
 - d. Pierce a hole in the stopper, fitted to the pH electrode (see Figure 1). Carefully insert the pH electrode through this hole. In order to prevent air penetration through this hole, use a material like modeling clay to seal the gap around the pH electrode.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Pressure Sensor and pH Sensor are selected under Measurements.

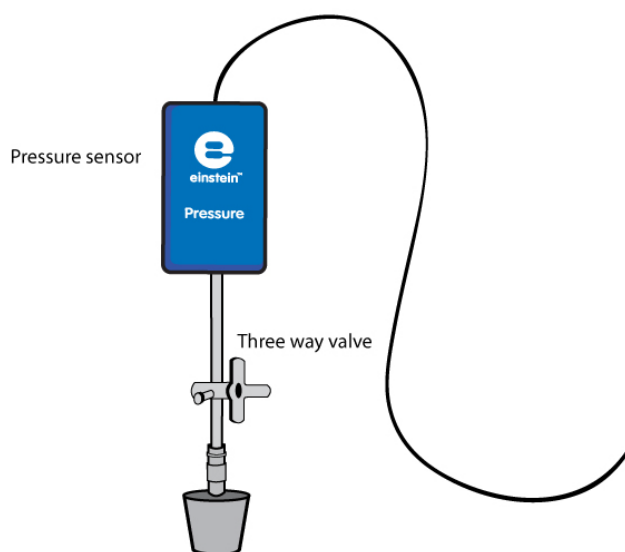


Figure 2



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Pressure (150-1150 mbar)
Measurements:	Pressure (mbar)
Sensor:	pH
Measurements:	pH (0-14)
Rate:	Every second
Samples	2000
Duration:	33 minutes 20 seconds




Note: Ensure that only the external Pressure Sensor (150-1150 mbar) is selected and not the internal Pressure Sensor (0-400 kPa).



Procedure

Checking the experimental setup: Before starting the experiment, make sure that the flask is tightly sealed. For more details see Sealing.

Performing the experiment:


1. Weigh 1.25 g dried yeast. Dissolve it in 50 ml water. Mix well to obtain a homogenous solution.
2. Add the magnetic stir bar and 25 ml of yeast solution to the glass flask.
3. Select **Run** () to begin recording data.
4. Add 25 ml of 2% glucose solution to the flask and start stirring.
5. Tightly close the flask with the stopper.
6. Follow the pressure level and pH in the Graph window of MultiLab4.
7. Press **Stop** () to stop recording
8. Turn the valve attached to the syringe extender until the pressure in the flask returns to atmospheric levels.
9. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Use the cursors on the graph to determine the changes in pressure and pH in the flask. What were the initial pressure and pH values? What were the final values? What is the difference between the initial and final values?
2. Compare the change in pH with that of the pressure:
 - a. At what stage in the experiment were the pH changes prominent?
 - b. At what stage in the experiment were changes in pressure observed?
3. Explain the course of changes you obtained in pH and pressure.
4. To calculate the rate of CO₂ release, apply a linear fit to the pressure graph:

- Use the cursors to select a linear section of the pressure graph.
- Select Curve fit () from the Analysis window on the upper menu bar.
- In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.
- The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
- The slope of the fit line is the rate of CO₂ release.

An example of the graph obtained in this experiment is shown below (the red line is the pH graph and the blue line is the Pressure graph):

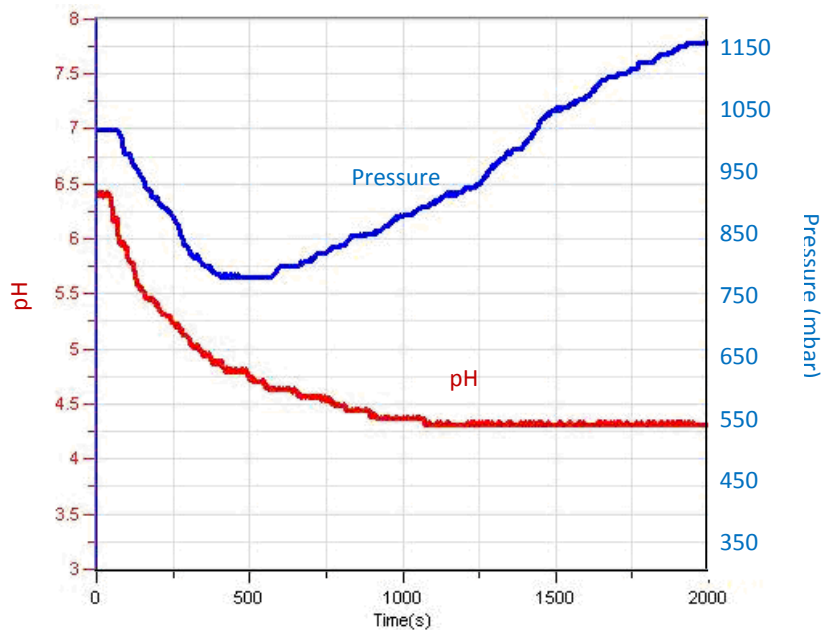


Figure 3



Questions

- How does the pressure generated during the experiment relate to the CO₂ release associated with yeast fermentation?
- What is the optimal pH range for yeast fermentation? Base your conclusions on the results you obtained in the experiment.
- Explain how the decrease in pH during the initial part of the experiment affects the solubility of CO₂ in water. Suggest an experiment to test your hypothesis.
- Temperature rise in the flask during the experiment can affect the rate of CO₂ release in two different ways: solubility of CO₂ in water and rate of fermentation. Explain these two effects.



Further Suggestions

- Add increasing amounts of yeast to the flask and observe the rate of CO₂ release in each case.
- Calculate the reaction rate obtained in each experiment.
- Compare the effect of different sucrose concentrations on the rate of fermentation.
- Compare different types of six-carbon sugars (glucose, fructose, galactose) to disaccharides (lactose, sucrose) and calculate the rate of fermentation obtained with each sugar.
- Perform the fermentation experiment in a buffer solution (set the pH value to 4.0).

Chapter 15

Effect of Temperature on the Permeability of Cell Membranes: Release of the Pigment Anthocyanin from Beets

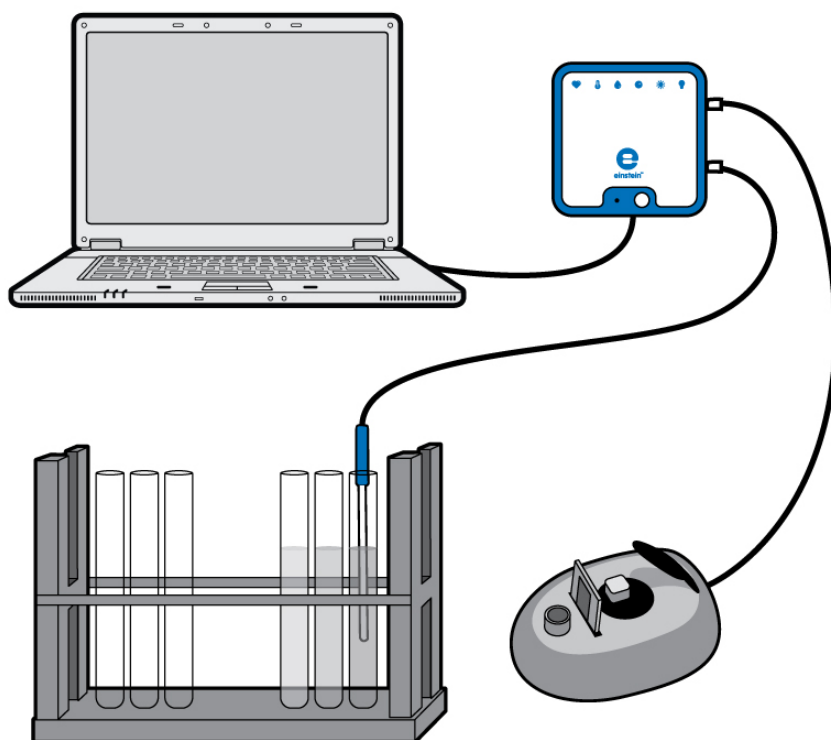


Figure 1



Introduction

Cell membranes consist of a phospholipid bilayer combined with a variety of proteins in a fluid mosaic arrangement. Cell membranes are selectively permeable. Some solutes cross the membrane freely, some cross with assistance (facilitated diffusion), and others do not cross at all. Upon heating, the structure of the cell membrane may be damaged and the permeability increases.

Anthocyanins are naturally occurring compounds that give color to fruit, vegetables and plants. They give red color to buds and young shoots and the purple and purple-red colors of autumn leaves. Anthocyanins are the pigments thought to play a major role in the high antioxidant activity levels observed in red and blue fruits and vegetables. The color and stability of an anthocyanin in solution is highly dependent on the pH. They are most stable and most highly colored at low pH values and gradually lose color as the pH increases. This characteristic limits the application of anthocyanins as a food colorant to products with a low pH.

In this experiment we follow the effect of heating on the permeability of beet cell membranes by using a Colorimeter to measure the amount of anthocyanins released to the surrounding solution.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Colorimeter
- Temperature Sensor (-40°C to 140°C)
- Cuvettes
- Water bath or hot plate
- Stop watch
- Rack with 12 test tubes
- 5 ml pipettes
- Three 100 ml beakers
- Three 50 ml test tubes
- 15 beet cylinders (should be freshly prepared just before the experiment)
- Paper towels



Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Colorimeter and the Temperature Sensor to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the sensor indicated in the procedure is selected under Measurements.



Current Setup Summary

For the first part of the experiment, use the Temperature Sensor to measure water temperature.

Sensor:	Temperature (-40°C to 140°C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	500
Duration:	8 minutes 20 seconds

Note: Ensure that only the external Temperature Sensor (-40-140 °C) is selected and not the internal Temperature Sensor (-30-50 °C).

For the *calibration* of the Colorimeter use the red filter. The setup is:

Sensor:	Colorimeter (0-100%)
Measurements:	Absorbance (%)
Rate:	Every second
Samples	100
Duration:	1 minute 40 seconds

For the *measurements* of color with the Colorimeter, the setup is:

Sensor:	Colorimeter
Measurements:	Absorbance (%)
Sampling:	Manual
Samples:	12








Procedure

Preparation of beet cylinders:

1. Prepare 15 beet cylinders (or cubes): 3 cm long, 7-10 mm in diameter.
2. Add five cylinders to each of the three 50 ml test tubes. Add 40 ml tap water.
3. Observe and note the color of the water.
4. Wash the beet cylinders with tap water for at least five times until the water remains clear.
5. Label three 50 ml test tubes A, B and C.
6. Add 20 ml tap water to each test tube.
7. Incubate each test tube for four minutes as follows:
 Test tube A: room temperature (measure using the Temperature Sensor)
 Test tube B: 70°C to 80°C
 Test tube C: boiling water
8. Prepare an additional four test tubes in the test tube rack for each temperature.
 Number them as follows: 1-4 for boiling water; 5-8 for 70°C to 80°C; 9-12 for room temperature
9. Start sampling from each of the 50 ml test tubes.
 - a. Take a sample of 4 ml *every minute*. Put these samples in the test tubes marked 1-12
 - b. After four minutes, take the cylinders out of each test tube and dry them on paper towels.
 Return them to the test tubes and add 20 ml tap water to each one. Leave the test tubes at room temperature for four minutes. Then take a 4 ml sample from each test tube and add it to a cuvette to measure the color intensity.

Note: You can measure the effect of each temperature separately. In this case, keep the unused beet cylinders in tap water. Wash them for the experiment just before you start.

10. Calibrate the Colorimeter:
 - a. Use the red filter.
 - b. Tap water will serve as a blank solution.
 - c. Pour the blank into a cuvette and insert it into the Colorimeter. Close the cover tightly.
 - d. Select **Run** () to begin recording data.
 - e. Turn the knob until you receive 100% transmission.
 - f. Select **Stop** () to stop the data logger.
11. Measure the color in each sample:
 - a. Select **Run** () to enable recording data.
 - b. Collect the data manually: Select **Manual Sampling** () each time you wish to record a data sample.
12. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.
13. Start a new measurement for each temperature.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Prepare a curve for each temperature.
2. Prepare a small table and compare the color obtained when the cylinders were incubated at room temperature following their incubation at a higher temperature. Compare it to cylinders kept at room temperature throughout the experiment.

An example of a graph obtained in this experiment at the end of four minutes incubation is shown below:

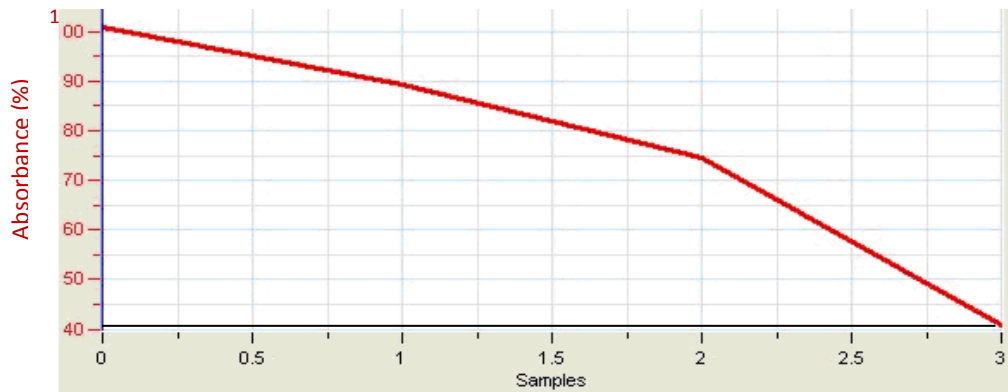


Figure 2



Questions

1. Explain why we observe color in the 50 ml test tubes when we added tap water to freshly prepared beet cylinders.
2. Why did we wash the cylinders several times before their incubation at different temperatures?
3. What changes in color did you observe in each test tube with time?
4. What is the effect of temperature on cell membranes according to your results?
5. Do you expect similar results in other plants as well? Explain.
6. Describe and explain the results you obtained when you incubated the cylinders in tap water at room temperature *after* their incubation at a higher temperature.
7. Higher temperatures accelerate the rate of diffusion. How did we discriminate in this experiment between the accelerating effect and the damage caused to the membrane?
8. Assume that the effect of temperature on membrane permeability is linear. Will it increase with the rise in temperature? What will happen at low (freezing) temperatures? Design an experiment to test your hypothesis.



Further Suggestions

1. Measure the effect of solvents such as alcohol, on membrane permeability and compare it with the effect of temperature.
2. Measure the effect of pH on anthocyanins. Extract them from cranberry or raspberry fruits, add them to water and adjust the pH of the solutions from 1 to 13. At pH 5 the anthocyanins are irreversibly destroyed. Check if the change in color at other pH values is reversible.
3. Measure anthocyanin levels in different fruits and in other parts of plants at different stages of development.

pH Measurements in Tissue Extracts

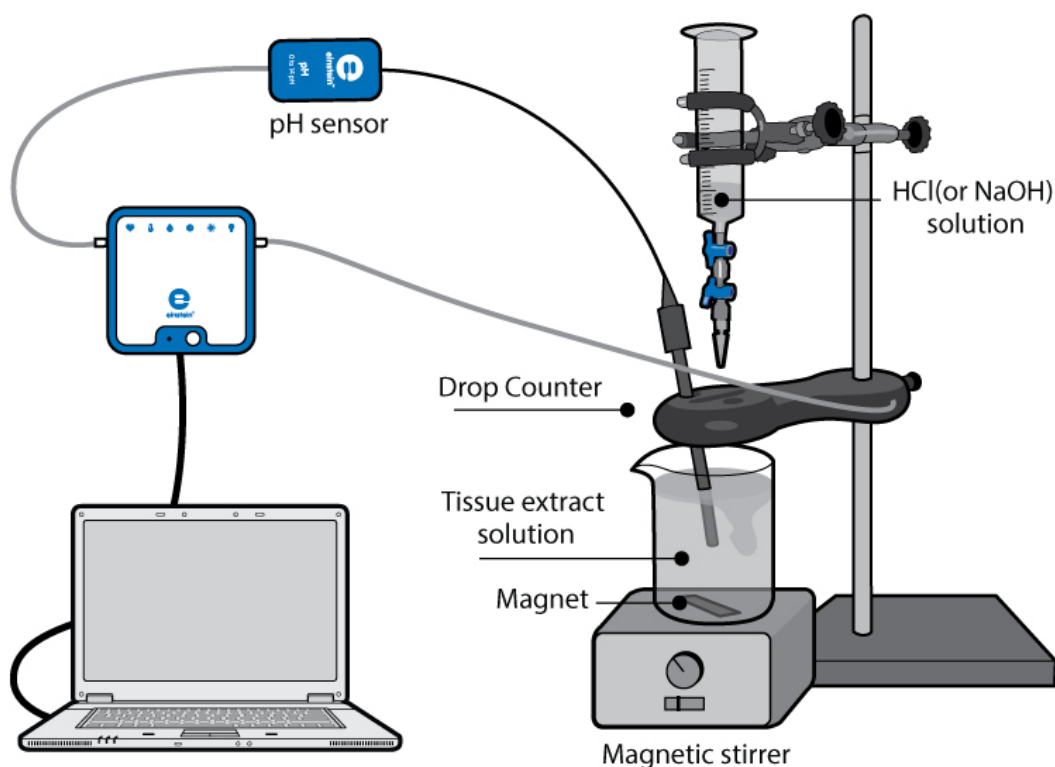


Figure 1



Introduction

The pH of all living cells is maintained within a very limited range. Even minimal changes in pH beyond this range can cause enormous damage to the cell structure and its components, proteins being the most sensitive. pH changes can destroy the three-dimensional structure of proteins, thus inhibiting their normal function. Since proteins are vital to normal functioning of the cell, damage to proteins can lead to cell death.

In order to prevent such hazards, all living cells contain buffers, chemicals that react with acids and bases to maintain stable pH in the cells. Phosphates are the most common buffers. However, other components of cells (including nucleic acids, proteins, lipids and small organic molecules) can act as buffers, reacting with acids and bases to block their influence on cell pH.

Acid-Base Titration is a process for determining the concentration of an acidic or basic solution by measuring the volume of acid or base of known concentration required to neutralize the solution in question.

In this experiment we will be determining the pH of tissue extracts from various sources of food: potato, eggs, liver, etc. by titration with an acid or base solution of known concentration.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- pH Sensor
- Drop Counter Sensor
- Temperature Sensor (-40°C to 140°C)
- Food samples: potatoes, carrots, sour apples, chicken livers
- Kitchen food grater
- 100 ml beaker
- 0.25 L beaker
- Centrifuge
- Piece of gauze
- Magnetic stirrer and stir bar

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the pH electrode to one of the ports of the einstein™ Tablet or einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.



Current Setup Summary



Sensor:	pH
Measurements:	pH (0-14)
Sensor:	Drop Counter
Measurements:	Drop Counter
Sensor:	Temperature (-40°C to 140°C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	2000
Duration:	33 minutes 20 seconds

Note: Ensure that only the external Temperature Sensor (-40-140 °C) is selected and not the internal Temperature Sensor (-30-50 °C).



Procedure

Prepare 100 ml tissue extract:

1. Use potatoes, carrots or sour apples
2. Grate them into small pieces using a kitchen food grater.
3. Place a piece of gauze over a 0.5 L beaker.
4. Collect the tissue extract:
 - a. Place the grated tissue on the gauze.
 - b. Cover the grated tissue with another piece of gauze and press it tightly.
5. Potatoes contain large amounts of starch. To remove the starch, place the extract in a table centrifuge for 1-2 minutes. The starch will be on the bottom of the tube. Collect the supernatant.
6. Apple extract must be diluted 1:1 with tap water.
7. For liver extract:
 - a. Weigh 70 g of chicken liver.
 - b. Add 150 ml tap water and mix the liver solution in a blender.
 - c. Use a table centrifuge to separate tissue debris from the extract.
 - d. Collect the supernatant and add tap water to bring the volume up to 200 ml.
8. Tighten the turn screw of the drop counter to the stand to hold it firmly in place.
9. Make sure that both two-way valves of the plastic reagent reservoir are in the closed position (horizontal).
10. Fill the Drop Counter reagent reservoir with 0.1 N HCl solution.
11. Before collecting data or calibrating the drops, you should adjust the flow rate of the two valves of the reagent reservoir. Temporarily, place another beaker below the spout of the reagent reservoir. First, completely open the bottom two-way valve; then slowly open the top valve until a very slow drip is achieved at a rate of one drop per second. Now close the bottom valve.
12. Pour 40 ml extract into the 100 ml beaker and put the magnetic stir bar in the beaker.
13. Insert the pH electrode into the extract.
14. Turn on the magnetic stirrer and begin stirring very carefully. Make sure the stir bar does not bump the pH electrode.
15. Select **Run** () to begin recording data.
16. Open the bottom valve of the Drop Counter to begin adding HCl to the extract.
17. Measure the rate of flow: the amount of acid solution (ml) added to the beaker in one minute.
18. Follow the pH changes until a constant straight line appears on the screen.
19. Repeat the experiment with 0.1 N NaOH solution.
20. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Use the first cursor to read the initial pH of the tissue extract.
2. Calculate the extent of change in pH which takes place during the titration over the course of the experiment. Use the cursors to find how much the pH changed and over what period of time.
3. Calculate the volume of acid added until the change was observed.
4. Measure the total volume of acid added to the tissue extract until the titration was completed.



Questions

1. Describe the curve recorded in the titration of the tissue extract with the acid.
2. What kind of information can we learn from the curve?
3. Compare the acid titration curve obtained with the base titration curve. How are they similar...different?
4. Compare the volume of acid added to the extract with the volume of base added at two points: at the end of the lag time and at the point where the titration was completed.
5. Discuss your results. Are living cells capable of maintaining a stable pH as acids or bases are added to them, and if so, to what extent?
6. Predict the effects of changing the concentration of the acid or base added to the tissue extract.
7. Which processes in the living cell can lead to changes in the pH?



Further Suggestions

1. Titrate the tissue extracts with diluted acid or base (0.01 N).
2. Present the changes in the pH of tissue extract as a function of the volume added.
3. Compare the titration curves obtained with tissue extracts with those of tap water and chemical buffer (for example, a mixture of $\text{NaH}_2\text{PO}_4^-$ with NaHPO_4^-).
4. Measure the pH of different types of liquid food. Follow changes in the pH with time and temperature. Check if they contain buffers.

Acidification of Milk

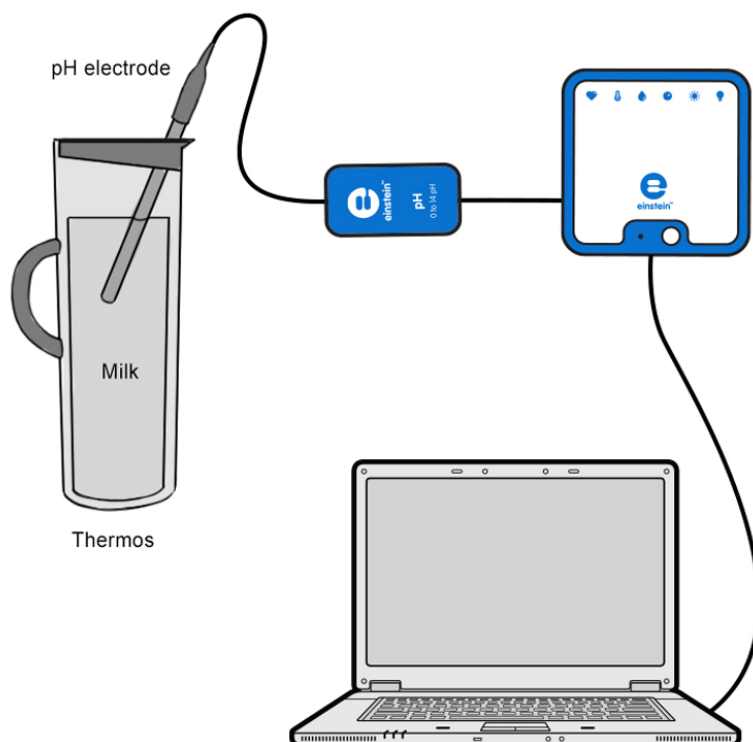


Figure 1



Introduction

There are two main types of bacteria in milk:

Lactic acid bacteria: Normally present in milk and also used as starter culture in the production of cultured dairy products such as cheese and yogurt.

Coliforms: Facultative anaerobes which optimally grow at 37°C. Coliforms are indicator organisms; they are closely associated with the presence of pathogenic bacteria. They can cause rapid spoilage of milk, because they are able to degrade milk proteins and ferment lactose, producing acid and gas.

In this experiment we follow the pH changes in milk over 30 hours of incubation.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- pH Sensor
- 1 liter thermos (with an opening that enables a good seal including the pH cable)
- Milk

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Equipment Setup

Note: This is a long experiment so ensure that the USB cable is connected to the einstein™ LabMate™ for the duration of the experiment, or USB cable is connected to a charging cable.

1. Launch MultiLab4 ().
2. Connect the pH electrode and the Temperature Sensor to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the pH Sensor and Temperature Sensor are selected under Measurements.



Current Setup Summary




Program the sensors to log data according to the following setup:

Sensor:	pH
Measurements:	pH (0-14)
Rate:	Every minute
Samples	2000
Duration:	1 day 9 hours 20 minutes

Note: Ensure that only the external Temperature Sensor (-40-140 °C) is selected and not the internal Temperature Sensor (-30-50 °C).




Procedure

1. Warm 750 ml of pasteurized milk and bring it to room temperature.
2. Pour the milk into the thermos.
3. Insert a pH electrode in the milk and cover the thermos gently to prevent any damage to the pH cable.
4. Select **Run** () to begin recording data.
5. After 30 hours of incubation, you can stop data logging by selecting **Stop** ().
6. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Use the cursors to mark the start and end of the experiment. Determine the extent of change in pH measured in the process.
2. Apply a linear fit to the graph:
 - a. Use the cursors to mark the start and end of the experiment.
 - b. Select Curve fit () from the Analysis window on the upper menu bar.
 - c. In the Curve fit window which opens, choose Linear from the Curve fit drop down menu.

- d. The fit equation will be displayed in the information bar when you drag the cursor to the linear fit line on the graph.
- e. The slope of the fit line is the rate of pH change.

An example of the graph obtained in this experiment is shown below:

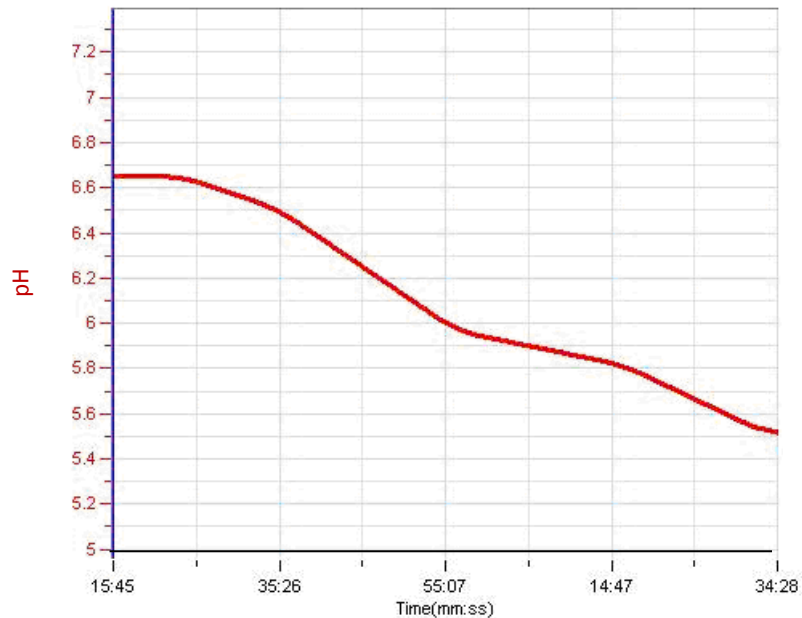


Figure 2



Questions

1. What causes the decrease in the pH of the milk?
2. Did you observe a decrease in the pH immediately after starting the incubation?
3. What could be the reason for this phenomenon?
4. Does the rate of pH change remain constant during the whole incubation period? Why do you think this is?
5. Why was it necessary to warm the milk and bring it to room temperature before transferring it to the thermos?
6. What would be the results of incubating unpasteurized milk in the thermos for 30 hours?



Further Suggestions

1. Perform a similar experiment with unpasteurized milk or milk from different species (e.g. goat milk).
2. Keep the thermos at different temperatures (in the refrigerator or an incubator).

Chapter 18

Regulation of Human Body Temperature - Loss of Heat through Sweat Production: Clay Jugs - A Model System

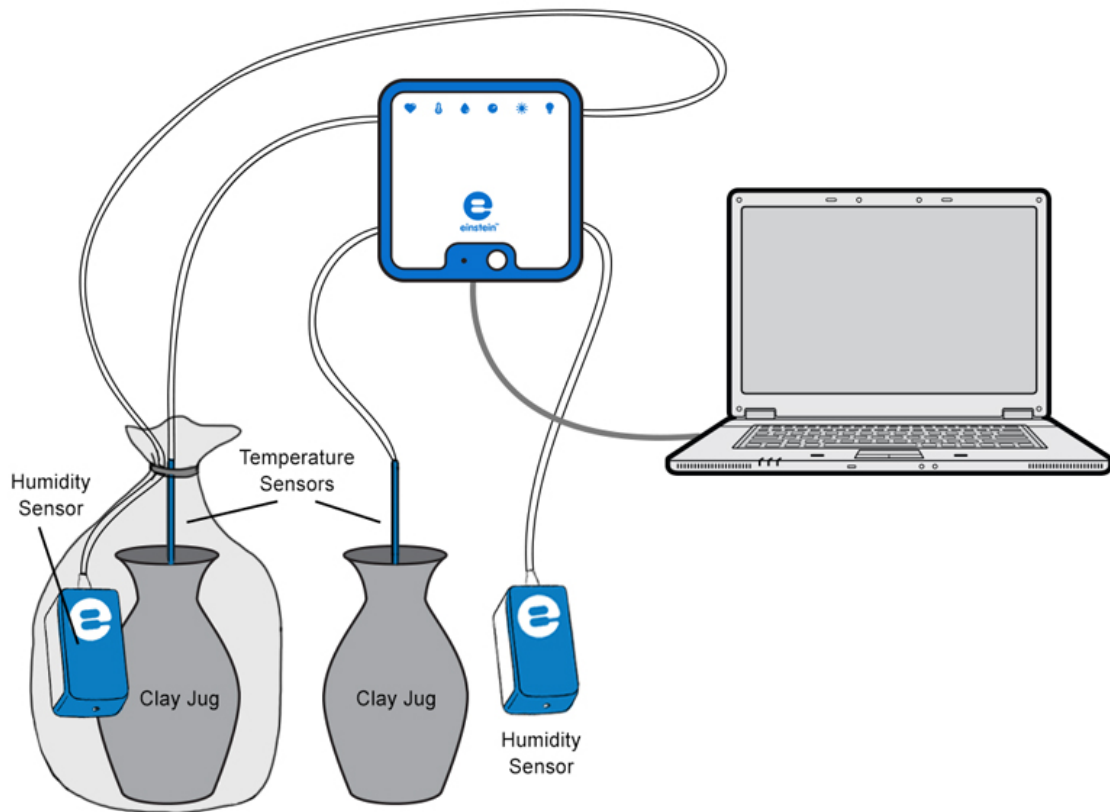


Figure 1



Introduction

In ancient as well as modern times, wandering tribes living in hot and arid areas kept their water in clay jugs. In this way, the water remained cool despite its exposure to heat. The clay is a porous material that enables water leakage. How is this property of the clay connected to the cooling of the water? What is the mechanism underlying this phenomenon?

In this experiment we will examine the effect of temperature and humidity on heat loss from clay jugs.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- 2 Temperature Sensors (-40°C to 140°C)
- 2 Humidity Sensors
- 2X250 ml clay jugs
- 2 clay covers, adaptable to the jugs. A hole fitted for the Temperature Sensor is pierced in each cover.
- Plastic bag
- 1 liter of hot water (about 70°C)

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Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Humidity Sensors and the Temperature Sensors to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Humidity Sensors and Temperature Sensors are selected under Measurements.



Current Setup Summary


Program the sensors to log data according to the following setup:


Sensor:	Humidity
Measurements:	Humidity (%)
Sensor:	Temperature (-40-140 °C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	2000
Duration:	33 minutes 20 seconds

Note: Ensure that only the external Temperature Sensor (-40-140 °C) and external Humidity Sensor are selected and not the internal Temperature Sensor (-30-50 °C) and internal Humidity Sensor.



Procedure

1. Place one of the clay jugs in a plastic bag. Put a Humidity Sensor beside it in the plastic bag. Leave the other jug out in the open and place a Humidity Sensor beside it.
2. Insert a Temperature Sensor through the hole in the cover of each clay jug.
3. Select **Run** () to begin recording data.

4. Pour hot water into the jugs (about 200 ml into each jug).
5. Tie the plastic bag covering one of the jugs shut.
6. Run the experiment for 10 minutes and follow changes in humidity in the room and in the plastic bag. Follow temperature changes in the two jugs.
7. After 10 minutes, remove the plastic bag covering the jug.
8. Follow changes in humidity and temperature for an additional 10 to 15 minutes.
9. The changes can be followed for longer periods of time, leaving your einstein™ device on play for several hours. Remember to adjust the number of samples collected accordingly.
10. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Use the cursors to mark the course of changes in humidity and temperature in the covered and exposed systems: What was the initial value in each system, the final value, and the difference between the two values?
2. Use the cursors to mark the time interval between the start of the experiment and:
 - a. The start of the decline in temperature in each system.
 - b. The change in the rate of heat loss in the covered system.

An example of the Temperature graph obtained in this experiment is shown below:

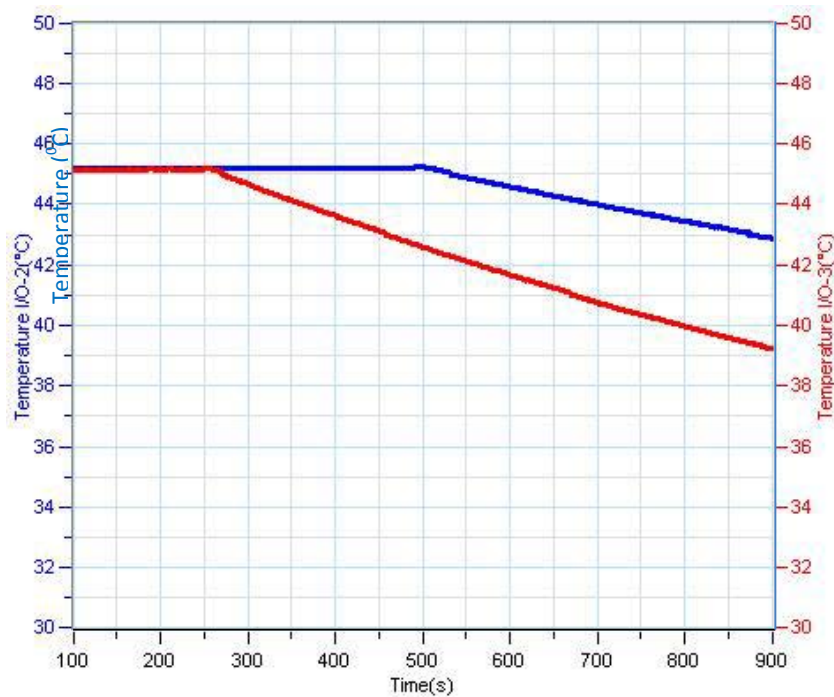


Figure 2



Questions

1. What is the effect of covering the jug with a plastic bag:
 - a. On the humidity measured in the bag?
 - b. On the temperature change of the water in the jug?
2. Compare the temperature changes in the two jugs: Did you observe a similar change in both jugs? Explain the differences.
3. Why does the humidity in the bag decrease immediately after opening the bag?
4. What eventually happens to the water accumulated in the plastic bag?
5. During the experiment the jug walls become wet. Why?
6. What happened to the water leaking out of the jugs?
7. What is your conclusion from this experiment, regarding the process of heat loss from the jugs?



Further Suggestions

1. Connect an additional Temperature Sensor and place it inside the plastic bag. Follow the temperature changes that occur in the bag at the same time as the changes happening inside the jugs.
2. Create airflow (using air conditioning, for example) around the jugs and follow its effect on the rate of heat loss.
3. Start the experiment with water at different temperatures and compare the rate of heat loss in each case.
4. Increase humidity of the surroundings and measure its effect on heat loss.
5. Calculate the rate of heat loss in each system. It should be proportional to $1/\Delta T^2$.

Chapter 19

Regulation of Human Body Temperature - Loss of Heat through Sweat Production: Heat Loss Measured at the Fingertips with Humidity and Temperature Sensors

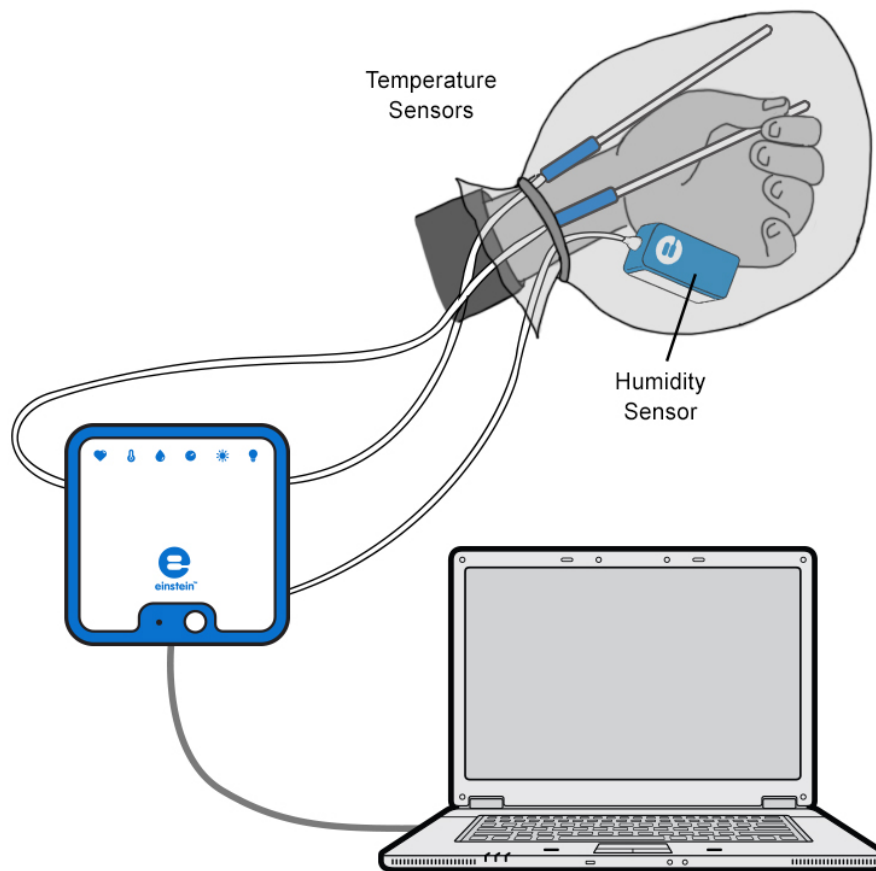


Figure 1



Introduction

Exposure of our bodies to high temperatures or physical exertion can lead to an increase in body temperature. Blood vessels near the skin's surface dissipate heat well. Therefore, blood flow in the skin rises when body temperature increases. To help dissipate heat, sweat production increases significantly. This is done by over three million sweat glands spread throughout the skin. Sweat production and evaporation is essential to maintaining body temperature but it can lead to dehydration if water loss is not replaced through drinking.

In this experiment we measure the effect of an increase in hand temperature on heat dissipation through sweat evaporation.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Humidity Sensor
- 2 Temperature Sensors (-40°C to 140°C)
- Plastic bag



Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Humidity Sensor and the Temperature Sensors to ports of the einstein™ LabMate.
3. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Humidity Sensor and Temperature Sensors are selected under Measurements.



Current Setup Summary



Program the sensors to log data according to the following setup:

Sensor:	Humidity
Measurements:	Humidity (%)
Sensor:	Temperature (-40-140 °C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	2000
Duration:	33 minutes 20 seconds

Note: Ensure that only the external Temperature Sensor (-40-140 °C) and external Humidity Sensor are selected and not the internal Temperature Sensor (-30-50 °C) and internal Humidity Sensor.



Procedure

1. Attach a Temperature Sensor to the fingers of your right arm, as illustrated in Figure 1 above. Make sure you are touching the tip of the Temperature Sensor.
2. Select **Play** () to begin recording data.
3. Follow temperature changes in your fingertips until it stabilizes (at about 2-3 minutes).
4. Cover the hand holding the Temperature Sensor with a plastic bag.
5. Place a Humidity Sensor inside the bag as well as an additional Temperature Sensor.
6. Tie the bag covering your hand, to prevent airflow into and out of the bag.
7. Follow changes in humidity and temperature inside the bag, for about 10 minutes.
8. Remove the plastic bag from your hand, leaving a Humidity Sensor and Temperature Sensor inside the bag. Follow changes in the humidity and temperature inside the plastic bag as well as the temperature of your fingertips, for an additional 10 minutes.
9. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Use the cursors to mark the changes in humidity and temperature while the hand is covered by the plastic bag. What was the initial value of each parameter, the final value, and the difference between the two values?

Mark the course of changes in humidity and temperature after the removal of the plastic bag.

An example of the graph obtained in this experiment is shown below (the black line is the temperature and the blue line is the humidity):

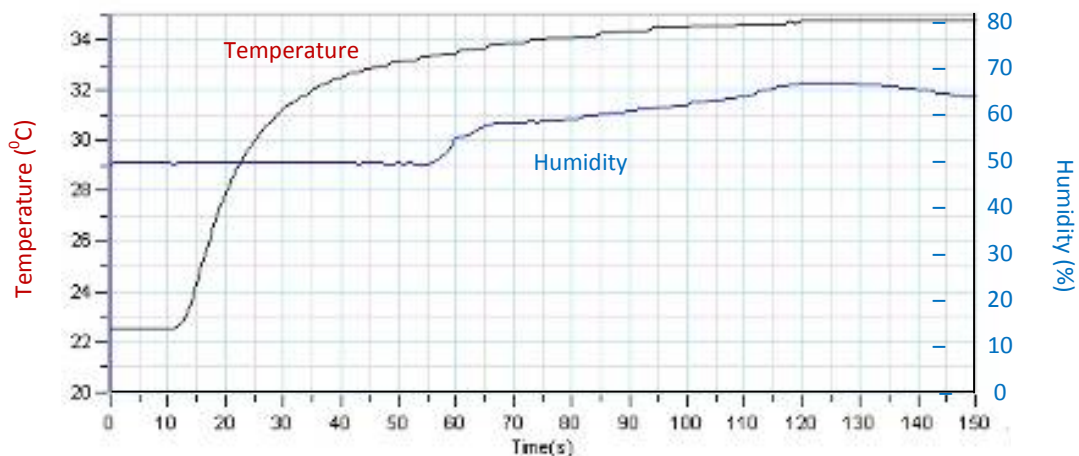


Figure 2

Examine your hand immediately after removal of the plastic bag. Is it moist or dry?



Questions

1. What is the effect of covering the hand with a plastic bag:
 - a. On the humidity level measured inside the bag?
 - b. On the temperature level measured at your fingertips?
 - c. On the temperature level measured inside the plastic bag?
2. What causes the changes in the temperature of your fingertips during the experiment?
3. Did you observe any change in the humidity of your skin during the experiment? Explain your observation.
4. Why did the humidity in the bag decrease immediately after the removal of the bag?
5. What is the source of the water accumulated in the bag?
6. What happens to the water accumulated in the plastic bag after the removal of the bag from the hand?
7. What can you conclude from this experiment, regarding:
 - a. Warming up of your hand held inside the plastic bag?
 - b. The process of heat loss from your hand after removal of the plastic bag?



Further Suggestions

1. Connect an additional Temperature Sensor to the fingertips of your other hand. Compare temperature changes in the hand covered by the plastic bag and the uncovered hand.
2. Perform exercise while holding the hand inside the plastic bag, and measure its effect on temperature and humidity.
3. Increase the humidity of the surrounding air and measure its effect on heat loss.
4. Create airflow close to your hand. Remove the plastic bag, and immediately measure the effect on temperature and humidity.

Chapter 20

Regulation of Human Body Temperature - Loss of Heat through Sweat Production: Heat Loss Measured at the Fingertips with Temperature

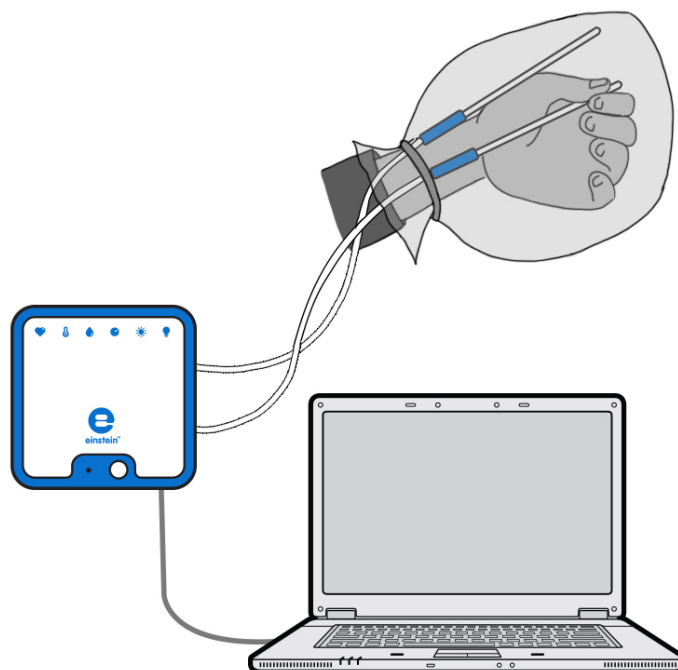


Figure 1



Introduction

Exposure of our bodies to high temperatures or physical exertion can lead to an increase in body temperature. Blood vessels near the skin's surface dissipate heat well. Therefore, blood flow in the skin rises when body temperature increases. To help dissipate heat, sweat production increases significantly. It is done by over three million sweat glands spread throughout the skin. Sweat production and evaporation are essential to maintaining body temperature, but can lead to dehydration if water loss is not replaced by drinking.


In this experiment we observe heat dissipation by measuring the effect of an increase in hand temperature on sweat evaporation.



Equipment

- einstein™ LabMate and a computer with MultiLab4
- 2 Temperature Sensors (-40°C to 140°C)
- Plastic bag

123 Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Temperature Sensors to ports of the einstein™ LabMate.
3. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Temperature Sensors are selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Temperature (-40-140 °C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	2000
Duration:	33 minutes 20 seconds

Note: Ensure that only the external Temperature Sensors (-40-140 °C) are selected and not the internal Temperature Sensor (-30-50 °C).

Procedure

1. Attach one Temperature Sensor to the outside of your hand and another to your fingertips as demonstrated in Figure 1 above. Make sure you are touching the tip of the Temperature Sensor with your fingertips.
2. Select **Play** () to begin recording data.
3. Follow temperature changes in your fingertips in the Graph window of MultiLab4 until the temperature stabilizes (about 2 - 3 minutes).
4. Cover the hand holding the Temperature Sensor with a plastic bag.
5. Tie the bag covering your hand to prevent airflow into and out of the bag.
6. Follow changes in temperature inside the bag for about 10 minutes.
7. Remove the plastic bag from your hand. Follow changes in the temperature inside the plastic bag as well as the temperature of your fingertips for an additional 10 minutes.
8. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Use the cursors to mark the changes in temperature while the hand was covered by the plastic bag. What was the initial value of temperature, the final value, and the difference between the two values?
2. Mark the course of changes in temperature after the removal of the plastic bag.
3. Examine your hand immediately after removal of the plastic bag: Is it moist or dry?



Questions

1. What is the effect of covering your hand with a plastic bag:
 - a. On the temperature level measured at your fingertips?
 - b. On the temperature level measured inside the plastic bag?
2. What causes the changes in the temperature of your fingertips during the experiment?
3. Did you observe any change in the humidity of your skin during the experiment? Explain your observation.
4. Why did the humidity in the bag decrease immediately after the removal of the bag?
5. What is the source of the water accumulated in the bag?
6. What happens to the water accumulated in the plastic bag after the removal of the bag from the hand?
7. What can you conclude from this experiment, regarding:
 - a. The warming up your hand held inside the plastic bag?
 - b. The process of heat loss from your hand after removal of the plastic bag?



Further Suggestions

1. Connect an additional Temperature Sensor to the fingertips of your other hand. Follow temperature changes in the covered and uncovered hands.
2. Perform exercise while holding your hand inside the plastic bag, and follow its effect on the temperature.
3. Increase the humidity of the surrounding air and measure its effect on heat loss.
4. Create airflow close to your hand. Remove the plastic bag, and immediately follow its effect on temperature.

Effect of Exercise on the Human Body: Temperature and Heart Rate

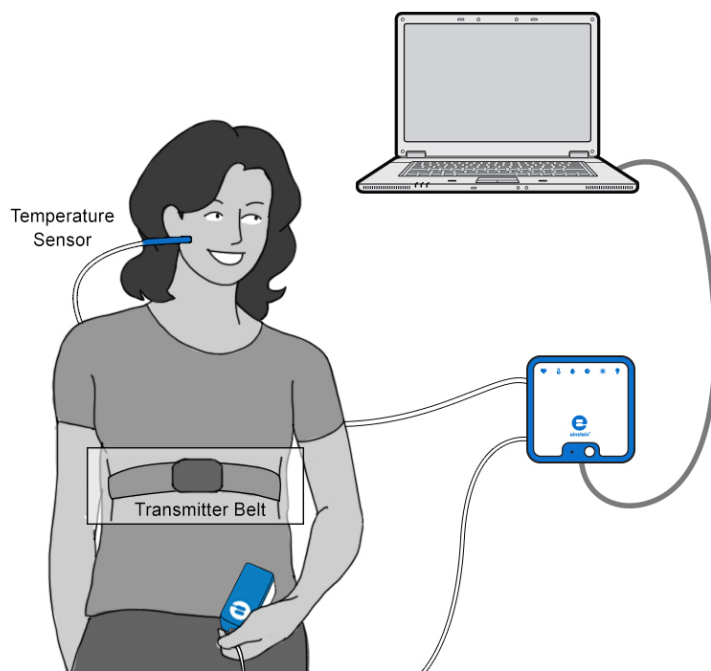


Figure 1



Introduction

During exercise, your muscles need more energy. They produce this energy by burning glucose or fat, which produces heat. Yet, the core body temperature remains almost unchanged. The body balances the amount of heat by losing heat to the environment.

More than 80% of this heat is lost through the skin's surface. Blood vessels near the surface of the skin dissipate heat. Therefore, heat loss is effectively achieved by an increase in blood flow in the skin.


In this experiment we measure the effect of exercise on body temperature and heart rate.



Equipment

- einstein™ LabMate and a computer with MultiLab4
- Temperature Surface Sensor (-40°C to 140°C)
- Heart Rate (Exercise) Sensor with transmitter belt
- Saline solution

123 Equipment Setup

1. Launch MultiLab4 ().
2. Connect the Temperature Sensor and the Heart Rate Sensor to ports of the einstein™ LabMate.
3. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Temperature Sensor and Heart Rate Sensor are selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Surface Temperature (-40-140 °C)
Measurements:	Temperature (°C)
Sensor:	Heart Rate
Measurements:	Heart Rate (bpm)
Rate:	25 samples per second
Samples	200
Duration:	8 seconds

Note: Ensure that only the external Surface Temperature Sensor (-40-140 °C) is selected and not the internal Temperature Sensor (-30-50 °C).

Procedure

1. Attach one plastic end of the elastic strap securely to the transmitter belt.
2. Wet the two electrode strips with a zigzag pattern of 4 drops of saline solution on the back side of the belt.
3. Place the transmitter belt over the base of the rib cage. The belt should be directly on your skin. Be sure the belt is in the right place by checking that the POLAR logo of the belt is centered. Pull the elastic strap to make sure it is fitted tightly (see Figure 1).
4. Hold the Temperature Sensor under your left ear lobe (without pressing).
5. Select **Run** () to begin recording data.
6. Follow changes in temperature and heart rate until they stabilize (at about two minutes).
7. Run in place for about two minutes.
8. Follow changes in temperature and heart rate for an additional one to two minutes after completing the exercise.
9. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Questions

1. What is the effect of the exercise you performed on:
 - a. The temperature measured at your ear lobe?
 - b. Your heart rate?
2. What causes the changes in temperature and heart rate?
3. After exercising, what changes in temperature and heart rate did you observe? Did both parameters return to the level registered before the exercise? Explain your observations.
4. What can you conclude from this experiment regarding:
 - a. Changes in body temperature following muscular activity?
 - b. Changes in heart rate following muscular activity?
 - c. The connection between the two parameters?



Further Suggestions

1. Compare temperature changes in both ear lobes at the same time.
2. Perform different types of exercise and measure their effect on heart rate and temperature measured at your ear lobes.
3. Compare your data with those of your classmates.

Amount of CO₂ Exhaled in Human Respiration

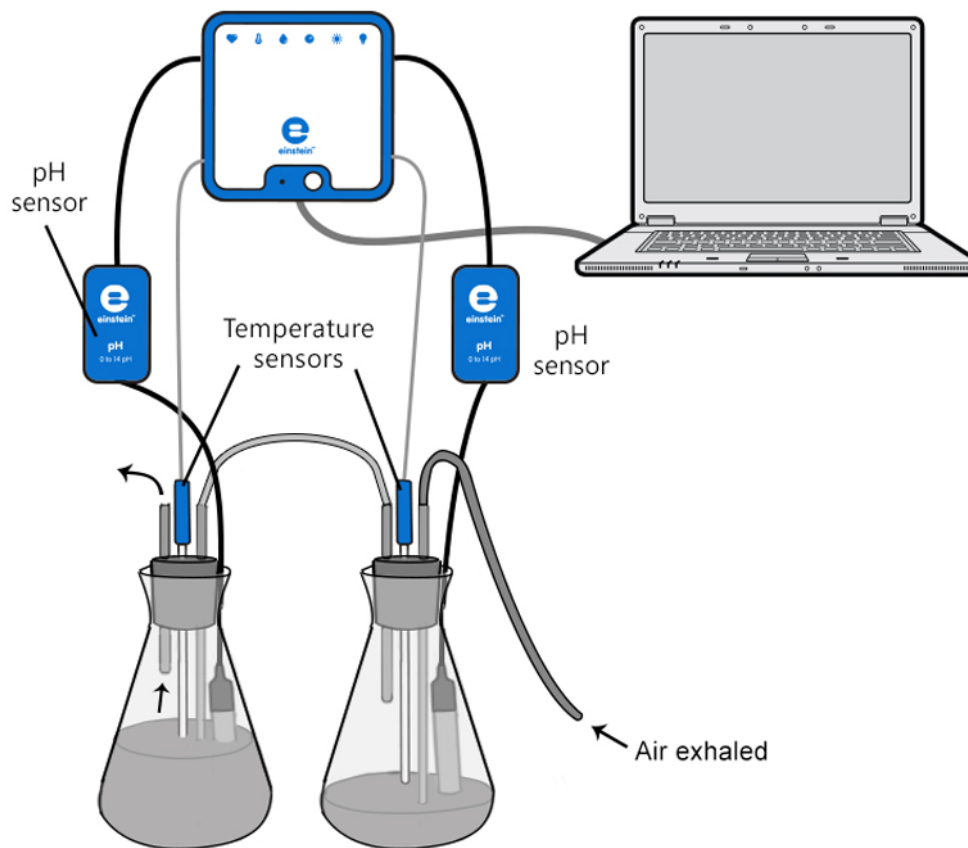


Figure 1



Introduction

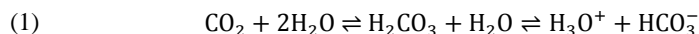
The respiratory system has two main roles: exchanging oxygen for CO₂ in the blood and maintaining stable blood pH through regulation of the CO₂ level.

At rest, we exchange about 0.5 L of air with each breath. This is tidal air. When taking a deep breath we can inhale up to 3 L of air. This is called aspiratory reserve air. At the end of a normal exhalation, we can exhale with effort an additional volume of 1 L of air. This is the expiratory reserve volume. Still, a volume of 1.5 L remains unchanged in our lungs. This is the residual volume.

At rest, we breathe an average of 8 L air volume per minute (an average exchange of 0.5 L in a breath, multiplied by 16 breaths per minute). During strong physical effort, we can exchange 4 L in one breath. This is the vital capacity, our whole expiratory reserve volume.

CO₂ concentration in the atmosphere is very low, only 0.03%. In the lungs, however, the concentration rises to as much as 7%, while in the air exhaled from the lungs it reaches a concentration of 5.1%.

In this experiment, the exhaled air is bubbled into a NaOH solution. Dissolution of CO₂ in water leads to the following reaction:



H₃O⁺ ions react with the NaOH and change the pH of the solution. In this experiment, the amount of CO₂ exhaled during one minute is determined by using a pH Electrode.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Two pH Sensors
- Two Temperature Sensors* (-40°C to 140°C).
- CO₂ Sensor (optional)
- Two 500 ml flasks
- Two stoppers
- Two short tubes (6 cm long)
- Two long tubes that can be inserted through the stoppers to reach the bottom of the flasks. The diameter of the tubes should be large enough to enable normal breathing (a diameter of about 6 mm).
- Two 30 cm length of silicone tubing
- 500 ml 0.04% NaOH solution
- 0.5% phenolphthalein solution
- Safety goggles

*The Temperature Sensors are used in order to compensate for the pH reading.



Equipment Setup

1. Launch MultiLab4 ().
2. Connect the pH Sensors and Temperature Sensors to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
4. Make sure the long tubes are immersed in the solution but are not touching the bottom of the flask. Make sure the short tube is not immersed in the solution.
5. Add 200 ml tap water to the first flask (the flask into which you directly exhale air).
6. Add 400ml tap water to the second flask (this is a CO₂ trap: CO₂ that does not dissolve in the first flask will reach the second flask through the connecting tube. This CO₂ will be dissolved in the second flask, containing a larger volume of solution).
7. Add 1 ml of 0.5% phenolphthalein indicator solution to each flask and then 1.0 ml of 0.04% NaOH solution.
Mix well.
8. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the pH Sensors and Temperature Sensors are selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	pH
Measurements:	pH (0-14)
Sensor:	Temperature (-40-140 °C)
Measurements:	Temperature (°C)
Rate:	Every second
Samples	1000
Duration:	16 minutes 40 seconds



Note: Ensure that only the external Temperature Sensors (-40-140 °C) are selected and not the internal Temperature Sensor (-30-50 °C).



Procedure

1. In this experiment, two flasks serve to trap CO₂ exhaled during respiration. Air is exhaled into a silicone tube directly connected to the first flask. The exhaled air passes through silicone tube, into the long tube which is immersed in the solution in this first flask.
2. The other flask is used to trap CO₂ that did not dissolve in the first flask. The long tube of this flask is connected with a silicone tube to the short tube of the first flask.
3. A pH electrode is inserted into each flask. Make a small groove at the side of the stopper that can fit the cable of the electrode. Make sure that the electrode reaches the bottom of the flask.
4. If you wish to ensure that no CO₂ is released to the free air above the solution in the second flask, do not cover the flask with a stopper. Instead, use the stopper of the CO₂ Sensor and insert the pH electrode cable and the long pipe in its groove.

Follow changes in the phenolphthalein indicator's color as you measure the pH. Place the flasks on a white page to make the color changes more prominent.

1. Select **Run** () to begin recording data.
2. Inhale air *only through your nose*. Exhale air for 30 consecutive seconds *only through the mouth*. The breathing should be normal. Practice it several times before you start the measurement.
3. Count the number of times you inhale and exhale air during the measurement. It should be around 14-16 times a minute.
4. After 30 seconds (or if you measure the CO₂ level with the sensor, when the CO₂ starts to rise), stop breathing through the pipe. Let the pH stabilize in the flasks for about 30 seconds. Then, take the stoppers and the CO₂ Sensor out of the flasks.
5. Add 0.04% NaOH solution to each flask and mix carefully until the pH returns to the initial level (it usually takes more than 20 ml). Make sure to measure and record the volume required to return to the initial pH. You can use a burette to facilitate the titration of the CO₂ with the NaOH solution.
6. The NaOH added to the tap water creates a basic solution. The indicator, phenolphthalein, is pink under basic conditions and turns colorless under neutral pH conditions.
7. Repeat the measurement at least twice. Each time replace the solution in the flasks with fresh tap water and NaOH solution.
8. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Measure the pH change in each flask. Use the cursors to find the appropriate values.

An example of the graph obtained in this experiment is shown below:

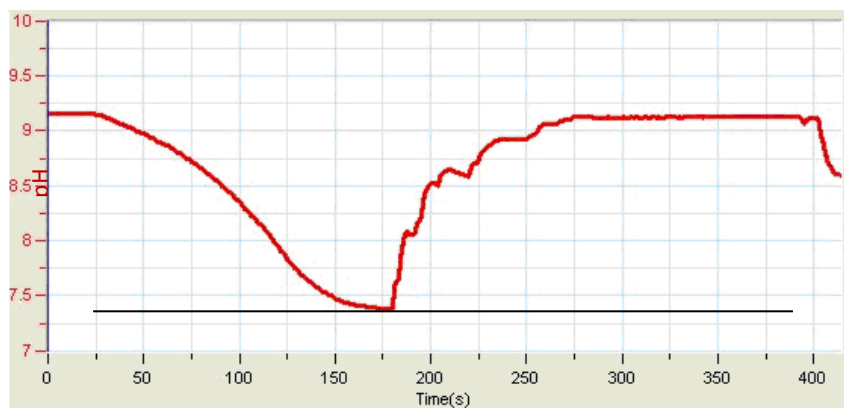


Figure 2

2. To find the amount of CO₂ exhaled *in one minute*, calculate the amount of NaOH you had to add in order to return the pH to its original level. (if you breathed through the mouthpiece for more than a 30 seconds, correct the calculation accordingly). 1 ml of 0.04% NaOH titrates 10 μmoles of CO₂. To calculate the total amount of CO₂ exhaled, you must add the volume of 0.04% NaOH added to both flasks and multiply it by 10. Then multiply it by 2 to determine the amount of CO₂ exhaled *in one minute*.

$$\text{CO}_2 \text{ exhaled in one minute (}\mu\text{moles)} = \text{total volume of 0.04\% NaOH} \times 10 \times 2.$$

The molecular weight of CO₂ is 44 g.

$$\text{Weight of CO}_2 \text{ exhaled in one minute (}\mu\text{g)} = \text{Amount of CO}_2 \text{ in } \mu\text{moles} \times 44.$$

If CO₂ was released to the free air and measured by the sensor, add this amount to the total amount of CO₂ (400 ppm = 72 μg CO₂).

3. Calculate an average of your results: the number of times you take a breath in a minute and the amount of CO₂ you exhale in a minute.



Questions

1. Why is the curve initially flat and only after a while, starts to descend?
2. Explain the differences in color observed in the two flasks during the experiment. Why is the change of color in the first flask much greater than in the second flask?
3. Why is it recommended that in the second flask you measure the release of CO₂ into the free air above the solution?
4. Compare your results with the results of other students in your class. Did you all receive similar results? What factors may cause variation?
5. Predict the effect of physical exercise on the amount of CO₂ exhaled. Explain.



Further Suggestions

1. Compare the amount of CO₂ exhaled at rest and after physical exercise. In this case, exhale air for a shorter period of time or add a larger volume of solution to the flasks.
2. Compare the amount of CO₂ exhaled by males and females.
3. Compare the amount of CO₂ exhaled by athletes and non-athletes.
4. Use a Spirometer (a sensor measuring volume of air flow) to measure volumes of air exhaled under different conditions.

EKG at Rest and after Activity

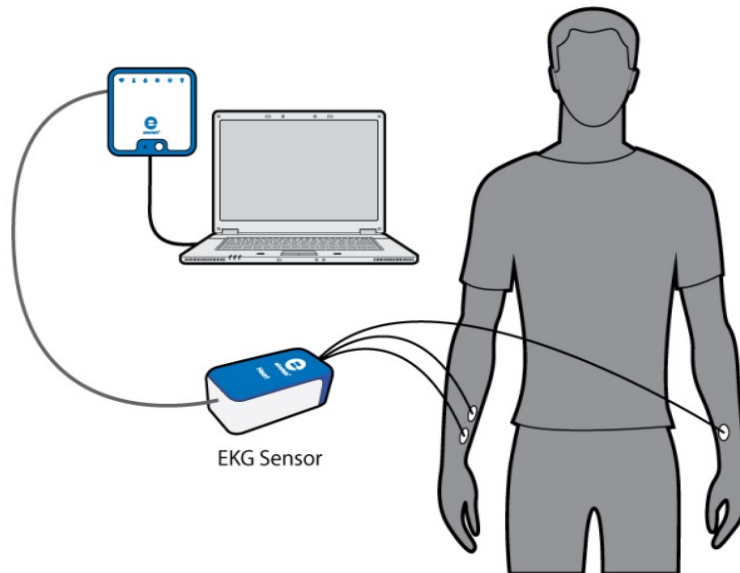


Figure 1



Introduction

The EKG (Electrocardiogram) is a procedure that measures the heart muscle's contractions by using electrodes located in different places on the body.

Ions and charged molecules such as potassium, calcium, chlorine, and charged protein molecules are involved in the depolarization and repolarization of the cardiac muscle. This process can be recorded by electrodes at the surface of the skin. A recording of the heart's electrical activity is called an electrocardiogram (EKG).

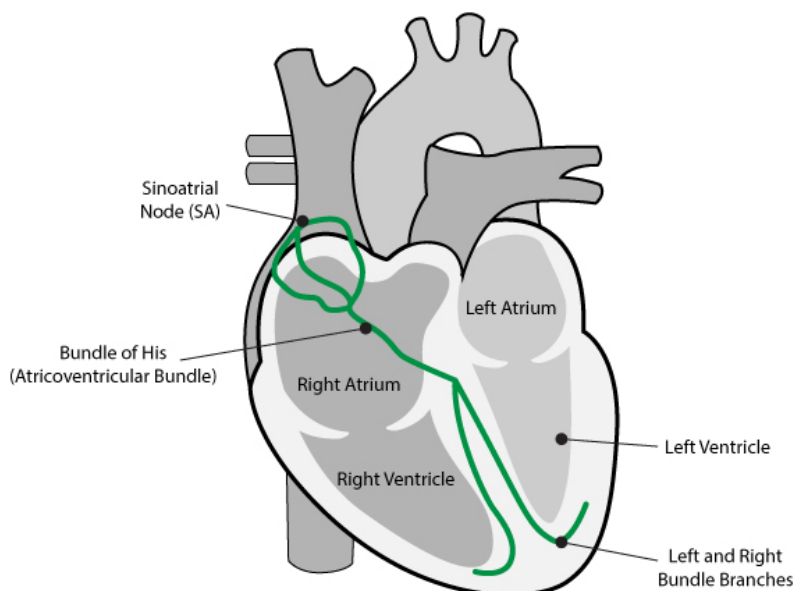
The cells of the heart's conducting system will depolarize spontaneously. This spontaneous depolarization is most apparent in a cluster of cardiac muscle cells embedded in the upper wall of the right atrium. This group of cells is called the pacemaker (also known as the sinoatrial or SA node). Depolarization of the pacemaker generates a current that leads to the depolarization of all other cardiac muscle cells. The depolarization of the cardiac muscles triggers the heart's contraction. The wave of depolarization travels from the right atrium to the left atrium quickly enough that both atria contract at essentially the same time.

The atria and the ventricles are isolated from each other electrically by connective tissue that acts like the insulation on an electric wire. The depolarization of the atria does not directly affect the ventricles. There is another group of cells in the right atria, called the atrioventricular or AV node that will conduct depolarization down to the ventricles via a special bundle of conducting fibers (called the Bundle of His) to the ventricles. The muscle wall of the ventricles contain the Purkinje Fibers, which are a special system of muscle fibers that cause depolarization in all parts of the ventricles almost simultaneously. This process causes a small time delay, so there is a short pause after the atria contract and before the ventricles

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

When a portion of the heart is polarized and the adjacent portion is depolarized, an electrical current is created that moves through the body. This current is greatest when one half of the connected portion of the heart is polarized and the adjacent half is not polarized. The current decreases when the ratio of polarized tissue to non-polarized tissue is less than one to one. The changes in these currents can be measured, amplified, and plotted over time. The EKG represents the summation of all the action potentials from the heart, as detected on the surface of the body. It does not measure the mechanical contractions of the heart directly.

The impulse originating at the SA node causes the atria to contract, forcing blood into the ventricles. Shortly after this contraction, the ventricles contract due to the signal conducted to them from the atria. The blood leaves the ventricles through the aorta and pulmonary artery. The polarity of the cardiac muscle cells returns to normal and the heart cycle starts again.



The Electrocardiogram:

The electrocardiogram (EKG) is a graphic tracing of the heart's electrical activity. A typical tracing consists of a series of waveforms occurring in a repetitive order. These waveforms begin from a flat baseline called the isoelectric line. Any deflection from the isoelectric line denotes electrical activity.

The five major deflections on a normal EKG are designated by the letters P, Q, R, S, and T. One heart cycle is represented by a group of waveforms beginning with the P wave, followed by the QRS wave complex, and ending with the T wave. The P wave represents the depolarization of the atria and is associated with their contraction. The QRS wave complex consists of three waves. The first negative deflection is the Q wave and is followed by a positive deflection called the R wave. The complex ends with a negative deflection known as the S wave. The QRS wave complex denotes depolarization of the ventricles and is associated with their contraction. Atrial repolarization occurs during the depolarization of the ventricles. For this reason, the waveform associated with atrial repolarization is undetectable on an EKG. The last wave is called the T wave, and is usually represented by a positive deflection. The T wave indicates ventricular repolarization.

Electrical energy is also generated by skeletal muscles, and can be seen as muscle artifacts if, for example, your arm is moved while the EKG is attached. The sequence from P wave to T wave represents one heart cycle. The number of cycles in a minute is called the heart rate and is typically 70-80 beats per minute at rest. Some typical times for portions of the EKG are:

P-R interval: 0.12 to 0.20 seconds

QRS interval: Less than 0.1 seconds

Q-T interval: Less than 0.38 seconds

The respiration rate as well as the air volume in each breath significantly increases during active exercise, as the body needs additional energy which can only be released through additional amounts of oxygen.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- EKG Sensor
- 3 EKG electrode patches



Equipment Setup

1. Launch MultiLab4 ().
2. Connect the EKG Sensor and the Spirometer to ports of the einstein™ LabMate.
3. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the EKG Sensor and Spirometer Sensor are selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	EKG (0-5V)
Measurements:	ECG/EKG (V)
Sensor:	Spirometer ± 315 L/min
Measurements:	Spirometer (L/min)
Rate:	100 samples per second
Samples	5000
Duration:	50 seconds

Procedure

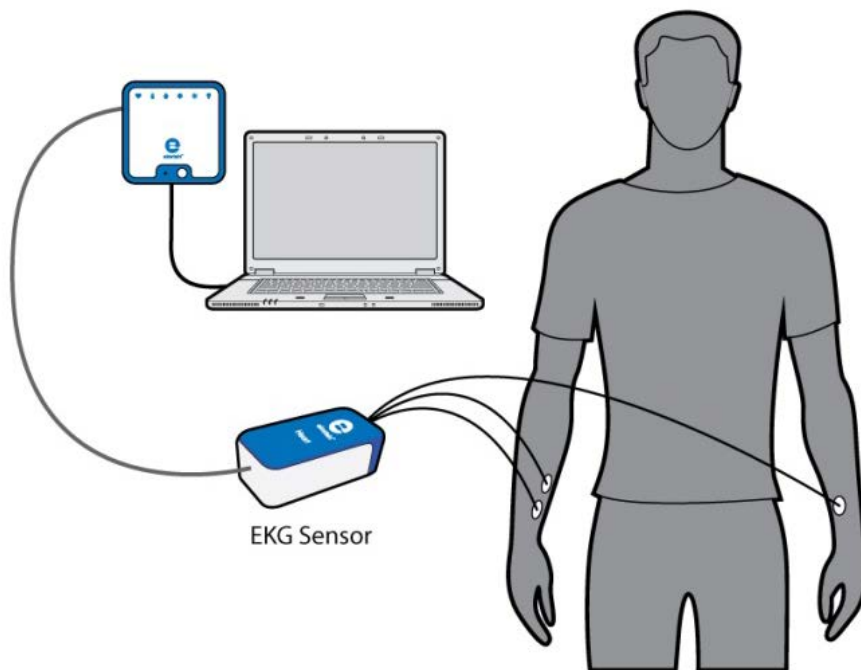




Figure 2

1. Apply the three EKG Electrodes:
2. 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.
3. Peel three electrode patches from the backing paper.
4. Place each electrode on the inside part of the arm (closer to the body), with the tab on the edge of the electrode patch pointing down. This way, the wire of the sensor can hang freely without twisting the edge of the electrode patch.
5. Firmly place the first electrode on the right wrist (see Figure 2).
6. Place a second electrode a few centimeters above the first one.
7. Place a third electrode on the inside of the left wrist.
2. Connect the micro-alligator clips of the sensor's three leads to the tabs on the edges of the electrode patches.
 - a. Connect the two leads labeled R.A. (right arm) to the right arm electrode patches.
 - b. Connect the lead labeled L.A. (left arm) to the left arm electrode patch.
3. Assume a comfortable position, so that during measurement you won't need to move. The electrodes are very sensitive to motion.
4. Select **Run** () to begin recording data.
5. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.
6. Perform some exercise and then repeat steps 3-5.



Data Analysis

1. Measure the EKG parameters in both the *rest position* and *after exercise*.

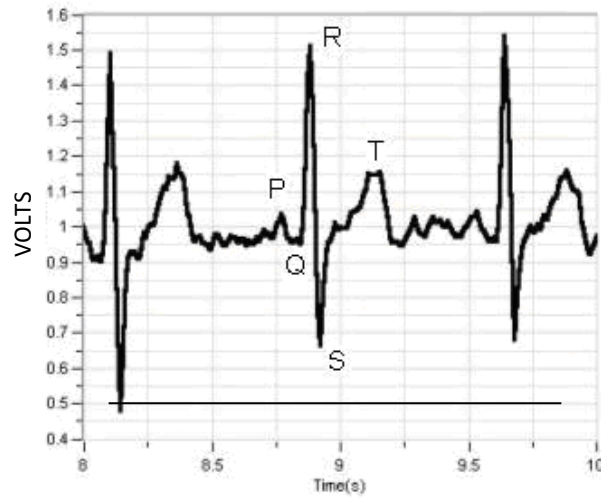


Figure 3

With the aid of the cursors make the following measurements (see Figure 3):

Item	Time – Rest (Seconds)	Time – Exercise (Seconds)	Typical Time (Seconds)
P-R			0.120 to 0.200
QRS			Under 0.100
Q-T			Under 0.380

2. What is your conclusion?



Further Suggestions

1. Compare your EKG and breath parameters in different body positions (standing, sitting, lying down).
2. Compare differences between you and some of your friends. Be careful not to overstress your body during the activities.

Impact of Crowded Urban Areas on Microclimate

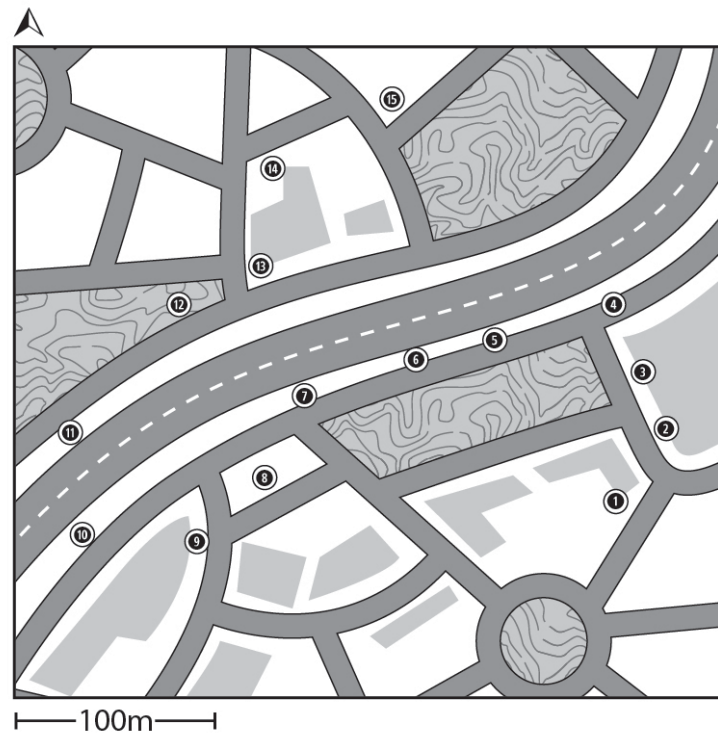


Figure 1: Route and Stops on a park map



Introduction

Crowded urban areas are often characterized by *heat islands*: unpleasant microclimate conditions marked by increased local temperatures and radiation intensity. Heavy traffic (among other factors) increases this effect. Vegetation reduces temperature and increases relative humidity. Thus, urban parks and green areas can dramatically improve urban microclimates, especially in hot regions. In this experiment we will compare crowded urban areas with heavy traffic to urban parks in terms of temperature and relative humidity.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Temperature Sensor (-40°C to 140°C)
- Humidity Sensor
- Radiation Shield
- Wooden or plastic pole 180 cm long
- Large scale map of the area where the experiment will take place



Equipment Setup

1. Place the Humidity and Temperature Sensors inside the Radiation Shield.
2. Attach the Radiation Shield to the top of the pole.
3. Launch MultiLab4 ().
4. Connect the Humidity Sensor and the Temperature Sensor to ports of the einstein™ LabMate.
5. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Humidity Sensor and Temperature Sensor are selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Humidity
Measurements:	Humidity (%)
Sensor:	Temperature (-40-140 °C)
Measurements:	Temperature (°C)
Sampling:	Manual
Samples	15

Note: Ensure that only the external Temperature Sensor (-40-140 °C) and external Humidity Sensor are selected and not the internal Temperature Sensor (-30-50 °C) and internal Humidity Sensor.



Procedure

1. Choose at least two sites at the outskirts of the city or by the seashore.
2. On the map, draw a route that passes through built-up areas on either side of the green area and also through the center of the green area itself. The line need not be straight. It could, for example, follow a road. In the green area, it is important that the route crosses a range of vegetation i.e. grass and nearby shady trees (Figure 1).
3. On the route, choose 15 locations where you will be able to take measurements. The locations should be separated by approximately equal distances and include a variety of areas (i.e. in the built-up area and in the green area).

4. Select **Run** (🎮) to enable recording data.
5. Collect the data manually: Select **Manual Sampling** (🔍) each time you wish to record a data sample.
6. Wait 60 seconds before collecting the first data sample.
7. Walk to *Location #2*. Wait 60 seconds and select **Manual Sampling** (🔍) to collect the second data sample.
8. Repeat the manual recording procedure for each location. Wait 60 seconds and select **Manual Sampling** (🔍) to record each data sample.
9. After recording data at the last station, select **Stop** (🛑) to stop the data recording.
10. Save your data by selecting **Save** (💾) from the Basic Tools window on the upper menu bar.

Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

An example of the graph obtained in this experiment is shown below (the humidity is the red graph and the temperature is the blue graph):

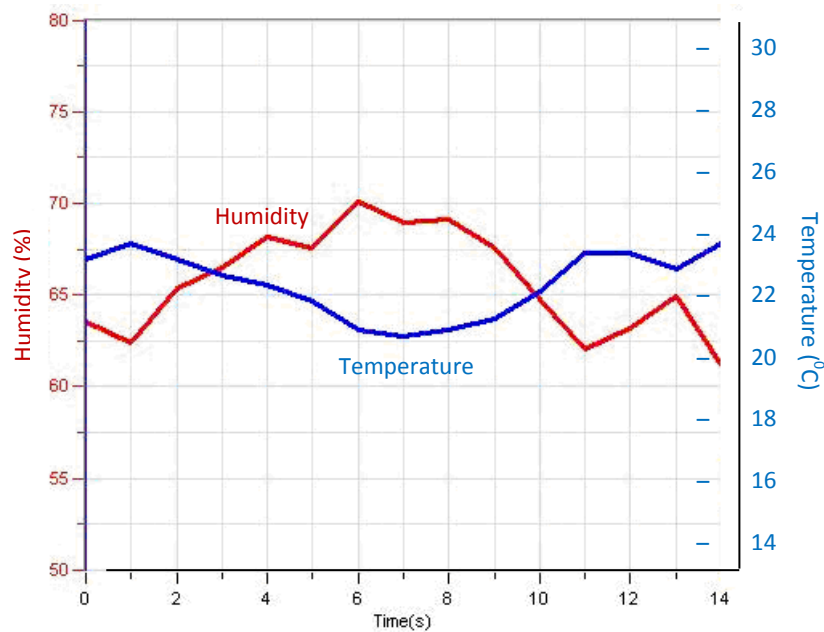


Figure 2

1. Compare the curve of the relative humidity line to the curve of the temperature line. Is there a correlation between the two?
2. Analyze the temperature and relative humidity values at each of the *locations* according to the characteristics of the area i.e. junctions, main road, side road, grass, trees, etc.
3. Compare the results for various types of locations.



Questions

1. What features of locations near crowded buildings affect temperature and relative humidity? Consider differences in street orientation, street and sidewalk materials, and access to sea breezes, etc.
2. How do areas of heavy traffic affect temperature and relative humidity?
3. Discuss the effect of urban parks on the climate in the surrounding built-up areas. Compare it to areas farther away from the park.
4. What differences in temperature and relative humidity did you find in different land uses within the urban park e.g. sand, grass, shrubs, under tall trees, under dense trees? Which land uses in the green area are most effective at reducing temperature?
5. To what extent would you encourage your local authority/municipality to invest in green areas or to limit traffic in residential areas? How would you explain the importance of doing so from the point of view of climate comfort? What other arguments in favor of the expansion of green areas and limiting traffic would you offer?



Further Suggestions

1. Replace the Temperature Sensor in the Radiation Shield with a Temperature TC-K Sensor and change the recording rate to 1 sample per second. This will provide an immediate response to temperature changes and can be used, for example, to measure temperature changes near bus stops as buses come and go.
2. Replace the Temperature Sensor in the Radiation Shield with a Temperature TC-K Sensor and change the recording rate to 1 sample per second. Walk slowly and stand in the doorway of an air-conditioned store. Move close to the vent of the air conditioner. What impact might these factors have on the temperature at street level?
3. Measure the temperature differences between the shady and the sunny sides of a street.
4. Compare measurements of the same route and locations during different seasons, and times of day.

Influence of Natural Ventilation on the Indoor Climate

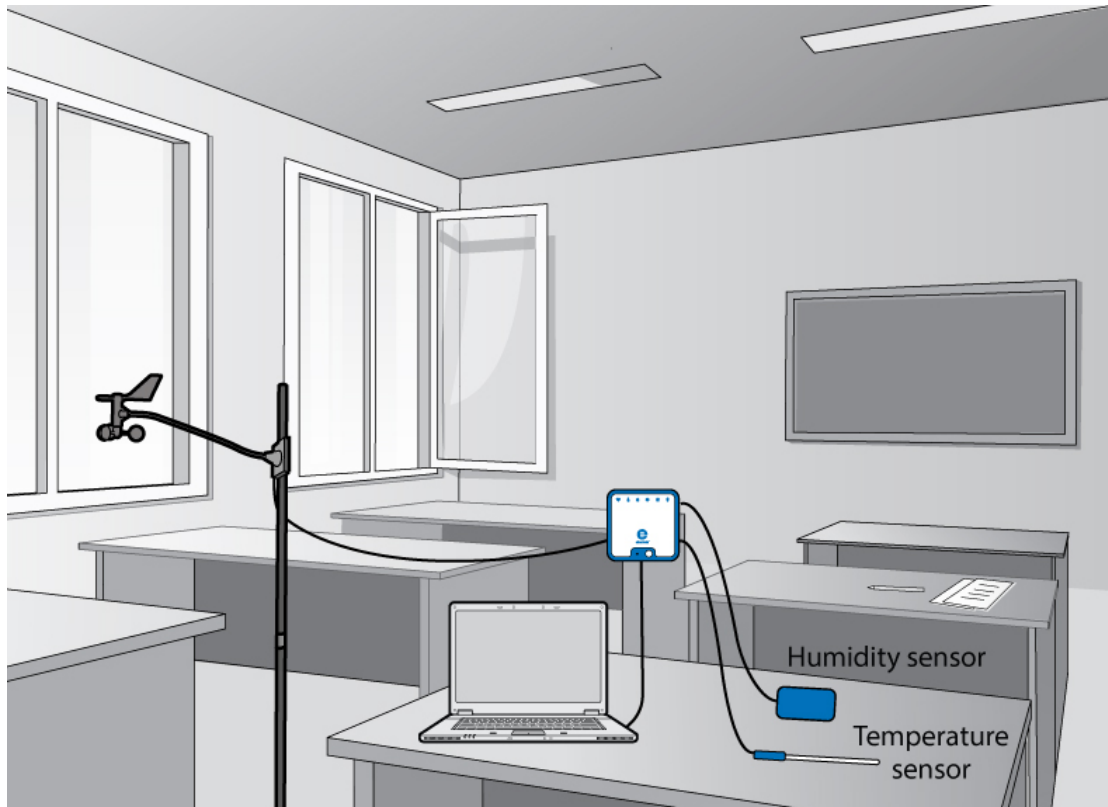


Figure 1: Meteorological station situated in a suitable classroom



Introduction

One of the factors influencing the indoor climate is ventilation. Ventilation depends on wind speed and the size and location of openings such as windows and doors. Effective natural ventilation can reduce the indoor temperature and improve comfort and environmental quality. In this experiment we will investigate the influence of natural ventilation.




Equipment

- einstein™ LabMate and a computer with MultiLab4
- Temperature Sensor (-40°C to 140°C)
- Humidity Sensor
- Anemometer (Wind Speed Sensor)

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Equipment Setup

1. Choose a classroom that has at least two openings facing in different directions. Ideally, one opening should be facing the windiest direction.
2. Position the sensors in the center of the classroom.
3. Attach the sensors at a height of 1 - 1.5 meters.
4. Launch MultiLab4 ().
5. Connect the Humidity Sensor, the Temperature Sensor and the Wind Speed Sensor to ports of the einstein™ LabMate.
6. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Temperature Sensor, Humidity Sensor and Wind Speed Sensor are selected under Measurements.




**Current Setup Summary**

Program the sensors to log data according to the following setup:

Sensor:	Temperature (-40-140 °C)
Measurements:	Temperature (°C)
Sensor:	Humidity
Measurements:	Humidity (%)
Sensor:	Wind Speed 4-280 km/h
Measurements:	Wind Speed (km/h)
Rate:	Every minute
Samples	100
Duration:	1 hour 40 minutes

Note: Ensure that only the external Temperature Sensor (-40-140 °C) and external Humidity Sensor are selected and not the internal Temperature Sensor (-30-50 °C) or internal Humidity Sensor.

**Procedure**

1. Leave the doors and windows of the classroom closed for at least an hour before beginning to record data.
2. Select **Run** () to begin recording data.
3. After half an hour, open the doors and windows.
4. Wait another forty minutes and then select **Stop** () to stop collecting data.
5. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Use the cursors to examine the curves of the climatic parameters and answer the following questions:
 - a. Until what stage are the curves stable?
 - b. What are the changes in each curve?
 - c. At what stages are the changes in the curve most pronounced?
 - d. Which curves stabilize and when?
2. Calculate the heat stress inside the classroom according to the Heat Stress Index:
(Dry bulb temperature + wet bulb temperature) / 2, at two points: 1) before ventilation 2) after ventilation.



Questions

1. What is the effect of temperature on humidity?
2. What is the impact of ventilation on indoor temperature and indoor heat stress?
3. What can be learned from this experiment about the impact of ventilation on indoor climate?
4. To what extent can natural ventilation reduce indoor temperatures?
5. How much time is required for ventilation to reduce temperature?
6. Which classroom in your school or college is best situated from a ventilation point of view?
Explain your answer.
7. What is the relationship between the air speed (ventilation) and the Heat Stress Index?



Further Suggestions

1. Conduct simultaneous tests in two classrooms with different opening orientations and compare the results. Based on your findings, what general recommendations would you make for the orientation and size of classroom windows and doors in order to create comfortable climatic conditions? For example, what orientation would you choose for the largest windows?
2. Measure the outdoor temperature and examine the relationship between outdoor and indoor climate, with and without ventilation. Where and when is the temperature highest? Where and when is the heat stress highest?

An Examination of the Thermal Insulation of a Building Envelope



Introduction

The building envelope is the physical separation between the interior and exterior environments of the building; in other words, the walls and the roof. The temperature inside a building depends upon how much solar radiation is absorbed by the building envelope. The color and type of materials used in construction influence the extent to which a building envelope absorbs solar radiation. In this experiment we will examine the influence of building materials and color on the exterior and interior temperature of three walls.



Equipment


- For each wall, the following equipment is required:
- einstein™ LabMate and a computer with MultiLab4
- 2 Thermocouple Sensors (0 to 1200 °C)
- White sticky tape



Equipment Setup

Note: If only one einstein™ LabMate is at your disposal, this experiment can be performed on three different walls on different days, at similar hours of the day and in similar weather conditions.

This is a long experiment so ensure that the USB cable is connected to the einstein™ LabMate for the duration of the experiment.

1. Choose three building envelopes, each of which should be made of a different material (e.g. concrete, bricks, plaster, etc.) or alternatively they should be made of the same materials but be different colors on the exterior wall. Ensure that all three of the walls have the same orientation. Also ensure that all heat control devices (central heating/air conditioners) have been turned off.
2. Place the Thermocouple Sensors in the center of each exterior and interior wall. Use the white sticky tape to keep it in place.
3. Connect the USB cable to the einstein™ LabMate.
4. Launch MultiLab4 ().
5. Connect the two Thermocouple Sensors to ports of the einstein™ LabMate.
6. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Thermocouple Sensor is selected under Measurements.



Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Thermocouple (0 to 1200 °C)
Measurements:	Temperature (°C)
Rate:	Every 10 minutes
Samples	50
Duration:	8 hours 20 minutes

Note: Ensure that only the external Thermocouple Sensor (0 to 1200 °C) is selected and not the internal Temperature Sensor (-30-50 °C).



Procedure

1. Select **Run** () to begin recording data.
2. After six hours, select **Stop** () to stop recording.
3. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.
4. The above procedure is for the measurement of one wall and should be repeated for each additional wall.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Analyze the graphs with the help of the cursors.
2. For each graph that you have produced, answer the following questions:
 - a. Which wall (interior or exterior) has the lowest temperature?
 - b. Which wall (interior or exterior) has the highest temperature?
 - c. Which curve has the highest range of temperature changes?
 - d. Do the temperature changes (peaks and dips) occur on both curves at the same time?
 - e. What is the minimum temperature gap between the two curves?
 - f. What is the maximum temperature gap between the two curves?
 - g. What is the average temperature gap between the two curves?



Questions

1. Which building material is the best insulator? How did you reach this conclusion?
2. Based on your findings, what color would you suggest painting exterior walls in a warm climate?; in a cold climate? Explain how you reached this conclusion.
3. Based on your results, what is the most important factor in determining optimal thermal insulation: the kind of building material or the color of the building envelope?
4. What other recommendations do you have for the optimal design (materials and colors) of the building envelope for different climatic regions?



Further Suggestions

1. Conduct the above experiment on one kind of building material that has been painted in a range of colors (for example white, black and green) and then compare it to three different materials painted in those same colors.
2. Conduct the experiment on three walls, all from the same material, but of variable thickness. What is the influence of the wall thickness on insulation?
3. Conduct the above experiment during a 24-hour period and study the daily thermal behavior of the wall.
4. Conduct the above experiment during different seasons and study the seasonal thermal behavior of the wall.

Measuring Abiotic Conditions in a Habitat beneath a Rock Using Light and Temperature Sensors

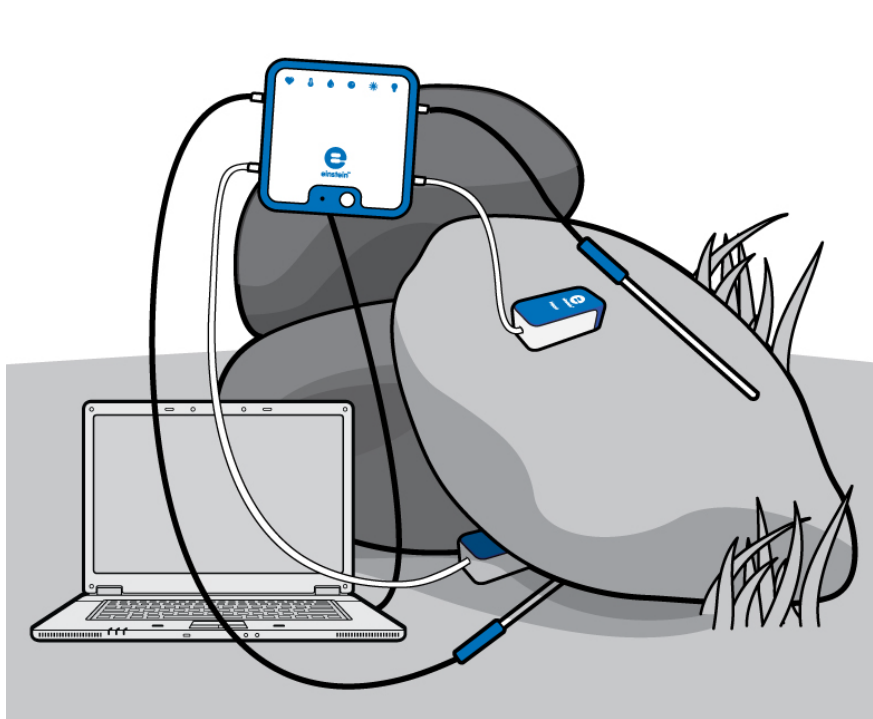


Figure 1



Introduction

Turning over a rock reveals a world teeming with life, consisting of organisms from different classes and families such as worms, arthropods, etc. The rock isolates the area it covers from the surroundings, thus creating relatively stable abiotic conditions. Three main abiotic parameters affect all living organisms: temperature, humidity and light. The intensity of light radiation varies daily and annually with solar radiation.

Radiation striking the rock and winds blowing in the area are the main sources for temperature and humidity fluctuations in the rock and its surroundings. In this experiment we use sensors to perform field measurements comparing temperature and light conditions found below and on the surface of a rock.




Equipment

- einstein™ LabMate and a PORTABLE computer with MultiLab4
- 2 Light Sensors (triple range)
- 2 Temperature Sensors (-40°C to 140°C)
- Adhesive tape
- Tape measure



Equipment Setup

Note: This experiment is performed in the field and the einstein™ LabMate is used detached from an external power source. Therefore, charge the battery prior to going outdoors.

1. Launch MultiLab4 ().
2. Connect the Light Sensors and the Temperature Sensors to ports of the einstein™ LabMate™.
3. Assemble the equipment as illustrated in Figure 1.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Light Sensors and Temperature Sensors are selected under Measurements.

Notes: Dangerous animals such as poisonous snakes and spiders may be present in the habitat being studied.
 Don't place the Light Sensor under the rock.
 Take security and safety precautions when leaving the einstein™ LabMate and computer in the field.







Current Setup Summary

Program the sensors to log data according to the following setup:

Sensor:	Light-150K
Range	0-150 klux
Measurements:	Light-150K (klux)
Sensor:	Temperature (-40°C to 140°C)
Measurements:	Temperature (°C)
Rate:	Every 10 seconds
Samples	500
Duration:	1 hour 23 minutes 20 seconds



Procedure

1. While surveying the area where you are going to perform this experiment, look for a rock with these characteristics:
2. The rock's length and width should be 20 – 40 cm.
3. The rock should not be tightly lodged in the soil.
4. The base should consist of small hollows that can easily support the necessary sensors.
5. It should be exposed to direct light radiation.
2. Turn the rock over and quickly place the Temperature Sensor beneath it.
3. Put the rock back in its initial position.
4. Place the Light Sensor on the ground near, but not under the rock.
5. Attach the additional Temperature Sensor and Light Sensor to the surface of the rock. Use adhesive strips of tape to ensure stable positioning of the sensors.
6. The part of the Temperature Sensor which makes the measurements is located in the tip of the probe. Make sure this part of the probe touches the surface of the rock.
7. Attach the Light Sensor to the rock, pointing in the direction in which maximal readings are obtained.
8. Place your computer and einstein™ LabMate in a stable position.
9. Select **Run** () to begin recording data.
10. While MultiLab is logging data, record additional important information:
 - a. Date and hour of measurements (automatically marked).
 - b. Weather conditions.
 - c. Type of site: open field, forest, etc.
 - d. Changes or events occurring during the measurements such as sudden winds, showers, cloud movements and animal movements.
 - e. Any other pertinent information such as recent timber cutting or construction activities
 - f. You can record this information using **notes** () from the Work Space menu bar.
11. After 45 minutes to an hour, when sufficient data is collected, select **Stop** () to stop recording data.
12. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs see: Working with Graphs in MultiLab4

1. Mark the course of changes in temperature and light intensity occurring on the surface and beneath the rock. Use the cursors to find the appropriate values.
2. Compare the temperature changes:
 - a. Beneath the rock.
 - b. On the surface of the rock.
3. Compare the light changes:
 - a. Beside the rock.
 - b. On the surface of the rock.



Questions

1. Are the conditions observed beneath the rock significantly different from those on the surface of the rock? Support your arguments with data.
2. Is there any connection between the conditions observed beneath the rock and the abiotic conditions in the surroundings? Explain your answer.
3. How is light related to the temperature & humidity changes you measured?



Further Suggestions

1. Compare abiotic conditions found beneath rocks located in different areas such as open fields, mountainous areas, and forests.
2. Compare abiotic conditions found beneath rocks during different seasons.

Measuring Abiotic Conditions in a Habitat beneath a Rock using Humidity and Temperature Sensors

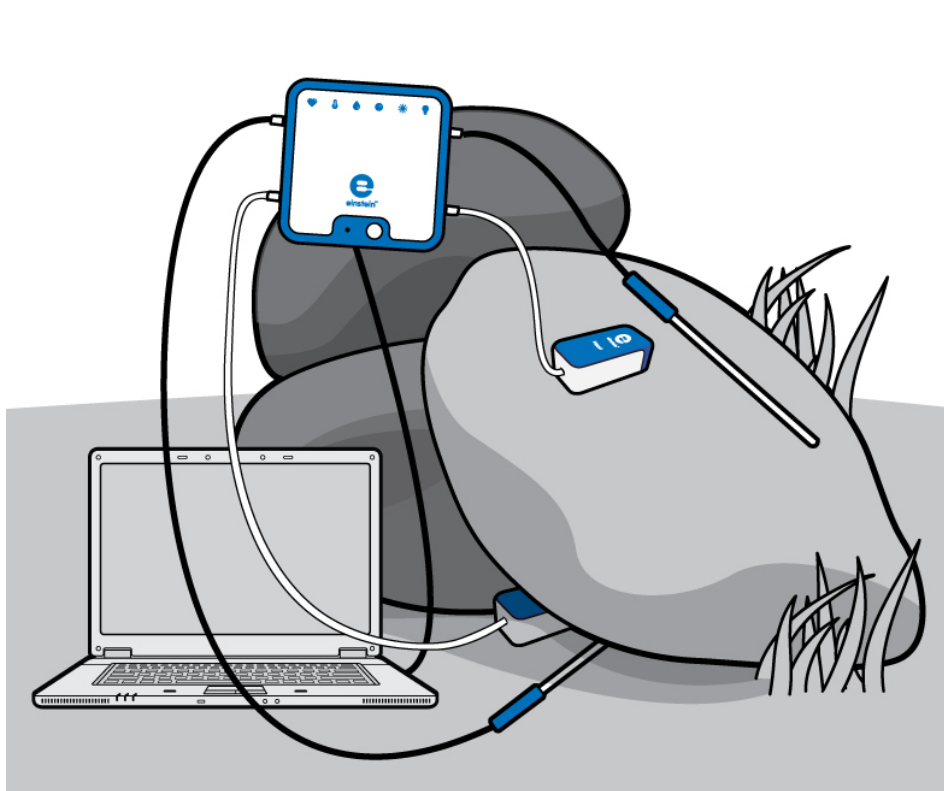


Figure 1



Introduction

Turning over a rock reveals a world teeming with life, consisting of organisms from different classes and families such as worms, arthropods, etc. The rock isolates the area it covers from the surroundings, thus creating relatively stable abiotic conditions. Three main abiotic parameters affect all living organisms: temperature, humidity and light. The intensity of light radiation varies daily and annually with solar radiation.

Radiation striking the rock and winds blowing in the area are the main sources for temperature and humidity fluctuations in the rock and its surroundings.

In this experiment we use sensors to perform field measurements comparing temperature and humidity levels found beneath and on the surface of a rock.




Equipment

- einstein™ LabMate and a PORTABLE computer with MultiLab4
- 2 Humidity Sensors
- 2 Temperature Sensors (-40°C to 140°C)
- Adhesive tape
- Tape measure

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Equipment Setup

Note: This experiment is performed in the field and the einstein™ LabMate is used detached from an external power source. Therefore, charge the battery prior to going outdoors.

1. Launch MultiLab4 ().
2. Connect the Humidity Sensors and the Temperature Sensors to ports of the einstein™ LabMate.
3. Assemble the equipment as illustrated in Figure 1.
4. In the Current Setup Summary window choose Full Setup and use the table below to set up the experiment. Make sure that only the Humidity Sensors and Temperature Sensors are selected under Measurements.

Note: Dangerous animals, such as poisonous snakes and spiders may be present in the habitat being studied. Take security and safety precautions when leaving the computer and einstein™ LabMate in the field.



Current Setup Summary





Program the sensors to log data according to the following setup:

Sensor:	Humidity
Measurements:	Humidity (%)
Sensor:	Temperature (-40-140 °C)
Measurements:	Temperature (°C)
Rate:	Every 10 seconds
Samples	1000
Duration:	2 hours 46 minutes 40 seconds

Note: Ensure that only the external Temperature Sensor (-40-140 °C) and external Humidity Sensor are selected and not the internal Temperature Sensor (-30-50 °C) and internal Humidity Sensor.



Procedure

1. While surveying the area where you are going to perform this experiment, look for a rock with these characteristics:
 - a. The rock's length and width should be 20 – 40 cm.
 - b. The rock should not be tightly lodged in the soil.
 - c. The base should consist of small hollows that can easily support the necessary sensors.
 - d. It should be exposed to direct light radiation.
2. Turn over the rock and quickly place the Temperature Sensor beneath it. Make sure to return the rock to its initial position.
3. Place the Humidity Sensor on the ground near but not under the rock.
4. Attach the additional Humidity Sensor and Temperature Sensor to the top of the rock. Use adhesive strips of tape to ensure stable positioning of the sensors.
5. The part of the Temperature Sensor which makes the measurements is located in the tip of the probe. Make sure this part of the probe touches the surface of the rock.
6. Place the computer and einstein™ LabMate in a stable position.
7. Select **Run** () to begin recording data.
8. While MultiLab is logging data, record additional important information:
 - a. Date and hour of measurements (automatically marked).
 - b. Weather conditions.
 - c. Type of site: Open field, forest, etc.
 - d. Changes or events occurring during the measurements such as sudden winds, showers, cloud movements, and animal movements.
 - e. Any other pertinent information such as recent timber cutting or construction activities.
 - f. You can record this information using **notes** () from the Work Space menu bar.
9. When sufficient data is collected, select **Stop** () to stop recording data.
10. Save your data by selecting **Save** () from the Basic Tools window on the upper menu bar.



Data Analysis

For more information on working with graphs, see: Working with Graphs in MultiLab4

1. Mark the course of changes in temperature and light intensity occurring on the surface and beneath the rock.
2. Use the cursors to find the appropriate values.
3. Compare the temperature changes:
 - a. Beneath the rock.
 - b. On the surface of the rock.
4. Compare the humidity changes:
 - a. Beneath the rock.
 - b. On the surface of the rock.



Questions

1. Are the conditions found beneath the rock significantly different from those on the surface of the rock? Support your arguments with data.
2. Is there any connection between the conditions found beneath and on the surface of the rock and the abiotic conditions in the surroundings? Explain your answer.
3. How is light related to the temperature and humidity changes you measured?



Further Suggestions

1. Compare abiotic conditions found beneath rocks located in different areas such as open fields, mountainous areas, and forests.
2. Compare abiotic conditions found beneath rocks during different seasons.



www.einsteinworld.com



USA

8940 W. 192nd St.
Unit I
Mokena
IL 60448
Tel: (877) 266-4066

Israel

16 Hamelacha St.
POB 11681
Rosh Ha'ayin 48091
Tel: +972-3-901-4849
Fax: +972-3-901-4999

www.FourierEdu.com

Info@fourierEdu.com

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