



# Experiments in Biology

for MiLAB™



imagine • explore • learn  
[www.einsteinworld.com](http://www.einsteinworld.com)

# Table of Contents

Experiments by Sensors	4
Preface	8
1. Transpiration: Evaporation of Water from Terrestrial Plants	18
2. Water Transport in Shoots and Leaves of Terrestrial Plants	23
3. Measuring the Photosynthesis Rate in Aquatic Plants - Elodea	30
4. Measuring the Photosynthesis Rate: Using an Oxygen Sensor	35
5. Effect of Light on the Photosynthesis Rate	39
6. Effect of Light on the Photosynthesis Rate: Using an Oxygen Sensor	45
7. Effect of Bicarbonate on the Photosynthesis Rate – Using Pressure Sensors	50
8. Measurement of Glucose Synthesis during Photosynthesis	55
9. Effect of Light on Chlorophyll Levels in Plant Leaves	60
10. Respiration Rate of Germinating Seeds	64
11. Measurement of CO <sub>2</sub> Released during Respiration of Germinating Seeds	68
12. Biological Catalysis: Decomposition of H <sub>2</sub> O <sub>2</sub> in Presence of the Enzyme, Catalase	71
13. Effect of Enzymes on Food: Degradation of Egg White Proteins in the Presence of Pepsin	76
14. Alcoholic Fermentation in Yeast	80
15. Effect of Temperature on the Permeability of Cell Membranes: Release of the Pigment Anthocyanin from Beets	85
16. pH Measurements in Tissue Extracts	89
17. Acidification of Milk	92
18. Regulation of Human Body Temperature - Loss of Heat Through Sweat Production: Clay Jugs - A Model System	95
19. Regulation of Human Body Temperature - Loss of Heat Through Sweat Production: Heat Loss Measured at the Fingertips With Humidity and Temperature Sensors	99

20. Regulation of Human Body Temperature - Loss of Heat Through Sweat Production: Heat Loss Measured at the Fingertips with Temperature	102
21. Effect of Exercise on the Human Body: Temperature and Heart Rate	105
22. Amount of CO <sub>2</sub> Exhaled in Human Respiration	108
23. EKG at Rest and after Activity	112
24. Impact of Crowded Urban Areas on Microclimate	117
25. Influence of Natural Ventilation on the Indoor Climate	121
26. An Examination of the Thermal Insulation of a Building Envelope	124
27. Measuring Abiotic Conditions in a Habitat Beneath a Rock using Light and Temperature Sensors	127
28. Measuring Abiotic Conditions in a Habitat Beneath a Rock using Humidity and Temperature Sensors	131

# Experiments by Sensors



## Colorimeter

8. Measurement of Glucose Synthesis during Photosynthesis	55
9. Effect of Light on Chlorophyll Levels in Plant Leaves	60
13. The Effect of Enzymes on Food: Degradation of Egg White Proteins in the Presence of Pepsin	76
15. Effect of Temperature on the Permeability of Cell Membranes: Release of the Pigment Anthocyanin from Beets	85



## CO<sub>2</sub>

11. Measurement of CO <sub>2</sub> Released during Respiration of Germinating Seeds	68
22. Amount of CO <sub>2</sub> Exhaled in Human Respiration	108



## EKG

23. EKG at Rest and after Activity	112
------------------------------------	-----



## Heart Rate

21. Effect of Exercise on the Human Body: Temperature and Heart Rate	105
--	-----





## Humidity

18. Regulation of Human Body Temperature - Loss of Heat Through Sweat Production: Clay Jugs - A Model System	95
19. Regulation of Human Body Temperature - Loss of Heat Through Sweat Production: Heat Loss Measured at the Fingertips With Humidity and Temperature Sensors	99
24. Impact of Crowded Urban Areas on Microclimate	117
25. Influence of Natural Ventilation on the Indoor Climate	121
28. Measuring Abiotic Conditions in a Habitat Beneath a Rock using Humidity and Temperature Sensors	131



## Light

5. Effect of Light on the Photosynthesis Rate	39
6. Effect of Light on the Photosynthesis Rate: Using an Oxygen Sensor	45
27. Measuring Abiotic Conditions in a Habitat Beneath a Rock using Light and Temperature Sensors	127



## OXYGEN

4. Measuring the Photosynthesis Rate: Using an Oxygen Sensor	35
5. Effect of Light on the Photosynthesis Rate	39



13. Effect of Enzymes on Food: Degradation of Egg White Proteins in the Presence of Pepsin	76
14. Alcoholic Fermentation in Yeast	80
16. pH Measurements in Tissue Extracts	89
17. Acidification of Milk	92
22. Amount of CO <sub>2</sub> Exhaled in Human Respiration	108

## 

1. Transpiration: Evaporation of Water from Terrestrial Plants	18
2. Water Transport in Shoots and Leaves of Terrestrial Plants	23
3. Measuring the Photosynthesis Rate in Aquatic Plants - Elodea	30
5. Effect of Light on the Photosynthesis Rate	39
7. Effect of Bicarbonate on the Photosynthesis Rate – Using Pressure Sensors	50
10. Respiration Rate of Germinating Seeds	64
12. Biological Catalysis: Decomposition of H <sub>2</sub> O <sub>2</sub> in Presence of the Enzyme, Catalase	71
14. Alcoholic Fermentation in Yeast	80

## 

23. EKG at Rest and after Activity	112
------------------------------------	-----

## 

26. An Examination of the Thermal Insulation of a Building Envelope	124
---	-----



## Temperature (-40°C to 140°C)

4. Measuring the Photosynthesis Rate: Using an Oxygen Sensor	35
6. Effect of Light on the Photosynthesis Rate: Using an Oxygen Sensor	45
7. Effect of Bicarbonate on the Photosynthesis Rate – Using Pressure Sensors	50
13. The Effect of Enzymes on Food: Degradation of Egg White Proteins in the Presence of Pepsin	76
15. Effect of Temperature on the Permeability of Cell Membranes: Release of the Pigment Anthocyanin from Beets	85
18. Regulation of Human Body Temperature - Loss of Heat through Sweat Production: Clay Jugs - A Model System	95
19. Regulation of Human Body Temperature - Loss of Heat Through Sweat Production: Heat Loss Measured at the Fingertips With Humidity and Temperature Sensors	99
20. Regulation of Human Body Temperature - Loss of Heat Through Sweat Production: Heat Loss Measured at the Fingertips with Temperature	102
21. Effect of Exercise on the Human Body: Temperature and Heart Rate	105
24. Impact of Crowded Urban Areas on Microclimate	117
26. Influence of Natural Ventilation on the Indoor Climate	121
27. Measuring Abiotic Conditions in a Habitat Beneath a Rock using Light and Temperature Sensors	127
28. Measuring Abiotic Conditions in a Habitat Beneath a Rock using Humidity and Temperature Sensors	131

# Preface

This book contains 28 student experiments in Biology that can be conducted using MiLab and einstein™ Sensors. MiLab can be accessed from the main menu of an einstein™Tablet and is also available as a free app for any Android or IOS Tablet for use with an einstein™LabMate™.

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 sensors (see page 5).

## einstein™ and LabMate Devices

### einstein™

The einstein™Tablet includes the following:

#### 8 built-in sensors:

- Heart Rate
- Light
- Relative Humidity
- Temperature
- UV
- GPS
- Microphone (sound)
- G-sensor (accelerometer)

#### + 4 ports for external sensors:

### einstein™LabMate

The einstein™LabMate includes the following:

#### 6 built-in sensors:

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

#### + 4 ports for external sensors

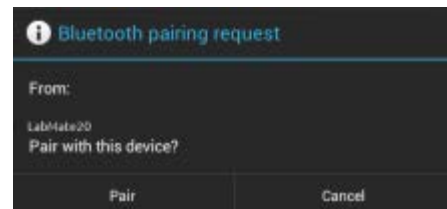
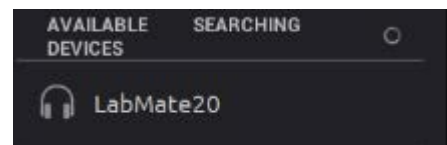
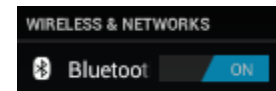
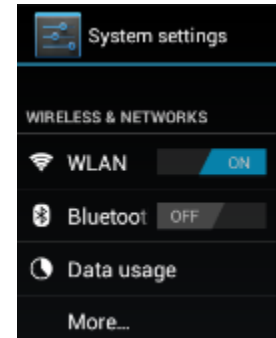
External sensors can be connected to either of these devices by inserting the sensor cable into one of their sensors ports.

## Using the einstein™LabMate

To use MiLAB on a non-einstein™ device, one must first pair with an einstein™LabMate via Bluetooth.

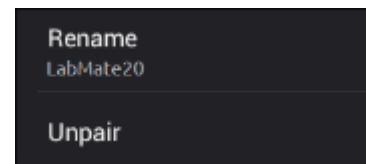
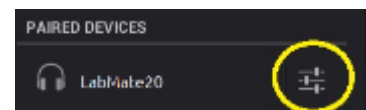
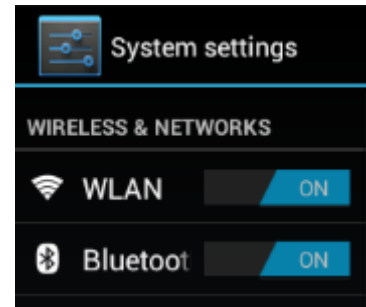
### Pairing:

1. Make sure the einstein™LabMate is on and not paired with any other device.
2. Select Main Menu on your tablet, and then select System Settings.
3. Select the Bluetooth OFF/ON button to turn the Bluetooth ON.
4. Once the Bluetooth setting is ON, the device will begin searching for Bluetooth devices.
5. Once the einstein™LabMate is discovered, it will appear in the list of discoverable devices.
6. Select the einstein™LabMate to pair. Your device will show a quick pairing message, followed by a Bluetooth pairing request.
7. Select Pair to approve the pairing process.
8. Once successfully paired, the LabMate will appear under paired devices.
9. NOTE: Please be patient. As every device is different, the pairing time can vary from a few seconds to a few minutes.



## Unpairing

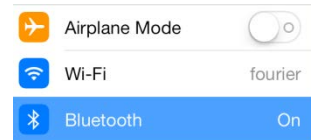
1. Select Main Menu on your tablet, and then select System Settings.
2. Select the icon next to LabMate that is listed under Paired Devices.
3. A new window will appear showing, Rename and Unpair. Select Unpair.



## Pairing with an iOS device

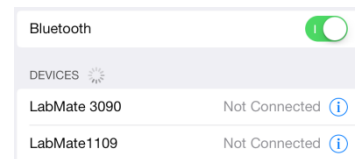
1. Make sure the LabMate™ is on and not paired with any other device.
2. Select Settings

3. Select the Bluetooth OFF/ON to turn the Bluetooth ON.



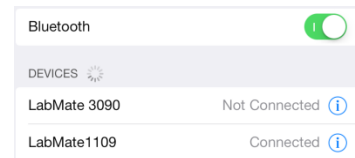
4. Once the Bluetooth setting is ON, the device will begin searching for Bluetooth devices.

5. Once the einstein™LabMate is discovered, it will appear in the list of discoverable devices.



6. Select the einstein™LabMate to connect.

7. Once successfully paired, the word Connected will appear next to the einstein™LabMate



## Unpairing

1. Select Settings
2. Select the paired einstein™LabMate.



## Working with Graphs in MiLAB

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

### Understanding Graphs

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

By default graphs in MiLAB automatically scale which means you can see the entire graph displayed.

To zoom in on one part of the graph touch the screen and spread 2 fingers.

To zoom back out pinch two fingers together.



Pinch to Zoom out



Spread to Zoom in

**Note:** You can also spread and pinch along the x or y-axis to zoom in or out on these axes.

Double tap on the graph to return to the original auto scale graph.

You can also move the graph or axes by touching and dragging them.

### Analyzing a Graph

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

To analyze a graph:

- Run an Experiment.
- In order to use MiLAB's analysis functions you must select at least one point on the graph – this is known as a cursor. Many functions require two cursors.

**Note:** if you are using more than one sensor, both points must be on the same sensor's graph line.

## Working with Cursors

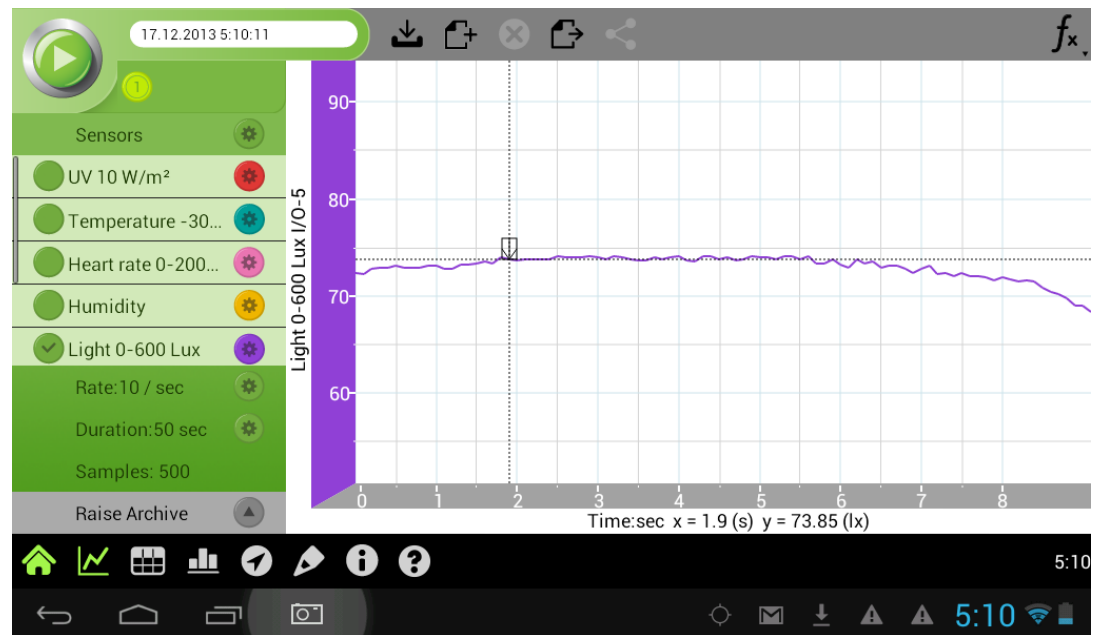
You can display up to two cursors on the graph simultaneously.

Use one cursor to display individual data recording values, to select a curve or to reveal a hidden Y-axis if using 3 or more sensors.

Use two cursors to analyze the data in the graph.

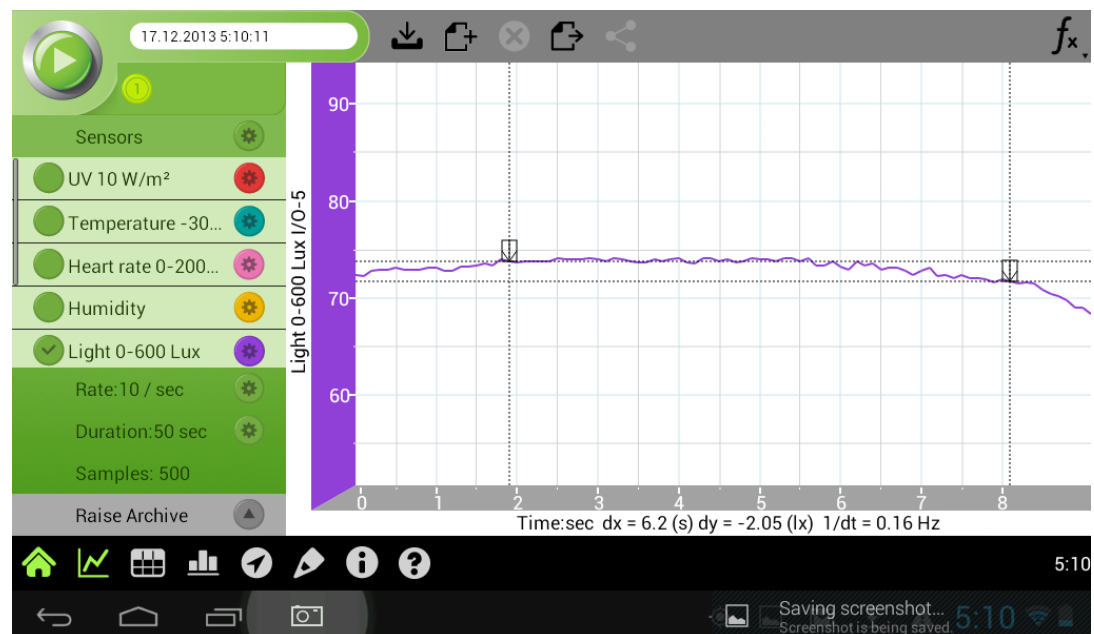
### To display the first cursor:

In graph view, tap any point on a plot line. MiLAB will now display the coordinate values.



### To display the second cursor:

Once the first cursor is placed, tap any point on the same plot line.



When there are 2 data points selected; the differences between the 2 points will appear at the bottom of the graph window.

- dx refers to the value between the X axis of the 2 points.
- dy refers to the value between the Y axis of the 2 points.

#### Moving the cursor

- Touch and hold a cursor then drag it left and right on a single plot line
- Tap the plot line of a different sensor to move the cursor to that plot line.

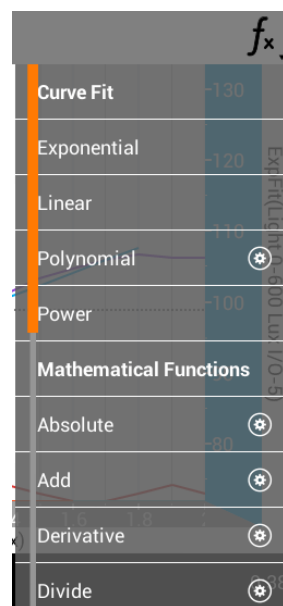
#### To remove the cursors:

- Tap and hold a cursor, flick it quickly off the screen in any direction.  
The cursor will disappear from the plot line

## Working with Functions

Once you have selected a cursor, this will activate the Functions button ( $f_x$ ).

Touch the Functions button to access the list of tools available to you.



Touch one of these to apply the function.

After you select a function a new plot line will appear on the graph displaying the results.

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

- Place two cursors on one of the plot lines.
- Select the Function button ( $f_x$ ).
- Select the Setup button (⚙️) next to the desired function.
- In the Setup menu G1 will be the plot line you selected.

Math Functions

Name: Sub(UV 10 W/m² I/O-1 - UV 10 W/m² I/O-1)

Unit: W/m²

(A \* G1) - (B \* G2)

G1: UV 10 W/m² I/O-1 A: 1

G2: UV 10 W/m² I/O-1 B: 1

Cancel OK

- Use the G2 dropdown menu to select the plot line you would like to compare it to.
- Touch **Okay**.
- A new plot line will appear on the graph displaying the results.



## Experiment 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
- **Data Logger Setup:** Recommended setup
- **Procedure:** Step-by-step guide to executing the experiment including:
- **Data Analysis**
- **Questions**
- **Further Suggestions**


## Sealing

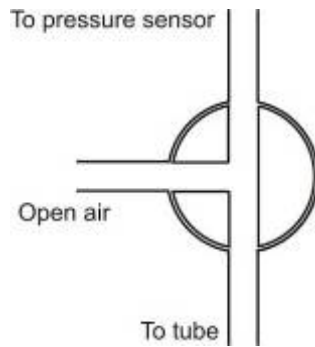
Many of the experiments in this book, especially those involving pressure measurements are dependent on the flasks or test tubes being tightly sealed. Following is a guide to ensure that these experiments run smoothly.

**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.

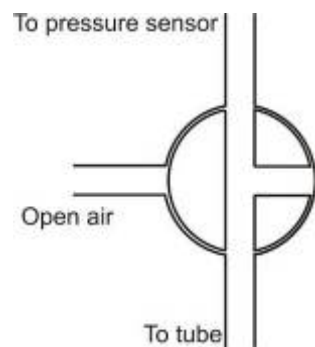
Once you have sealed the flask or test tube, you can test the seal.

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 surrounding (Position A – see Figure 1).  
The readings should now indicate the atmospheric pressure.



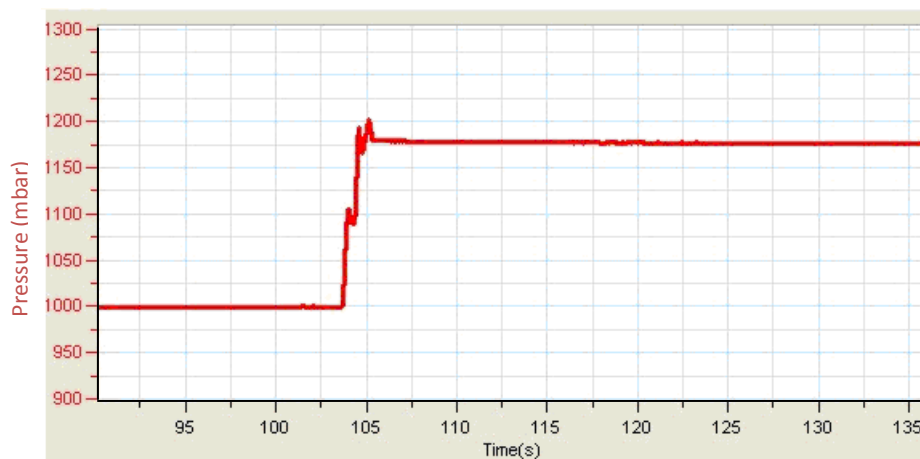
**Figure 1: Three-way valve – Position A**

3. (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**

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



**Figure 3**

5. 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.

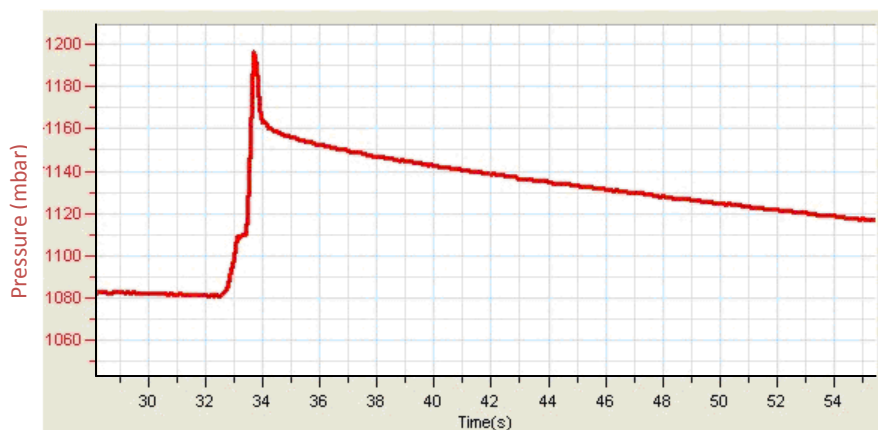



Figure 4

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

## MiLAB setup

When using an einstein™Tablet – select the MiLAB icon (  ) on the application desktop.

When using an Android or IOS Tablet, you must first pair the Tablet with the einstein™LabMate (through Bluetooth). Once the einstein™LabMate is paired with the Tablet, you can start MiLAB.

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 MiLAB™ screen should match that on the underside of your einstein™LabMate device.

# Transpiration: Evaporation of Water from Terrestrial Plants

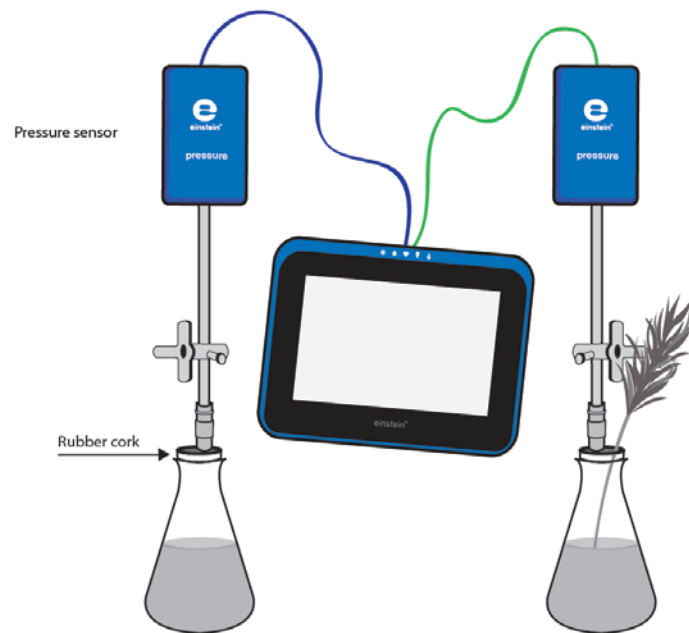


Figure 1



## 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, 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 evaporates from the leaves the amount of air in the flask will decrease leading to a reduction in pressure (in accordance with Boyle's Law). This reduction will be recorded by the Pressure Sensor.






## Equipment

- einstein™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- 2 Pressure Sensors (150 – 1150 mbar)
- 2 sensor cables
- 2X 250 ml glass flask
- 1 rubber stopper with hole
- 1 rubber stopper with two holes
- Piece of modeling clay (optional)
- 2 syringe extenders\*
- 2 three-way valves\*

\* contained in the einstein™ Pressure Kit



## Equipment Setup

1. Launch MiLAB (  ).
2. Connect the Pressure Sensors to the ports on the einstein™Tablet or einstein™LabMate
3. Make sure that only the Pressure sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.
5. Perform the experiment in an aerated and well-lit room. If possible, place the experiment close to a window.
6. Select a shoot of a tree or bush whose leaves have a large surface area (either many small leaves or several big leaves).
7. Fill two 250 ml flasks with water. Make sure the flask is filled with water leaving only a 1mm gap at the top.
  - a. Insert the shoot of a tree or bush into one of the flasks.
  - b. Insert a syringe extender into both stoppers (Figure 2).
  - c. Attach three-way valves to the other end of the syringe extenders.
  - d. Make sure the flasks are completely sealed; you may need to use clay or other materials to complete the seal.
  - e. Connect a Pressure Sensor to the valve.
  - f. Turn the valve until its opening is directed vertically. In this position air can flow through the valve.

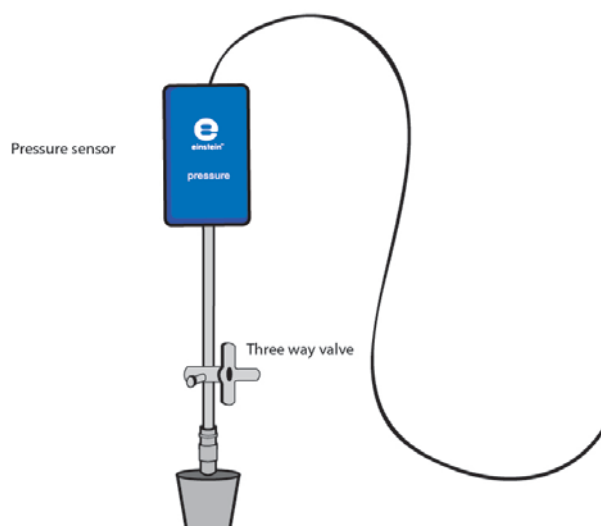


Figure 2



## Data Logger Setup

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

Pressure (150 – 1150 mbar)	
Rate:	Every 1 sec
Duration:	20000 sec





## Procedure

### Checking the experiment setup:

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

### Performing the experiment:

Reset the apparatus. Turn the three-way valves to position A, and then return to position B (see Figures 3 and 4). The pressure in the tubes should now equal the atmospheric pressure.

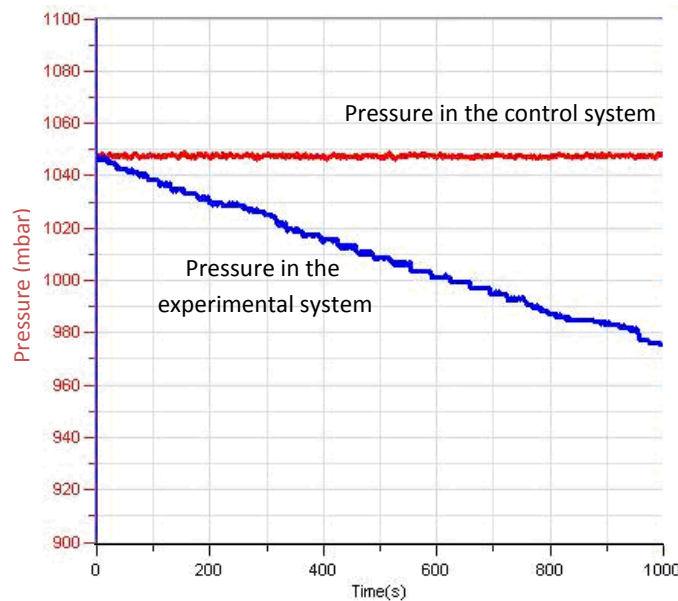
1. Select **Run** (  ).
2. Follow the pressure recorded on the screen.
3. Insert the shoot into one of the flasks through the hole in the stopper until it almost touches the flask's bottom. (Seal with clay or other material if necessary).
4. Run the experiment at least 25 min.
5. Save your data by selecting **Save** (  ).

## Data Analysis

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

1. To calculate the Transpiration rate you'll need to create a difference graph.
2. Save the graph.
3. Select the graph of Input 1 (the control flask) then select the lowest point of Input 2.
4. Select **Functions** ( $f_x$ ).
  - a. Select **Subtract** from the **Functions** dropdown menu.
  - b. In the **G1** drop down menu select **Pressure -1**. In the **G2** drop down menu select **Pressure -2**.
  - c. In the **Name** edit box enter a name (e.g. Difference).
  - d. Click **OK**
5. Apply a linear fit to the graph:
  - a. Select the difference graph
  - b. Select **Linear fit** from the **Functions** dropdown menu. The fit equation will be displayed below the x-axis.
  - c. 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?
  - a. Why is a control flask necessary in the experiment?
  - b. What is the effect of light on the rate of transpiration during the experiment?  
Would you expect similar changes in the dark?
1. What would be the effect of an increase in humidity on the rate of water suction? Explain your answer.
2. Why is a shoot with a large surface area of leaves necessary for this experiment?
3. What is the source of water loss in this experiment?
4. 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 rate of water loss: Use shoots of different sizes and numbers of leaves.

# Water Transport in Shoots and Leaves of Terrestrial Plants

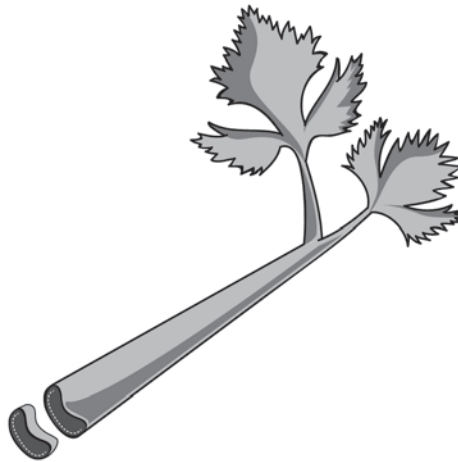


Figure 1



## 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** - 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 out the 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  $\text{CO}_2$  is needed for photosynthesis. During the day the stomata open allowing the plant to “breathe in”  $\text{CO}_2$ . 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 leaf (*Apium graveolens*) as it absorbs water colored with methylene blue.

The extent of water loss in transpiration is followed by measuring water intake by a shoot of *Nerium oleander* inserted into a flask full of water. Evaporation of water from the leaf leads to suction of the water from the flask. The suction of the water continuously increases the air volume 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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 2 Pressure Sensors (150 – 1150 mbar)
- 2 sensor cables
- 5X250 ml glass flasks
- 2 rubber stoppers with 2 holes each
- Piece of modeling clay
- 2 syringe extenders\*
- 2 latex tubes\*
- 2 three-way valves\*
- Magnifying glass
- Plastic knife
- 20 cm ruler
- Celery Leaf
- 1% methylene blue

\*contained in einstein™ Pressure Kit

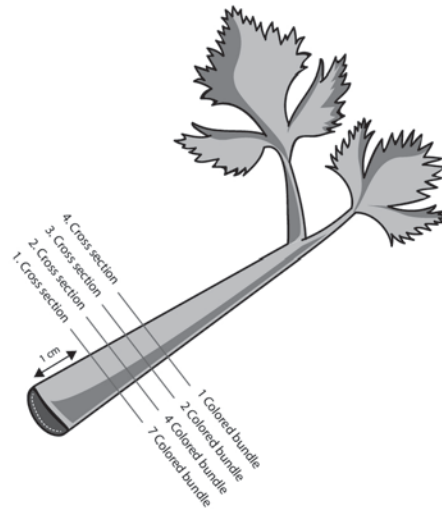
## Part 1: Water circulation in celery leaves



## Procedure

Pour 100 ml of 1% methylene blue solutions into three 250 ml flasks. Number them: 1-3.

1. Divide the celery stalk into 3 strips. Each strip should begin 1 cm from the bottom of the stalk and include an equal number and type of leaves - preferably the younger inner leaves, and the stalk cm of the stalk.
2. Observe the cross section under a magnifying glass. Try to identify the xylem tubes (see Figure 1).
3. Place one strip in each flask.
4. Wait five minutes, and then take one stalk out of the solution. Dry off excess color.
5. 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.
6. Repeat the procedure until you reach a section without colored bundles (see Figure 2).
7. Wait 10 minutes, take out the second stalk. Cut cross sections and check them under the magnifying glass as performed in steps 5 and 6. Count the number of xylem bundles you observe in the section.
8. After 20 minutes take out the third leaf and repeat steps 5 and 6.



**Figure 2**

9. Prepare a table to display your results:


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

10. Calculate the average height the color has reached in each stalk.
11. 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
  - d. 3 cm X five bundles = 15
12. Sum up the total height in all the sections: 32
13. Divide it by the total number of bundles: 9
14. The average height reached by the water after 5 minutes was 3.5 cm.
15. 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 MiLAB (  ).
  - a. Connect the Pressure Sensors to the ports on the einstein™Tablet or einstein™LabMate.
  - b. Make sure that only the Pressure Sensors are selected.
2. Assemble the equipment as illustrated in Figure 3.
3. Perform the experiment in an aerated and well-lit room. If possible, place the experimental systems close to the window.
4. Choose a shoot of a tree or a bush with a large surface area of leaves (containing a high number of small leaves or big leaves). The surface of the shoot should be smooth and cylindrical, to ensure a tight fit in the stopper.
5. Fill the two 250 ml flasks with water.
6. Insert the shoot of a tree or bush into the flask.
7. Insert a syringe extender into the stopper (Figure 4).
8. Attach a three-way valve to the syringe extender
9. Make sure the flasks are completely sealed, you may need to use clay or other material
10. Connect a Pressure Sensor to the valve through another short latex tube.
11. Turn the valve until its opening is directed vertically. In this position air can flow through the valve.

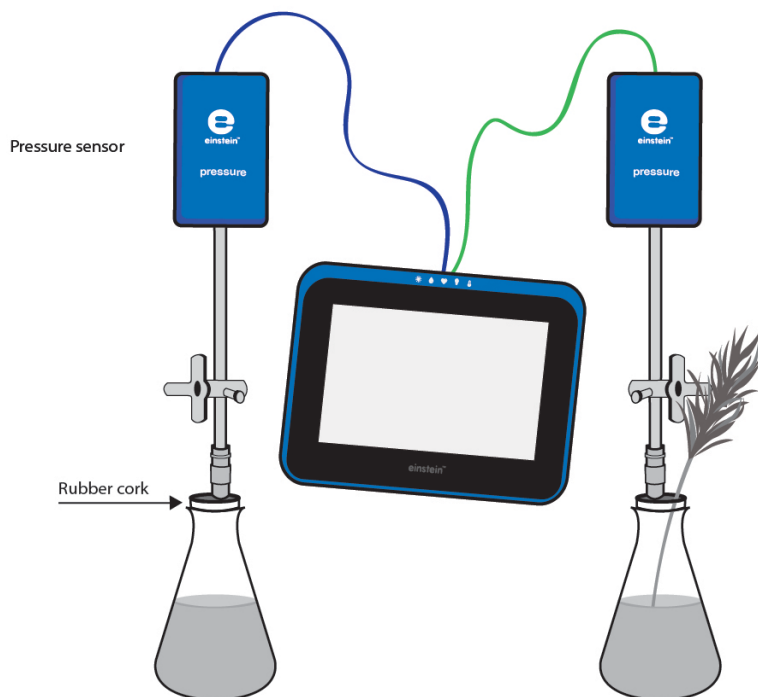


Figure 3

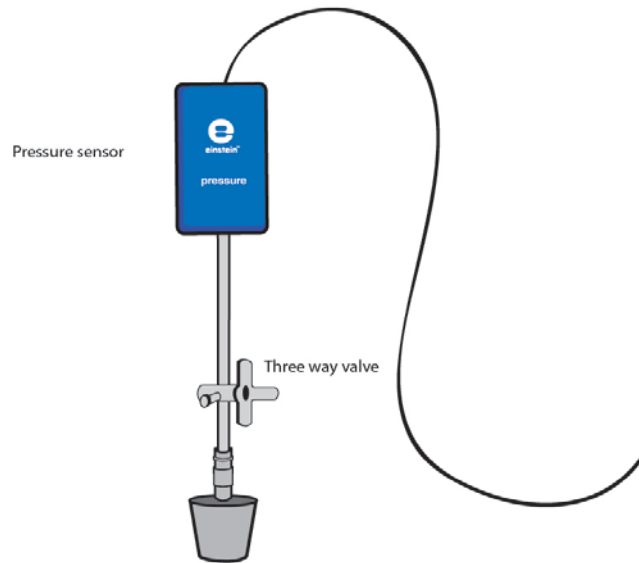


Figure 4



## Data Logger Setup

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

---

**Pressure (150 – 1150 mbar)**

---

Rate: Every 1 sec

---

Duration: 20000 sec

---





## Procedure

### Checking the experiment setup:

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

### Performing the experiment:

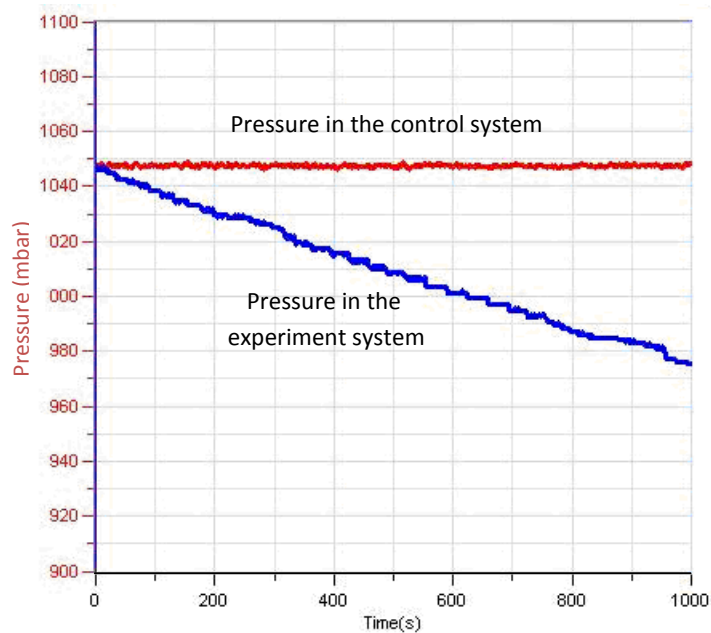
1. Reset the apparatus. Turn the three-way valves to position A, and then return to position B (see Figures 5 and 6). The pressure in the flasks should now equal the atmospheric pressure.
2. Select **Run** (  ).
3. Follow the pressure recorded on the screen.
4. Insert the shoot into one of the flasks through the hole in the stopper until it almost touches the flask's bottom. Make sure to reseal the flask – you may need to use clay or other material.
5. Close the second flask with the other stopper.
6. Save your data by Selecting **Save** (  ).

## Data Analysis

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

1. To calculate the Transpiration rate you'll need to create a difference graph.
2. Save the graph.
3. Select the graph of Input 1 (the control flask) then select the lowest point of Input 2.
4. Select **Functions** ( $f_x$ )
  - a. Select **Subtract** from the **Functions** dropdown menu
  - b. In the G1 drop down menu select Pressure -1. In the G2 drop down menu select Pressure -2.
  - c. In the Name edit box enter a name (e.g. Difference).
5. Apply a linear fit to the difference graph:
  - a. Select the difference graph
  - b. Select **Linear fit** from the **Functions** dropdown menu. The fit equation will be displayed below the x-axis.
  - c. 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

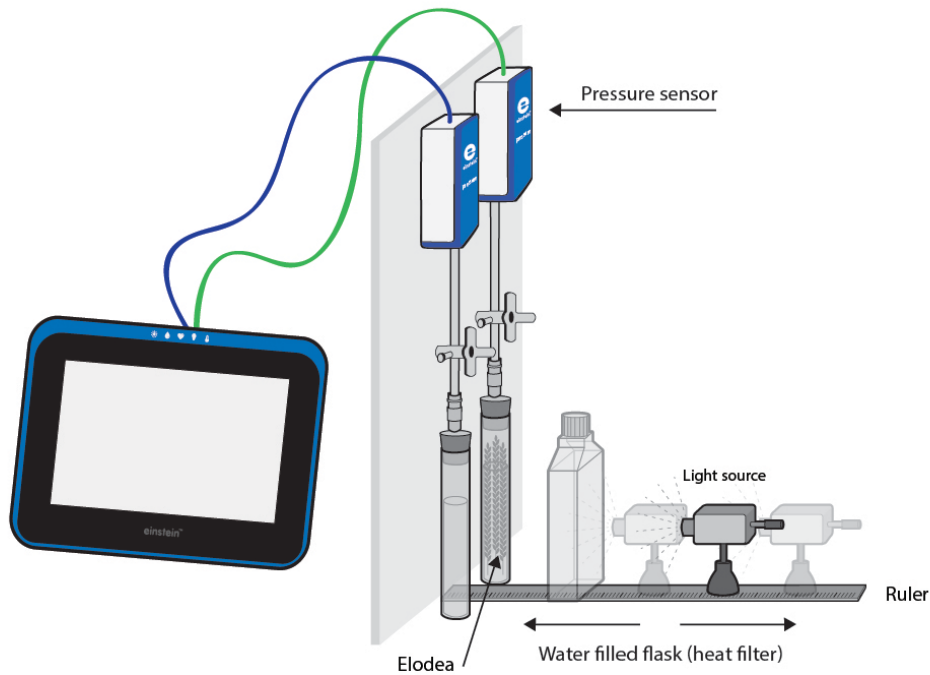


Figure 1

## Introduction

Most plant life is dependent on photosynthesis to survive. This process uses the energy from light to turn Carbon Dioxide ( $\text{CO}_2$ ) and water into carbohydrates. In this process molecular oxygen is released. 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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 2X50 ml glass test tubes with stoppers
- 2 syringe extenders\*
- 2 three-way valves\*
- Latex tube\*
- Perspex stand to support tubes and sensors
- 600 ml flat plastic bottle (heat filter)
- 2 Pressure Sensors (150-1150 mbar)
- 2 sensor cables
- 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



## 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 tubes
  - 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 a syringe extender into the stopper (Figure 2)

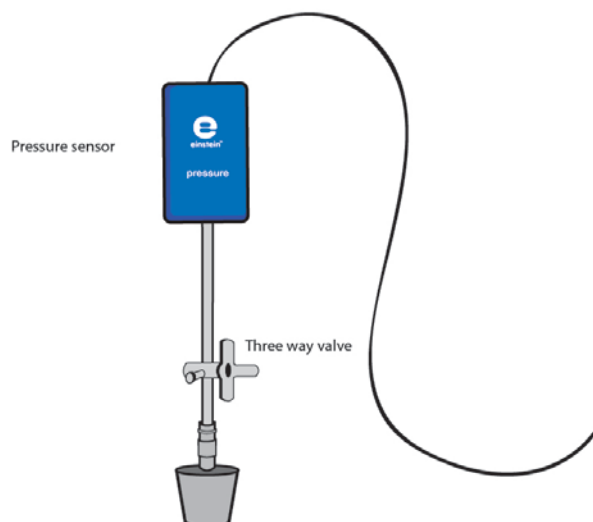



Figure 2

- f. Attach a three-way valve to the other end of the syringe extender
- g. Connect a Pressure Sensor to the valve.
- h. Turn the valve until its opening is directed vertically. In this position, air can flow through the valve.

- i. Position the light source 25 cm from the glass test tubes (see Figure 1).
  - j. Fill the flat plastic bottle with water and place it between the light source and the test tubes. The water blocks the heat that radiates from the light source.
2. Launch MiLAB ()
3. Connect the Pressure Sensors to the ports on the einstein™Tablet or einstein™LabMate
4. Make sure only the Pressure sensors are selected



## Data Logger Setup

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

Pressure (150 – 1150 mbar)	
Rate:	Every 1 sec
Duration:	5000 sec






## Procedure

### Checking the experiment setup

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

### Performing the experiment

1. Reset the apparatus. Turn the three-way valves to position A, and then return to position B (see Figures 3 and 4). The pressure in the tubes should now equal the 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** ()
6. Save your data by Selecting **Save** ()



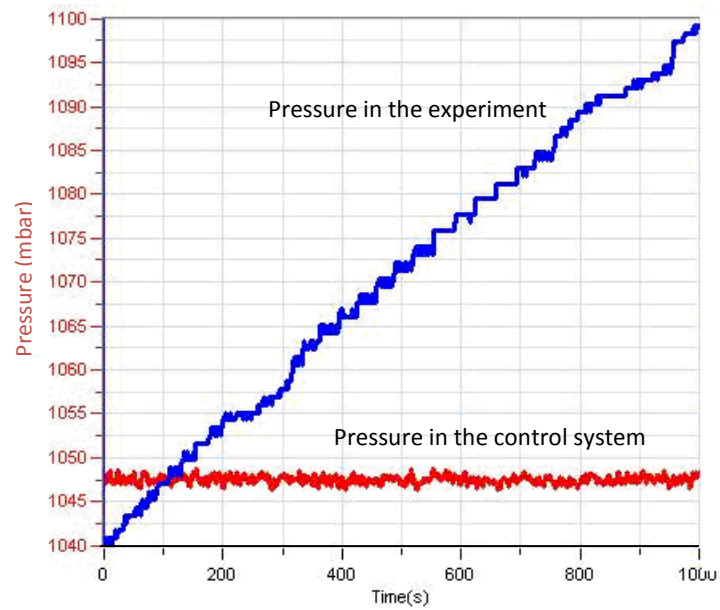
## Data Analysis

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

1. To calculate the Transpiration rate you'll need to create a difference graph.
2. Save the graph
3. Select the graph of Input 1 (the control flask) then select the lowest point of Input 2.
4. Select **Functions**
  - a. Select **Subtraction** from the **Functions** dropdown list.
  - b. In the **Functions** drop down menu select **Subtract**.
  - c. In the **G1** drop down menu select **Pressure -1**. In the **G2** drop down menu select **Pressure -2**.
  - d. In the **Name** edit box enter a name (e.g. Difference).
5. Apply a linear fit to the difference graph:
  - a. Use the First cursor and the Second cursor by tapping on the screen. Then, select the desired range. (To remove the cursor, select and quickly flick it off the screen in any direction)
  - b. Select **Linear fit**. The fit equation will be displayed below the x-axis.
  - c. The slope of the fit line is the net reaction rate.

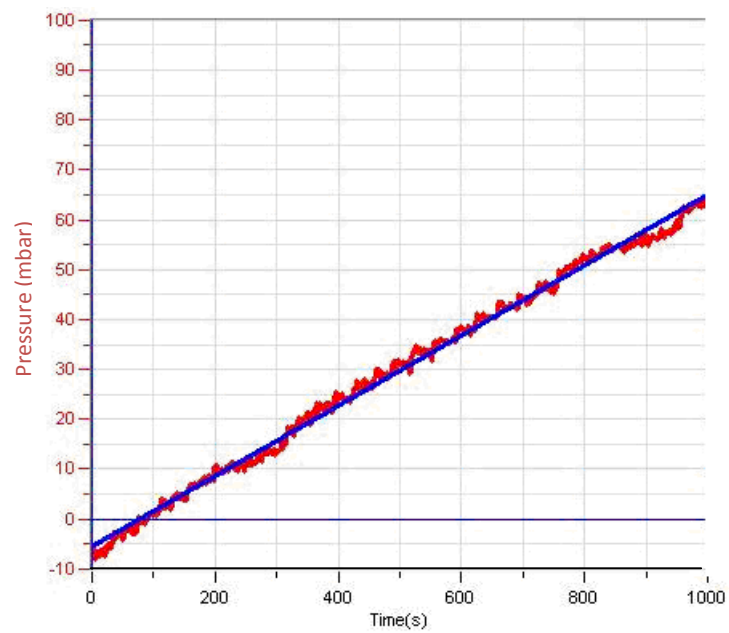


An example of the graph, obtained in this experiment is shown below:



**Figure 7**

In the following graph, the difference graph and linear fit are shown:



**Figure 8**



## 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

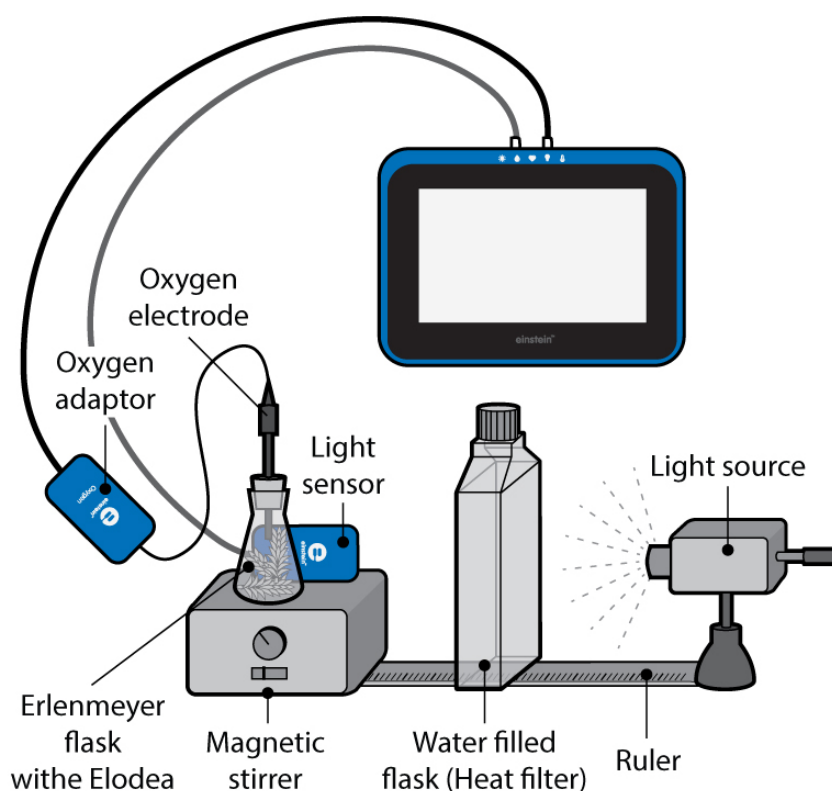


Figure 1



### Introduction

Photosynthesis provides food for most plant life on earth. This process uses the energy from light to turn Carbon Dioxide ( $\text{CO}_2$ ) and water into carbohydrates. In addition, this causes oxygen to be released. 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 release.




### Equipment

- einstein™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- Oxygen Sensor
- Multi-range Light Sensor

- 2 sensor cables
- 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 modeling clay (Optional – two holes, one for a Temperature sensor).
- About 1 liter of distilled water
- Magnetic stirrer
- 1 liter flat water bottle (glass or plastic) or tissue culture bottles
- Optional Temperature Sensor (-40 °C to 140 °C)

## 123 Equipment Setup

1. Launch MiLAB ()
2. Connect the Oxygen (DO<sub>2</sub>) sensor, the light Sensor and the temperature sensor to the ports on the einstein™Tablet or einstein™LabMate.
3. Make sure only the Oxygen sensor, the Light sensor and the (optional) Temperature sensor are selected.
4. 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).
  - b. The flask is placed on a magnetic stirrer. Using the stand, carefully place the Oxygen sensor electrode in the flask. (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 that is exposed to the Elodea.
  - 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 flasks, a flat 1 liter water bottle is placed between the light source and the flasks.

## Data Logger Setup

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

<b>Temperature (-40°C to 140°C)</b>	
Rate:	Every 1 sec
Duration:	5000 sec
<b>Oxygen</b>	
Rate:	Every 1 sec
Duration:	5000 sec
<b>Light</b>	
Rate:	Every 1 sec
Duration:	5000 sec



## Procedure

1. Select **Run** (▶) to begin recording data.
2. Switch on the light and observe the oxygen DO<sub>2</sub> percentage 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 bottles. After about half hour, turn the light off and cover the bottle, so that the Elodea is not exposed to light.

3. Select **Stop** (■) to stop collecting data.
4. Save your data by Selecting **Save** (↓).



## Data Analysis

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

1. Check the rate of change of the DO<sub>2</sub> level by selecting one point at the beginning of the graph and one point at the end of the graph.  
Then select **Linear fit**. The fit equation will be displayed below the x-axis.

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

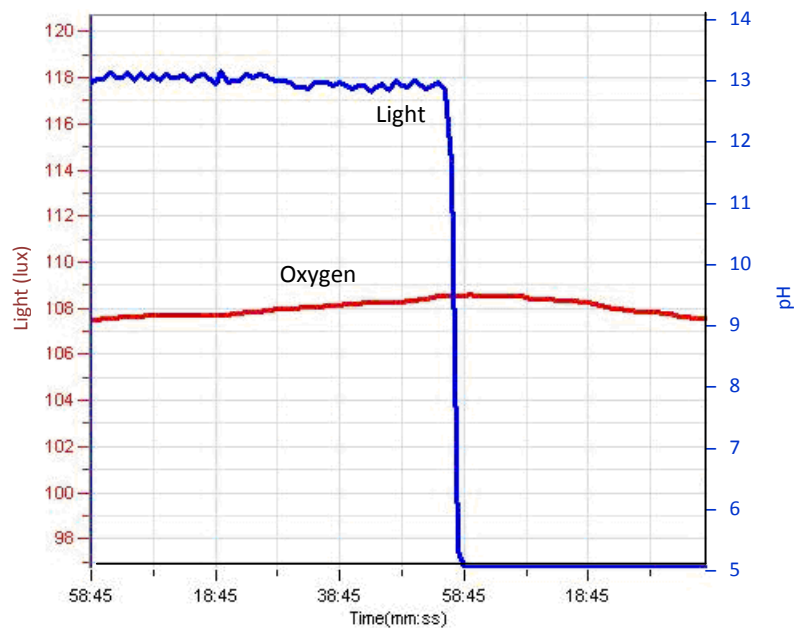


Figure 2



## 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

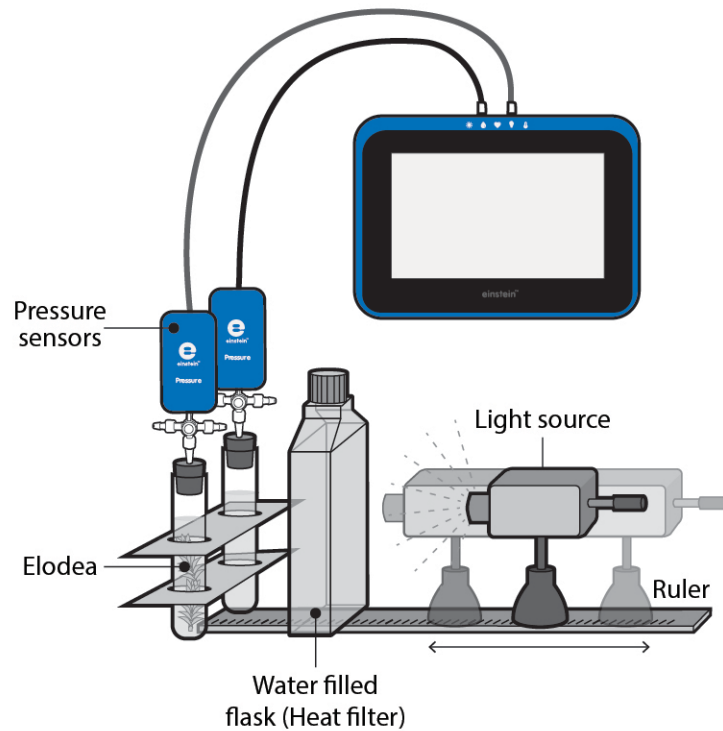


Figure 1

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.

$$I \propto \frac{1}{R^2}$$

Where  $I$  is the light intensity and  $R$  is 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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 2 g of fresh Elodea
- 150 W reflector lamp
- 2X50 ml glass test tubes with stoppers
- 2 syringe extenders\*
- Latex tube\*
- 2 three-way valves\*
- Stand to support the sensors
- 600 ml flat plastic bottle (heat filter)
- 2 Pressure Sensors (150 - 1150 mbar)
- Light Sensor (0 – 150 Klux)
- 3 sensor cables
- Bright light source (e.g. 150 W Halogen lamp)
- Optional Temperature Sensor (-40°C to 140°C)
- Meter stick

\*contained in einstein™ Pressure Kit



## Equipment Setup

1. Launch MiLAB ().
2. Connect the Pressure sensors and the Temperature sensor to the ports on the einstein™ Tablet or einstein™ LabMate.
3. Make sure only the temperature sensor and the pressure sensors are enabled.
4. Assemble the equipment as illustrated in Figure 1.
  - a. Slice 2 g of the Elodea branch into segments that fit the test tube size.
  - b. Place the Elodea segments into one test tube. The other test tube will serve as the experimental control.
  - c. Seal the test tubes tightly with the stoppers.
  - d. Insert a syringe extender into the stopper (Figure 2).
  - e. Attach a three-way valve to the other end of the syringe extender.
  - f. Connect a Pressure Sensor to the valve.
  - g. Turn the valve until its opening is directed vertically.  
In this position, air can flow through the valve.



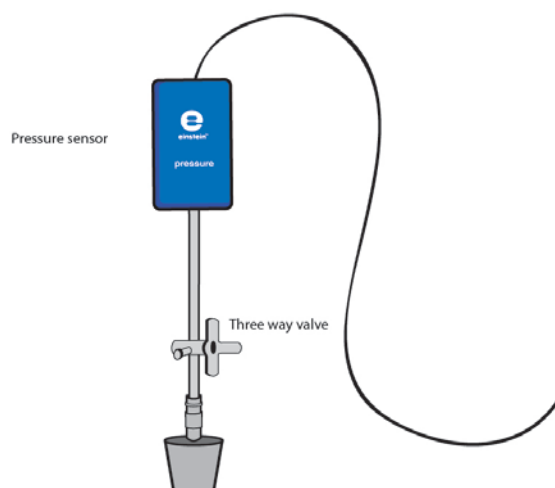


Figure 2

5. Fill the flat plastic bottle with water and place it between the light source and the test tubes. The water blocks the heat radiating from the light source.
6. Program the sensors to log data according to the following setup



## Data Logger Setup

<b>Pressure (150 – 1150 mbar)</b>	
Rate:	Every 1 sec
Duration:	5000 sec
<b>Temperature (-40°C to 140°C)</b>	
Rate:	Every 1 sec
Duration:	5000 sec




## Procedure

### Checking the experiment setup:

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

### Performing the experiment:



1. 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.
2. 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.
3. 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.
4. The experiment consists of at least two test tubes, with one serving as a control. Add 2 g of fresh *Elodea* to one of the test tubes.

5. 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 onset of the experiment. Otherwise, a lag period of about six minutes is observed.
6. 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.
7. Reset the apparatus. Turn the three-way valves to position A, and then return to position B (see Figures 3 and 4). The pressure in the tubes should now equal the atmospheric pressure.
8. Select **Run** (  ) to begin recording data.
9. Follow the pressure level on the graph.
10. Let the experiment run for at least 8 minutes.
11. 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.

12. Repeat the experiment from 2-3 additional distances.




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

13. 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.
14. Select **Stop** (  ) to stop collecting data.
15. Save your data by Selecting **Save** (  ).

## Measurement of light intensity at different distances

1. Place a 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™ Tablet or einstein™ LabMate.
5. Program the sensors to log data according to the following setup:

Light (0 – 150 Klux)	
Rate:	10 / sec
Duration:	1 sec

5. Select **Run** (  ) to begin recording data.
6. Prepare a table and record the light intensity at different distances from the test tubes.
7. Select **Stop** (  ) to stop collecting data.
8. Save your data by Selecting **Save** (  ).

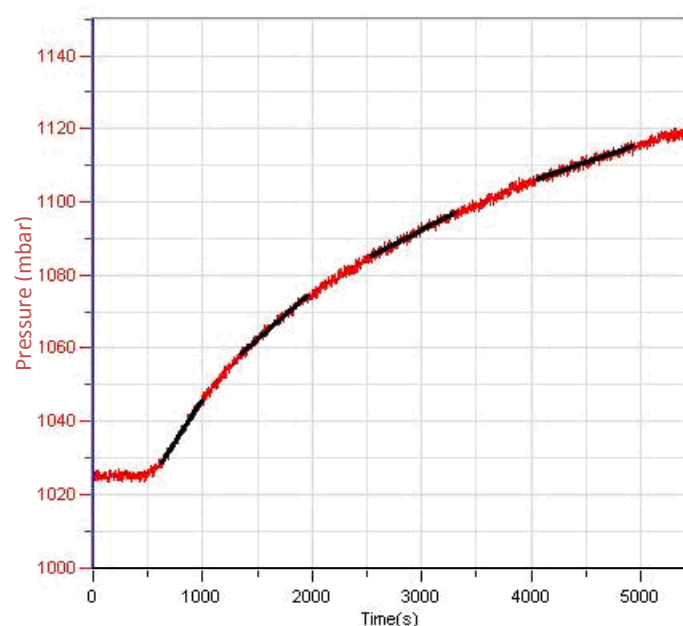


## Data Analysis

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

1. To calculate the net reaction rate, you will need to create a difference graph by subtracting the **Pressure** graph obtained in the control system from that of the experimental system:
2. Select **Analysis wizard** (  $f_x$  ) on the upper tool bar and select **Functions**.
3. In the **Functions** drop down menu select **Subtract**.
4. In the **G1** drop down menu select **Pressure -1**. In the **G2** drop down menu select **Pressure -2**.
5. In the **Name** edit box enter a name (e.g. Difference).
6. In this experiment, a set of linear segments are obtained, each representing a different distance of the light source from the test tubes.
7. 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.
  - a. Apply a linear fit to the selected segment of the graph:
  - b. Select **Linear fit**. The fit equation will be displayed below the x-axis.
  - c. The slope of the fit line is the net reaction rate.
  - d. Repeat steps 2 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:
  - a. Does the rate depend on light intensity in the whole range of intensities examined?
  - b. 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

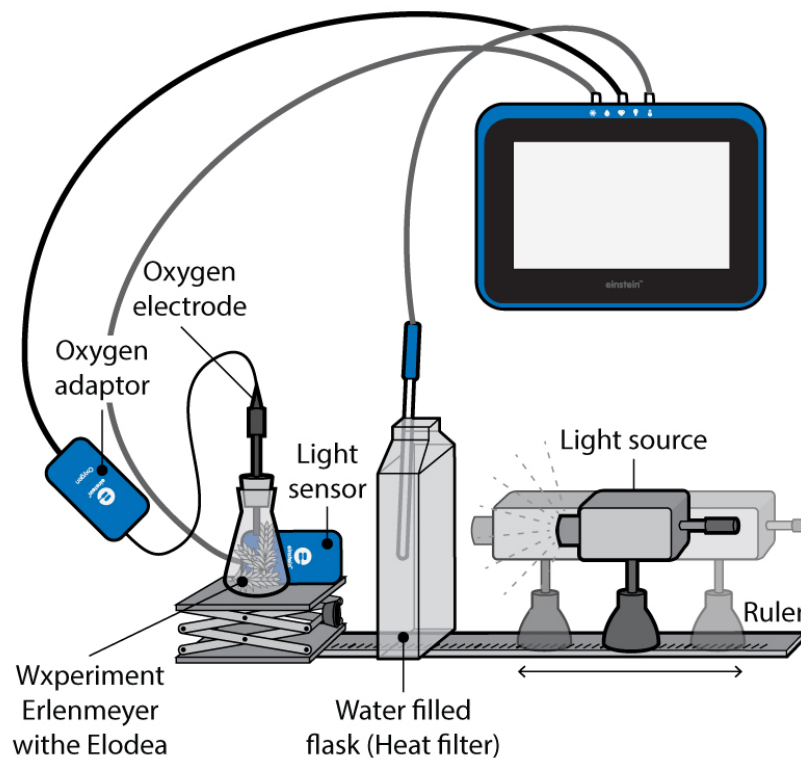


Figure 1



### Introduction

Photosynthesis provides food for most plant life on earth. This process uses the energy from light to turn Carbon Dioxide ( $\text{CO}_2$ ) and water into carbohydrates. In addition, this causes oxygen to be released. 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 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.

$$I \propto \frac{1}{R^2}$$

Where  $I$  is the light intensity and  $R$  is 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.

The rate of photosynthesis at various light intensities is measured by following the concentration of oxygen released into the air during the process.





## Equipment

- einstein™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 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 modeling clay
- Laboratory jack
- 2 one-liter flat water bottles (glass or plastic) or tissue culture bottles
- Oxygen Sensor
- Optional Temperature Sensor (-40°C to 140°C)
- Multi-range Light Sensor
- 2 sensor cables
- 0 - 2% bicarbonate solution



## Equipment Setup

1. Launch MiLAB ().
2. Connect the Oxygen Sensor and the Light Sensor to your einstein™ device.
3. Enable each sensor by selecting the circle () to the left of the appropriate sensor.
4. Assemble the equipment as illustrated in Figure 1.
  - a. Set up a 250 ml transparent glass Erlenmeyer filled with 1% bicarbonate solution and about 9 g. of fresh Elodea.
  - b. The rate of photosynthesis may vary with the species of plant available and the season of the year. Therefore it is recommended to conduct one experiment under optimal conditions of light (about 20 cm distance between the light source and the Erlenmeyer flask) and a bicarbonate concentration (0.5% - 1.0%), before measuring the effect of light intensity on photosynthesis rate.
  - c. Concentration of oxygen released to the free air above the bicarbonate solution with the plant is followed using the Oxygen Sensor.
  - d. In order to produce a reasonable rate, about 5 ml of free air should be kept in the Erlenmeyer, just enough to fit the oxygen electrode's tip.
  - e. Keep the tip of the electrode above the solution.
  - f. The Erlenmeyer 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 opening with modeling clay.
  - g. The Light Sensor is mounted behind the Erlenmeyer to measure the light intensity exposed to the Elodea.
  - h. Because heat can affect the reaction rate, two flat water bottles are placed between the light source and the Erlenmeyer to prevent heating of the bicarbonate solution.






## Data Logger Setup

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

<b>Oxygen (0 – 25%)</b>	
Rate:	Every 1 sec
Duration:	5000 sec
<b>Light (0 – 150klux)</b>	
Rate:	Every 1 sec
Duration:	5000 sec
<b>Temperature (-40°C to 140°C)</b>	
Rate:	Every 1 sec
Duration:	5000 sec



## 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. Mark a line, about 5 cm below the Erlenmeyer edge.
4. Cut the *Elodea* into short pieces and arrange them so that they are parallel to each other to ensure maximal exposure to the light. Then place the plants inside the Erlenmeyer.
5. Fill the Erlenmeyer with bicarbonate solution up to the line marked.
6. Insert the oxygen electrode and tightly close the Erlenmeyer.
7. It is recommended to illuminate the Erlenmeyer 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.
8. Select **Run** (  ) to begin recording data.
9. Start the experiment with the light source at the maximal distance chosen. Make sure the light is directed at the Erlenmeyer.
10. Switch on the light and follow the oxygen percentage level.
11. Follow photosynthesis rate for 5-8 minutes, until a straight line is received. At large distances from the light source the rate may be very low.
12. After 5-8 minutes, turn off the light.
13. Select **Stop** (  ) to stop collecting data and save your data by Selecting **Save** (  ).
14. Move the light source to the second distance and turn the light on again.
15. Repeat steps 10 - 13 at three to four additional distances.



## Data Analysis

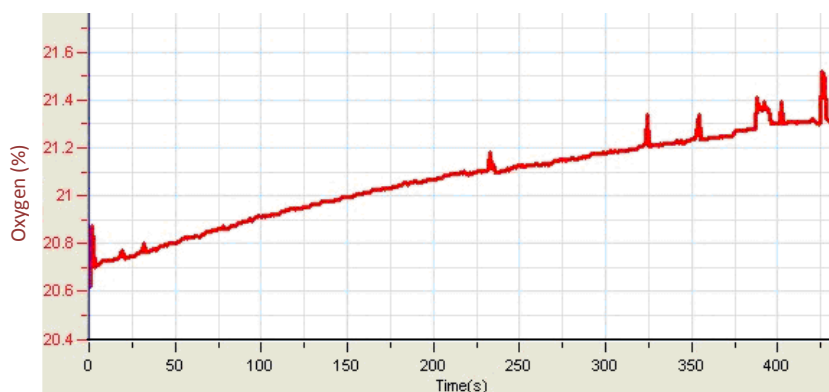
For more information on working with graphs see: **Working with Graphs in MiLAB**

- When the experiment is carried out with a 0.5% bicarbonate solution, a set of linear segments is obtained. Each segment represents a different distance of the light source from the Erlenmeyer.
- Use the cursors to select the first segment of the difference graph.

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

- To display coordinate values: select a curve, or to reveal a hidden y-axis, select any point on the graph. The coordinate values for the selected point will appear below the x-axis.
  - To move the cursors: drag it along the curve
  - To remove the cursor: select and quickly flick it off the screen in any direction.
  - Select any two points on the graph to display the difference between two sets of coordinates or to select a range of data points. The difference between the two sets of coordinates will be displayed below the x-axis.
- Apply a linear fit to the selected segment of the graph:
    - Select Linear fit ( $\text{y} = \text{mx} + \text{b}$ ). The fit equation will be displayed below the x-axis.
    - The slope of the fit line is the net reaction rate.
  - Repeat steps 1 and 3 for each linear segment of the graph.

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



**Figure 2**

- Use the cursor to read from the Light graph the light intensity and fill in the following table:

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

- Use Excel to draw a graph describing the relationship between light intensity and the rate of photosynthesis (slope).
- Repeat steps 1-6 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 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<sub>2</sub> (Dissolved Oxygen) and a magnetic stirrer should be used to ensure an even distribution of oxygen in the solution. If DO<sub>2</sub> is measured, a successive measurement at various wavelengths is impossible. The solution must be replaced and a different measurement for each wavelength 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

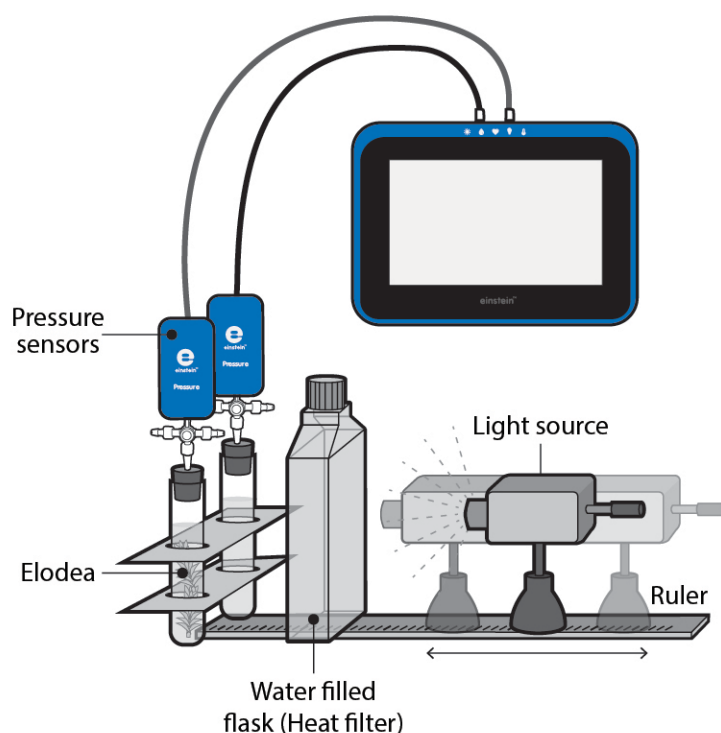


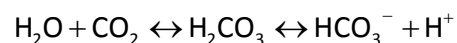
Figure 1



### 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  $\text{CO}_2$  is broken down, or fixed and used to create carbohydrates.

The main source for the  $\text{CO}_2$  consumed in photosynthesis is the atmosphere, consisting of about 0.03%  $\text{CO}_2$ . Dissolution of  $\text{CO}_2$  in water leads to the following reaction:



The bicarbonate ions produced in this reaction serve as a source of  $\text{CO}_2$  for the dark reactions of photosynthesis.

In this experiment we measure photosynthesis rate at different  $\text{CO}_2$  concentrations.




## Equipment

- einstein™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 2X50 ml glass test tubes with stoppers
- 2 syringe extenders\*
- 2 three-way valves\*
- Latex tube\*
- Perspex stand to support the tubes and sensors
- 600 ml flat plastic bottle (heat filter)
- 2 Pressure Sensors (150 – 1150 mbar)
- 2 sensor cables
- 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 MiLAB ().
2. Connect the Pressure Sensors to the ports on the einstein™ Tablet or einstein™ LabMate.
3. Make sure only the Pressure sensors and (optionally) the Temperature sensor are selected.
4. Assemble the equipment as illustrated in Figure 1.
  - a. The experiment consists of at least two 50 ml test tubes, with one serving as the control.
  - b. Add 2 g of fresh Elodea to one of the test tubes. The tubes must be completely sealed by the rubber stoppers.
  - c. Place the test tubes side by side, in front of the light source. Make sure the test tubes are equally illuminated.
  - d. A very small volume of air should remain between the stopper and the solution surface.
  - e. The concentrations of the bicarbonate solution used in this experiment vary in the range of 0-2%.
  - f. A very fresh branch of Elodea, weighing 2 g, is sliced into segments, suitable in length to the test tube size. The segments are arranged parallel to each other to ensure maximal exposure to light.
  - g. A 150 W reflection lamp serves as the light source. It is placed at a distance of 25 cm from the test tubes.
  - h. In order to prevent heating of the test tubes, two 1 liter flat bottles filled with water are placed between the light source and the test tubes.
  - i. The temperature of the water in the bottles is followed throughout the experiment.
  - j. Insert a syringe extender into the stopper (Figure 2).
  - k. Attach a three-way valve to the other end of the syringe extender
  - l. Connect a Pressure Sensor to the valve through another short latex tube.
  - m. Turn the valve until its opening is directed vertically. In this position, air can flow through the valve. In order to stop airflow, turn the valve until its opening reaches a horizontal position.

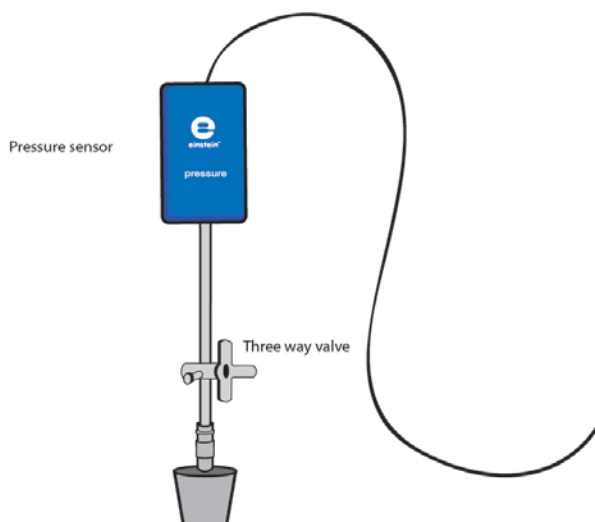


Figure 3: Three-way valve – Position A

## Data Logger Setup

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


<b>Pressure (150 – 1150 mbar)</b>	
Rate:	Every 1 sec
Duration:	5000 sec

## Procedure

### Checking the experiment setup:


Before starting the experiment make sure that the flasks 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. 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 onset of the experiment. Otherwise, a lag period of about six minutes is observed.
3. Reset the apparatus. Turn the three-way valves to position A, and then return to position B (see Figures 3 and 4). The pressure in the tubes should now equal the atmospheric pressure.
4. Select **Run** () to begin recording data.
5. Follow the pressure level registered in the MiLAB software.
6. 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.
7. 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.
8. Track the rate of photosynthesis for at least eight minutes.

9. Pour out the bicarbonate solution from both test tubes and add a bicarbonate solution of a different concentration.
10. Measure the reaction rate for an additional six minutes.



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

11. Repeat steps 10-12, three more times, each time adding a bicarbonate solution of a different concentration.
12. 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.
13. Save your data by Selecting **Save** (  ).



## Data Analysis

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

1. To calculate the net reaction rate, create a difference graph: subtract the graph obtained in the control system from that of the experimental system:
  - a. Select Analysis wizard (  ) on the upper tool bar and select Functions.
  - b. In the Functions drop down the menu select Subtract.
  - c. In the G1 drop down menu select Pressure -1. In the G2 drop down menu select Pressure -2.
  - d. In the Name edit box enter a name (e.g. Difference).
2. Apply a Linear fit to the difference graph:
  - a. Select **Linear fit** (  ). The fit equation will be displayed below the x-axis.
  - b. The slope of the fit line is the measured rate of water loss in the experiment.
  - c. 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:

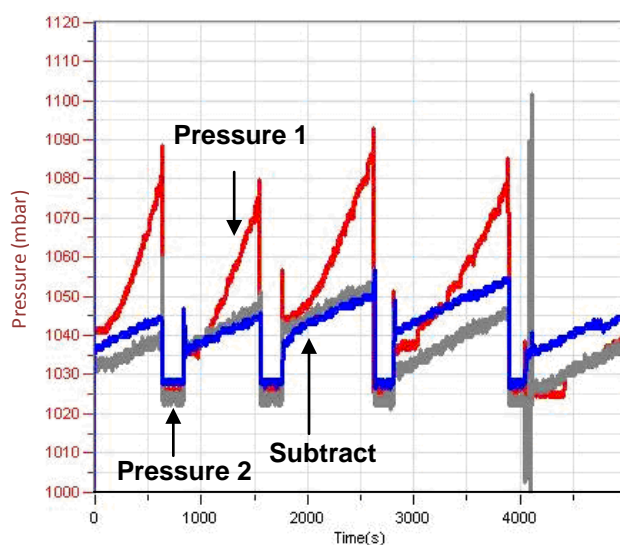


Figure 2

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

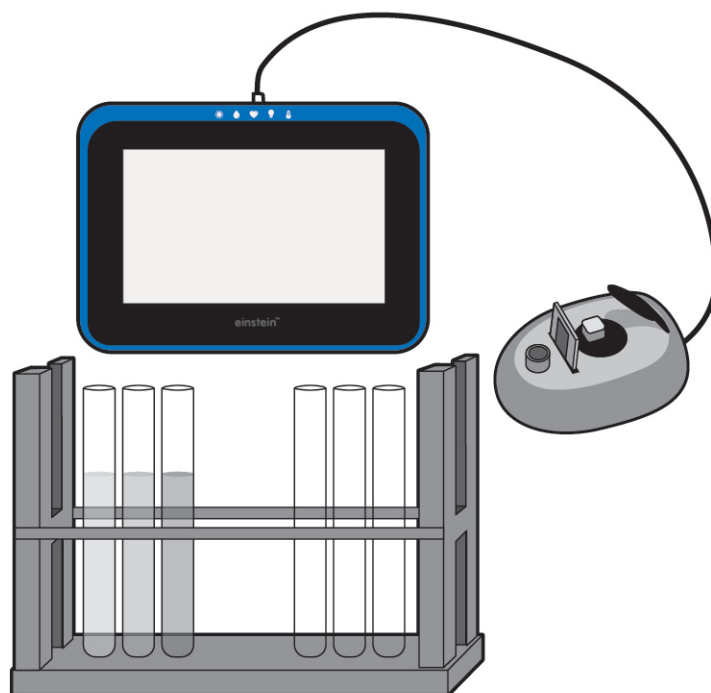


Figure 1



## Introduction

Photosynthesis is the fundamental process in which organic compounds, such as sugars (form of carbohydrate) are produced 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 surface area of the plant exposed to light. In this experiment we use a Colorimeter to follow the levels of glucose synthesized in terrestrial plants.





## Equipment

- einstein™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- Colorimeter
- sensor cable
- 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
- 1% DNS solution:
- 10 g DNS (dinitrosalicylic acid)
- 2 g phenol (optional, it intensifies the color received)
- 0.5 g sodium sulfite
- 10 g NaOH
- Add water to 1 liter
- 20 g per liter phenol (optional)
- Cuvettes
- Gauze
- Safety goggles

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

## 123 Equipment Setup

1. Launch MiLAB (.
2. Connect the Colorimeter to one of the ports on the einstein™ Tablet or einstein™ LabMate.
3. Enable the sensor by selecting the circle () to the left of the appropriate sensor.
4. Assemble the equipment as illustrated in Figure 1.
5. The first setup is for calibration and the second is for taking measurements.

## Data Logger Setup

### Colorimeter

Rate:	Every 1 sec
Duration:	100 sec

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

### Colorimeter

Rate:	10 / sec
Duration:	1 sec





## Procedure



1. Illuminate the plant you choose or place it outside in full day light.
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 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 green separate layer of n-Hexane with the chlorophyll extract is formed 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 in 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 begin recording data.
4. The setup is *manual*; therefore you have to select **Run** for each sample.
5. Select **Stop** (  ) to stop collecting data.

### Measure glucose levels in your samples:

1. Prepare a standard curve: five test tubes with 3 ml of the following glucose concentration: 1%, 0.5%, 0.1%, 0.05%, 0 (blank solution).
2. Add 3 ml of 1% DNS solution to 3 ml samples of glucose solutions.
3. Cover the test tubes with glass caps or other covers to avoid evaporation.
4. Heat the mixture 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. After cooling you can add 1 ml of phenol solution to intensify the color.

## Calibrate the Colorimeter:

1. Use the red filter.
2. 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:

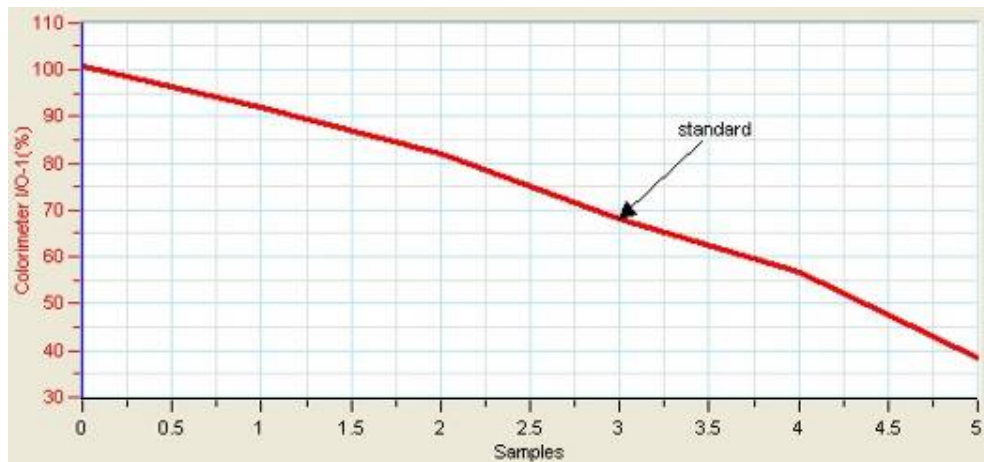
1. Pour each sample into a cuvette and insert it into the Colorimeter.
2. Close the Colorimeter cover tightly.
3. Select **Run** (▶) to begin recording data.
4. The setup is *manual*; therefore you have to select **Run** for each sample.
5. Select **Stop** (◻) to stop collecting data.

## Data Analysis

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

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. Select any point on the graph to read the % Transmittance for each glucose level at each time point of your samples, and prepare a table as shown below:

Time (Hours)	% Transmittance	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.

# Effect of Light on Chlorophyll Levels in Plant Leaves

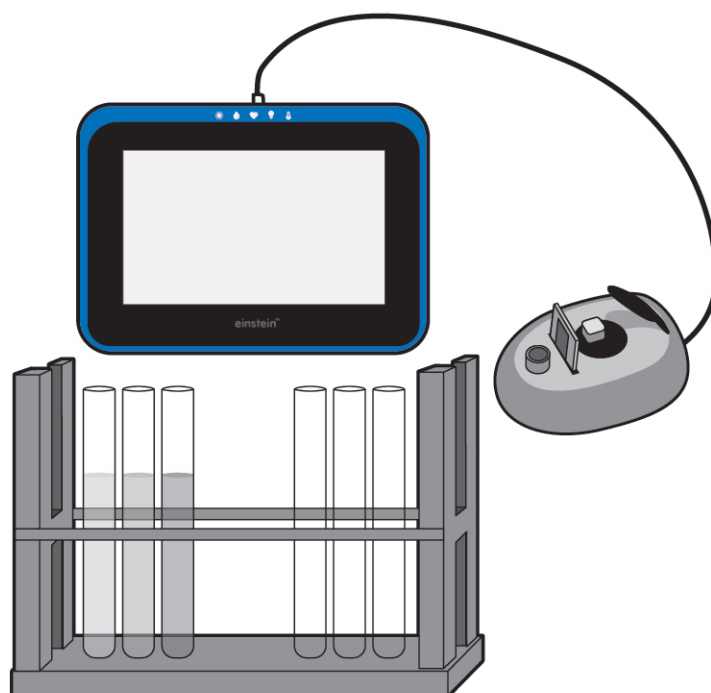


Figure 1



## Introduction

Chlorophyll is a green photosynthetic pigment found in plants, algae and cyanobacteria. Chlorophyll absorbs sunlight and uses its energy to synthesize carbohydrates from  $\text{CO}_2$  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-violet) 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 blue (450-500 nm).

**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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- Colorimeter
- sensor cable
- Cuvettes
- Mortar
- 95% ethanol
- Rack with test tubes
- Plants (at least 2 of each species)
- Safety goggles



## Equipment Setup

1. Launch MiLAB (.
2. Connect the Colorimeter to one of the port of the einstein™ Tablet or einstein™ LabMate.
3. Enable the sensor by selecting the circle (  ) to the left of the appropriate sensor.
4. Assemble the equipment as illustrated in Figure 1 above.



## Data Logger Setup

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

Colorimeter	
Rate:	Every 1 sec
Duration:	100 sec






Use the **green** filter for chlorophyll extracts.

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

Colorimeter	
Rate:	10 / sec
Samples:	1 sec



## 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 in 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 cover tightly.
  - e. Select **Run** (  ).
  - 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. The setup is manual; therefore you have to Select **Run** (  ) for each sample.
  - b. Run a separate measurement for each species of plant.
  - c. Select **Stop** (  ) to stop collecting data.
  - d. Save your data by Selecting **Save** (  ).
6. Run a separate measurement for each species of plant.



## Data Analysis

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

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):

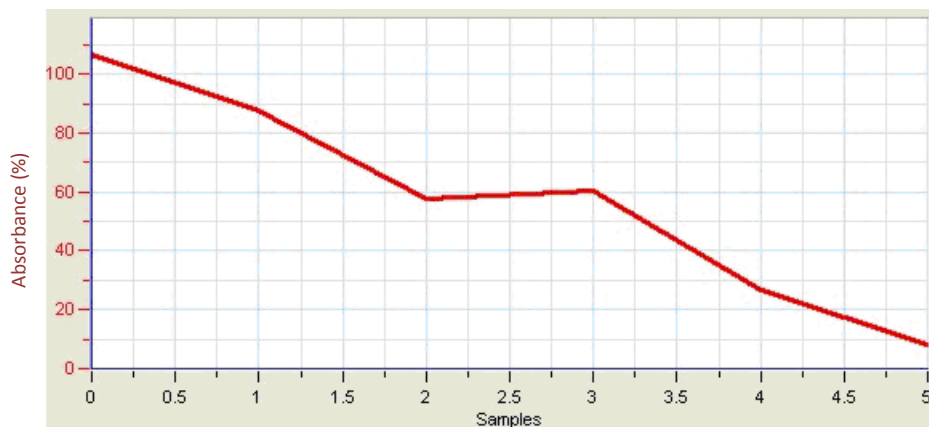


Figure 2



## 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 light, 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

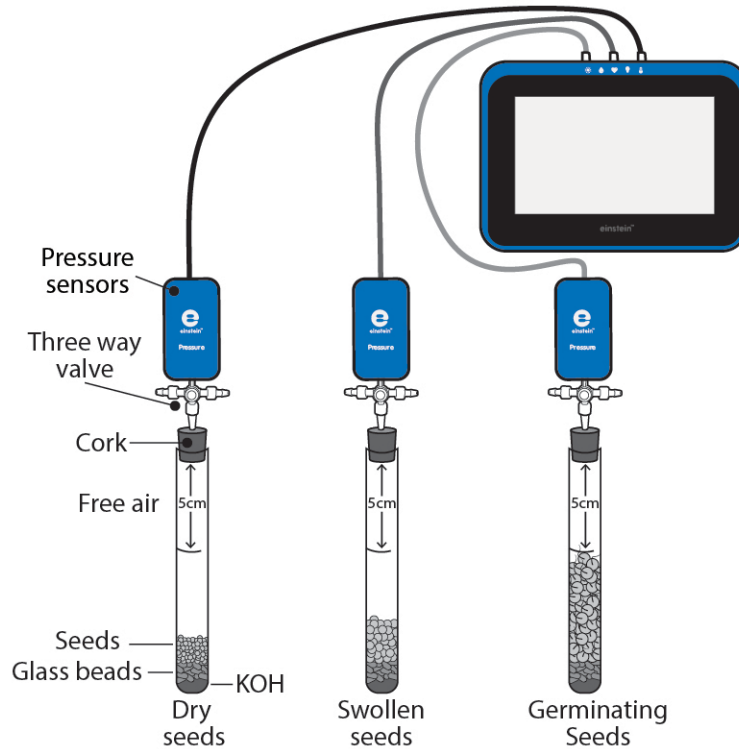


Figure 1



## Introduction

Germination is the process where 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  $\text{CO}_2$  is released.

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.

Following 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  $\text{CO}_2$  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  $\text{CO}_2$  released in the respiration process.  $\text{CO}_2$  is heavier than air. It precipitates to the bottom of the test tube and reacts with KOH. In this manner  $\text{CO}_2$  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™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- 3 Pressure Sensors (150 – 1150 mbar)
- 3 sensor cables
- 3X50 ml test tubes
- 3 stoppers
- 3 syringe extenders\*
- 3 latex tubes\*
- 3 three-way valves\*
- 9 g dry KOH
- Glass beads
- Seeds (pea or bean): 60 dry seeds, 45 swollen seed, 35 germinating seeds

\*contained in the einstein™ Pressure Kit



## Equipment Setup

1. Launch MiLAB ()
2. Connect the pressure sensors to the ports of the einstein™Tablet or einstein™LabMate.
3. Enable each sensor by selecting the circle () to the left of the appropriate sensor.
4. 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 through another short latex tube.
  - d. Turn the valve until its opening is directed vertically. In this position, air can flow through the valve. In order to stop airflow, turn the valve until its opening reaches a horizontal position.

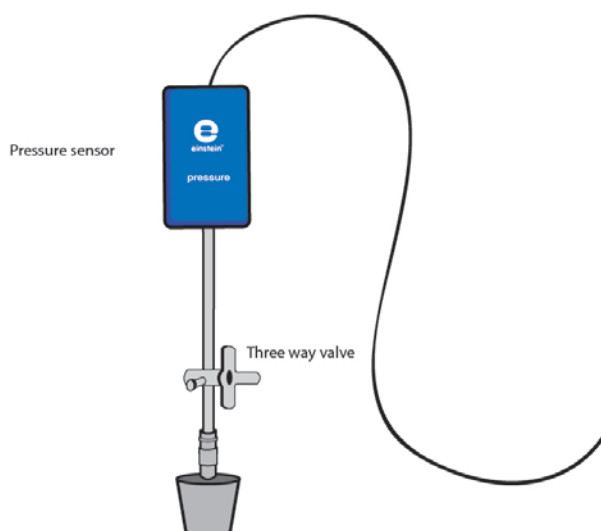


Figure 2

## Data Logger Setup

Pressure (150 – 1150 mbar)

Rate: Every 1 sec

Duration: 2000 sec




### Checking the experiment setup:

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

## Procedure

### Performing the experiment:

Number the test tubes 1-3. Mark a line on each test tube 5 cm from the top.

1. Reset the apparatus. Turn the three-way valves to position A, and then return to position B. The pressure in the tubes should now equal the 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 KOH and the seeds.
3. Weigh the test tube with the KOH.
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 weighs the test tubes together with the seeds.
5. Seal each test tube with a stopper that has a syringe extender inserted into it. Attach a three-way valve and a Pressure Sensor to the syringe extender.
6. Select **Run** () to begin recording data. Follow the pressure recorded on the screen.
7. Select **Stop** () to stop collecting data.
8. Save your data by Selecting **Save** ()



## Data Analysis

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

Apply a linear fit to each curve:

1. Select any two points on the graph to select a range of data points.
2. Select **Linear fit** (☒). The fit equation will be displayed below the x-axis.
3. The slope of the fit line is the measured rate of pressure changes due to oxygen consumption in the experiment.
4. The units used are mbar per second.
5. Multiply the slope 60 times to calculate the change in pressure (mbar) per minute.
6. Compare the slopes received in the three test tubes.
7. Calculate the weight of seeds in each test tube.
8. Calculate the rate of change in pressure per gram of seed weight.



## Questions

1. Describe the curves received in 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. Did it change the relative rates in the different test tubes?
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 CO<sub>2</sub> Released during Respiration of Germinating Seeds

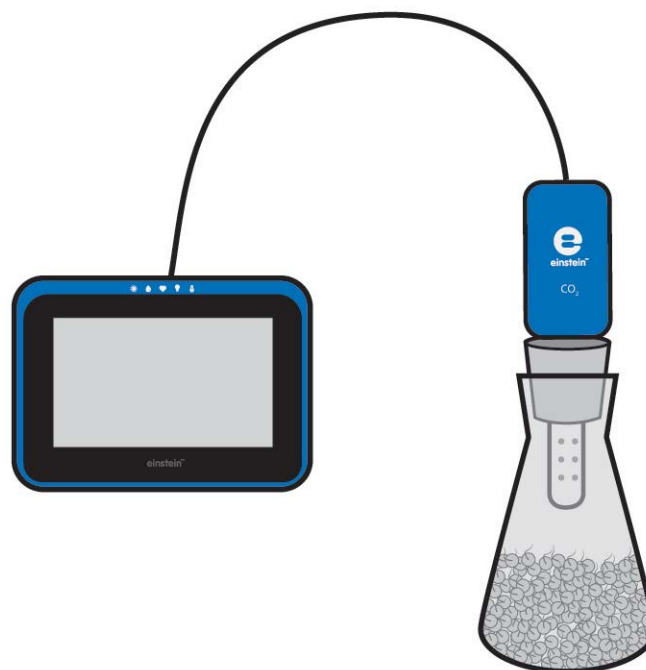


Figure 1



### Introduction

Germination is the process where 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<sub>2</sub> is released.

The germination process requires a large amount of energy supplied by cellular respiration. In this process storage materials are broken down releasing CO<sub>2</sub> and oxygen is consumed.

Respiration rate of dry seeds are at a very low rate. Addition of water to dry seeds increases their water content. In swollen seeds respiration accelerates, thereby increasing the rate of CO<sub>2</sub> 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 CO<sub>2</sub> Sensor to compare amounts of CO<sub>2</sub> released during respiration in swollen, dry, and germinating pea seeds.





## Equipment

- einstein™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- Seeds (pea or bean): 100 dry seeds, 50 swollen seeds, 35 germinating seeds
- Flask
- Rubber stopper with a hole suitable for the CO<sub>2</sub> sensor
- CO<sub>2</sub> Sensor
- sensor cable
- Scale



## Equipment Setup

1. Launch MiLAB ()
2. Connect the CO<sub>2</sub> Sensor to one of the ports of the einstein™ Tablet or einstein™ LabMate.
3. Enable the sensor by selecting the circle () to the left of the appropriate sensor. Then, choose the appropriate rate & samples as specified below.
4. Assemble the equipment as illustrated in Figure 1.






## Data Logger Setup

CO <sub>2</sub>	
Rate:	Every 1 sec
Duration:	2000 sec



## Procedure

1. Weight 50 swollen seeds.
2. Add 50 swollen seeds to the flask.
3. Insert the stopper into the flask and the CO<sub>2</sub> 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 CO<sub>2</sub> levels in the flask recorded on the screen.
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** ()



## Data Analysis

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

Apply a linear fit to each curve:

1. Select any two points on the graph to select a range of data points.
2. Select **Linear fit** (☒). The fit equation will be displayed below the x-axis.
3. The slope of the fit line is the measured rate of pressure changes due to CO<sub>2</sub> release in the experiment.
4. The units used are mbar per second.
5. Compare the slopes for the three different types of seeds.
6. Calculate the rate of change in CO<sub>2</sub> concentration per gram of seed weight.

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

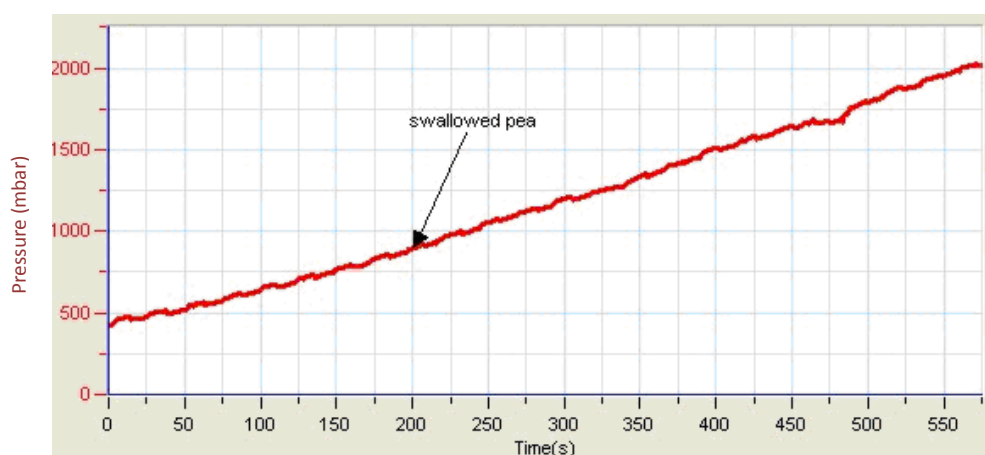


Figure 2



## 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 CO<sub>2</sub> released the fastest? The slowest?
3. Explain the differences in the rate of CO<sub>2</sub> released in the three groups of seeds.
4. Compare the calculated rates per gram weight for each group of seeds. Did it change the relative rates?
5. Explain why the change in CO<sub>2</sub> released is expressed in terms of rate per gram weight.
6. Predict the effect of an increase in temperature on the rate of CO<sub>2</sub> released in each group of seeds?
7. Predict the effect of a decrease in temperature on the rate of CO<sub>2</sub> released in each test tube?
8. What other factors can affect CO<sub>2</sub> release?
9. Design an experiment similar to this one to measuring these effects.



## Further Suggestions

1. Use an Oxygen Sensor to follow the rate of oxygen consumption by seeds during germination in parallel to CO<sub>2</sub> release.
2. Use seeds of different plants to follow CO<sub>2</sub> released during germination.
3. Measure the effect of temperature on CO<sub>2</sub> released during seed germination.

# Biological Catalysis: Decomposition of $\text{H}_2\text{O}_2$ in Presence of the Enzyme, Catalase

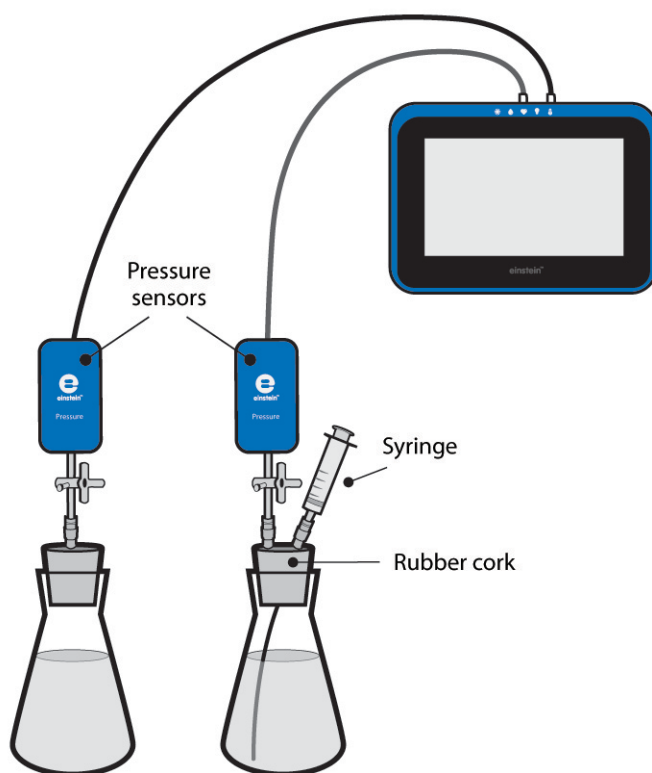


Figure 1



## Introduction

When hydrogen peroxide or  $\text{H}_2\text{O}_2$  (3%) solution is poured on a skin wound to cleanse it, the hydrogen peroxide decomposes into water and oxygen gas. As a result, the solution bubbles vigorously. The component 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  $\text{O}_2$ .

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

In this experiment we use Pressure Sensors to observe and measure the release of  $\text{O}_2$  from a  $\text{H}_2\text{O}_2$  solution within yeast.





## Equipment

- einstein™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 2 Pressure Sensors (150 – 1150 mbar)
- 2 sensor cables
- 2X50 ml glass flasks
- 2 stoppers with a hole for syringe extenders
- 2 ml plastic syringe\*
- 3 syringe extenders\*
- 3%  $\text{H}_2\text{O}_2$  solution
- 1 g dried yeast

\*contained in the einstein™ Pressure Kit



## Equipment Setup

1. Launch MiLAB (  ).
2. Connect the pressure sensors to the ports of the einstein™ Tablet or einstein™ LabMate.
3. Enable each sensor by selecting the circle (  ) to the left of the appropriate sensor.
4. 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. Turn the valve until its opening is directed vertically.  
In this position, air can flow through the valve.
  - d. In one of the stoppers, insert an additional syringe extender. A syringe filled with 3%  $\text{H}_2\text{O}_2$  solution will be later attached to this syringe extender.

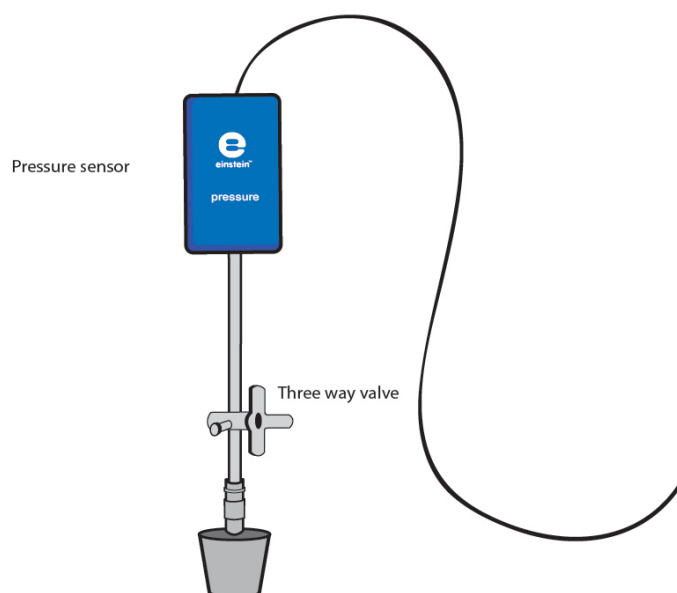


Figure 2





## Data Logger Setup

Pressure (150 – 1150 mbar)

Rate: Every 1 sec

Duration: 500 sec

### Checking the experiment setup:

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




## Procedure

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%  $\text{H}_2\text{O}_2$  solution.
3. Number two flasks 1 and 2.
4. Add to flask #1: 8 ml water and 2 ml 3%  $\text{H}_2\text{O}_2$  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%  $\text{H}_2\text{O}_2$  solution through the additional syringe extender inserted into the stopper.

### Performing the experiment:

Reset the apparatus. Open the three way valves and then close them. The pressure in the tubes should now equal the atmospheric pressure.


Select Run (  ) to begin recording data.

Follow the pressure level registered on the computer monitor.

Turn the valves attached to the stoppers of the two flasks until they are at atmospheric pressure (about 1000 mbar).

Inject the  $\text{H}_2\text{O}_2$  solution into flask #2, and immediately turn the valves of the two flasks to stop air from flowing into them.

Follow changes in pressure registered on the computer monitor during the experiment.

Select Stop (  ) to stop collecting data.

Save your data by Selecting Save (  ).



## Data Analysis

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

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**, create a difference graph: subtract the graph obtained in the control system from that of the experimental system:

- a. Place a cursor at the beginning of the **Pressure 1** plot line (the flask injected with  $\text{H}_2\text{O}_2$  and another at the end of the plot line).
  - b. Select **Analysis wizard** (  $f_x$  ) on the upper tool bar and select **Functions**.
  - c. In the **Functions** drop-down menu select **Subtract**.
  - d. In the **G1** drop-down menu select **Pressure -1**. In the **G2** drop down menu select **Pressure -2**.
  - e. In the **Name** edit box enter a name (e.g. Difference).
3. Apply a linear fit to the difference graph:
    - a. Use the cursors to select the desired range.
    - b. Select **Linear fit**. The fit equation will be displayed below the x-axis.
    - c. The slope of the fit line is the net reaction rate.

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

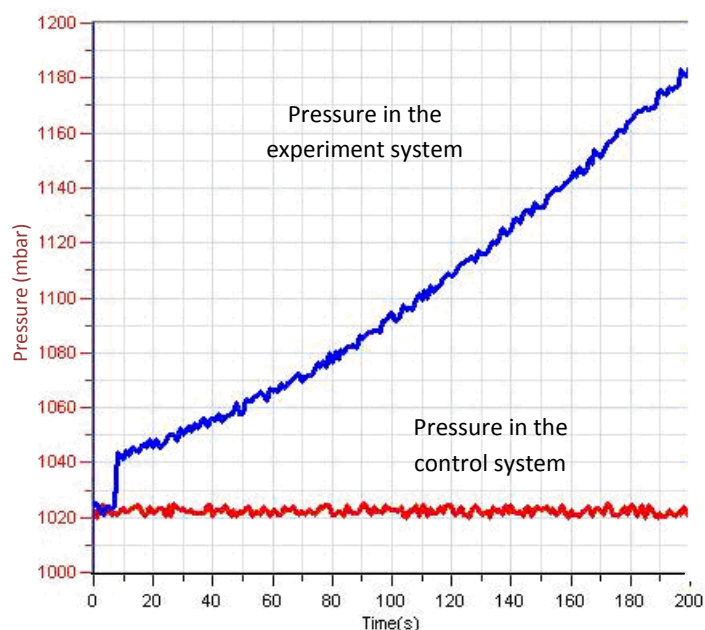


Figure 3

## Questions

1. How does the pressure generated in this experiment relate to the decomposition of  $\text{H}_2\text{O}_2$ ?
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  $\text{H}_2\text{O}_2$  decomposition 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  $\text{H}_2\text{O}_2$  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 decomposition rate of  $\text{H}_2\text{O}_2$ .
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

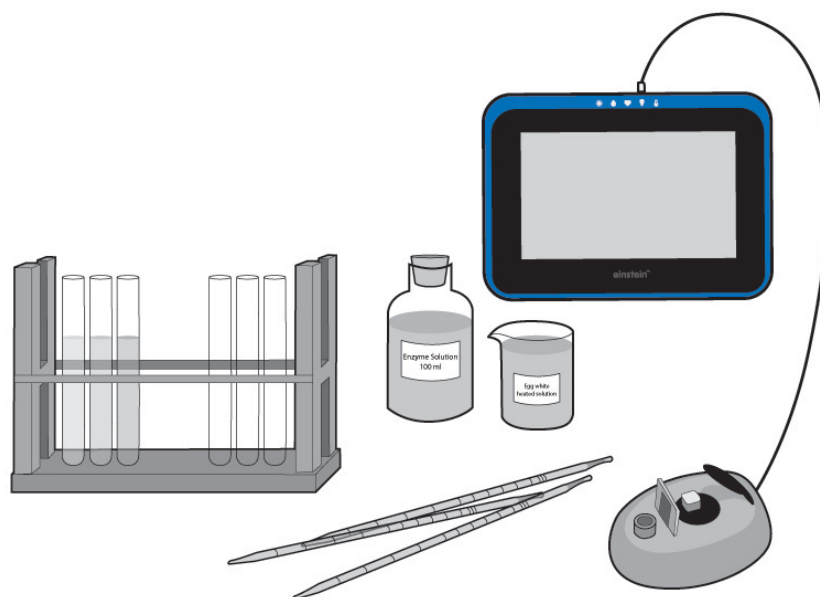


Figure 1



### 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 intestine lining.

Pepsin is produced in the mucosal lining of the stomach. It is initially secreted in the inactive form, trypsinogen and then, under very low pH conditions (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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- Colorimeter
- 2 sensor cables
- 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
- Temperature Sensor (-40°C to 140°C)
- pH Sensor
- 400-600 ml flask
- 5 ml and 1 ml pipettes
- Rack with 10 test tubes
- Cuvettes
- Wooden stick
- Safety goggles



## Equipment Setup

1. Launch MultiLab ()
2. Connect the Colorimeter, pH Sensor and Temperature Sensor to the ports of the einstein™ Tablet or einstein™ LabMate.
3. Make sure that only the Colorimeter, pH Sensor and Temperature Sensor are selected.
4. Assemble the equipment as illustrated in Figure 1 above.











## Data Logger Setup

Colorimeter, pH or Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	500 sec



## Procedure

1. Prepare the egg white solution:
  - a. In a flask, add 40 ml distilled water to 10 ml egg white.
  - b. Mix it rapidly with a fork and filter it through four layers of gauze.
  - c. Select **Run** (  ) on the main toolbar.
  - d. Follow the temperature graph.
  - e. Heat the solution up to 55°C – 60°C (and not above this temperature) with constant stirring until a turbid solution ID is obtained. At this stage the solution should resemble diluted milk.
  - f. Select **Stop** (  ) to stop collecting data.

This solution is the substrate used in the experiment. Keep it in a small flask.
2. Calibrate the Colorimeter:
  - a. Connect the Colorimeter to one of the ports of the einstein™ Tablet or einstein™ LabMate.
  - 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** (  ) on the main toolbar.
  - f. Follow the Colorimeter graph and turn the knob until you receive 100% transmission.
  - g. Select **Stop** (  ) to stop collecting data.
3. Measure the pH of the solution using the pH Sensor:
  - a. Connect the Temperature Sensor for temperature compensation.
  - b. Connect the pH Sensor to one of the ports of the einstein™ Tablet or einstein™ LabMate.
4. 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
  - d. The pH of the solution should be in the range of 2.0 - 3.0 pH. Check using the pH sensor and the Temperature sensor. If necessary, adjust the pH by changing the volume of 0.2N HCl that you add.
  - e. Select **Stop** (  ) to stop collecting data.
5. Measure the rate of protein degradation:
  - a. Add the egg white solution prepared above into a cuvette.
  - b. Connect the Colorimeter Sensor to one of the ports of the einstein™ Tablet or einstein™ LabMate.
  - c. Select **Run** (  ) on the main toolbar.
  - 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 registered on the computer monitor during the experiment.
  - h. Select **Stop** (  ) to stop collecting data.
6. Save your data by Selecting **Save** (  ).
7. Repeat steps 4-5 with at least 2-4 different enzyme concentrations.



## Data Analysis

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

1. The rate of protein degradation is calculated from the rate of change in light transmission.
2. Apply a linear fit to the difference graph:
  - a. Use one cursor to select the beginning of a plot line and another to select the end of the plot line.
  - b. Select **Linear fit**. The fit equation will be displayed below the x-axis.
  - c. The slope of the fit line is the net reaction rate.

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

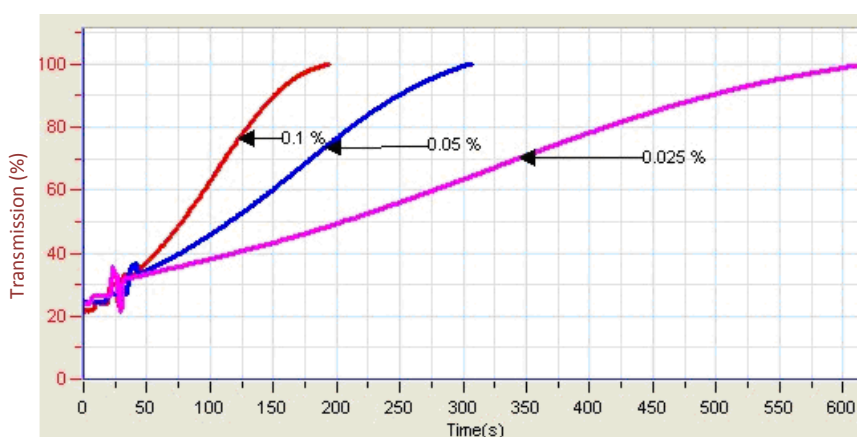


Figure 2

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  $\text{Na}_2\text{CO}_3$ .
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

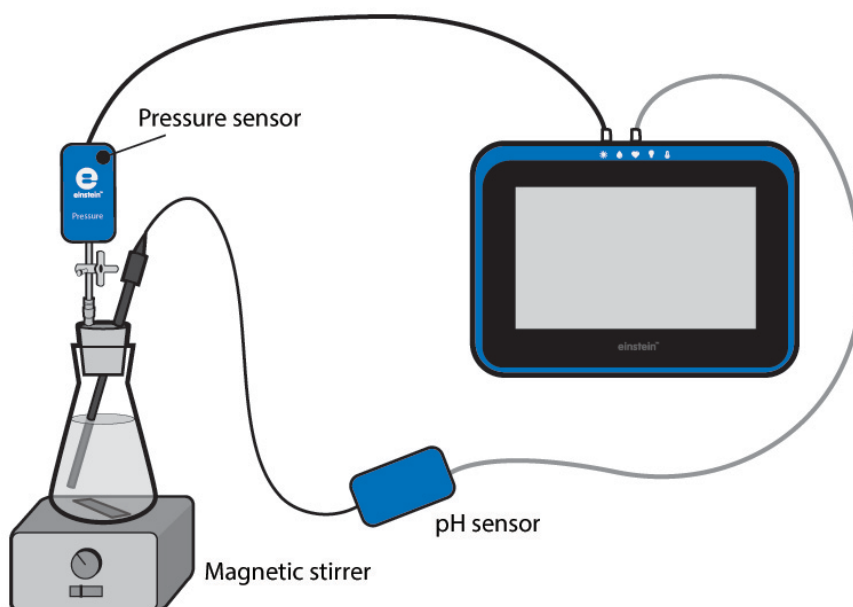
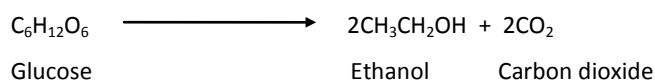


Figure 1

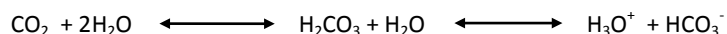


## Introduction

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 terminates with two molecules of the 2-carbon alcohol, ethanol, and two molecules of  $\text{CO}_2$ :



The  $\text{CO}_2$  released in the process dissolves in water and forms a carbonic acid. This acid dissociates to form hydrogen carbonate and hydronium ions:



In acidic solutions, the dissolution of  $\text{CO}_2$  in water decreases, and it is released to the air.

In this experiment we observe changes in pH and  $\text{CO}_2$  release during yeast fermentation.







## Equipment

- einstein™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- Pressure Sensor (150 – 1150 mbar)
- pH Sensor
- 2 sensor cables
- 50 ml glass flask
- Stopper with a hole to insert the pH sensor
- Syringe extender\*
- Three-way valve (used with infusions)\*
- 1.25 g dried yeast
- 50 ml of 2% glucose solution
- Magnetic stirrer
- Scale

\*contained in the einstein™ Pressure Kit



## Equipment Setup

1. Launch MultiLab ()
2. Connect the Pressure Sensor and pH Sensor to the ports of the einstein™ Tablet or einstein™ LabMate.
3. Enable each sensor by selecting the circle () to the left of the appropriate sensor.
4. 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. Turn the valve until its opening is directed vertically. In this position, air can flow through the valve.
  - e. 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, spread use a material like modeling clay around the pH electrode.

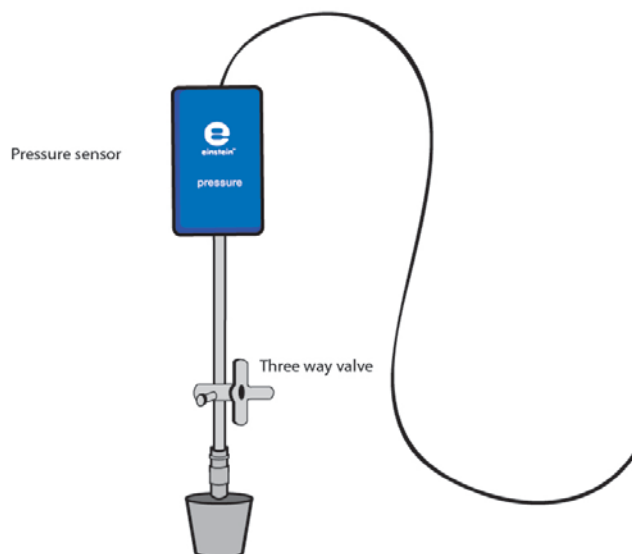


Figure 2



## Data Logger Setup

Pressure (150 – 1150 mbar), pH or Temperature (-40°C to 140°C)

Rate: Every 1 sec

Duration: 2000 sec






## Procedure

### Checking the experiment setup:

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

### Performing the experiment:

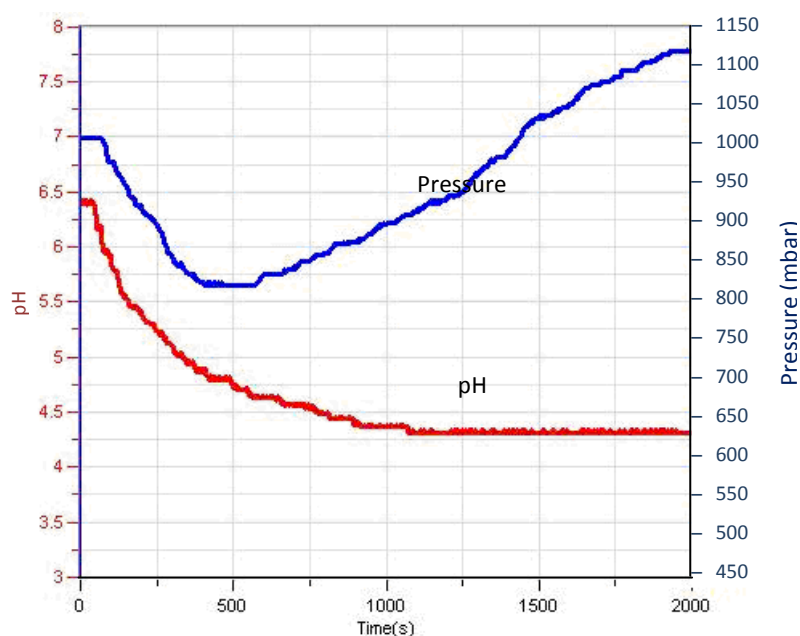
1. Reset the apparatus. Open the three way valves and then shut them. The pressure in the tubes should now equal the atmospheric pressure.
2. Weigh 1.25 g dried yeast. Dissolve it in 50 ml water. Mix well to obtain a homogenous solution.
3. Add 25 ml of yeast solution to the glass flask.
4. Select **Run** (  ) to begin recording data.
5. Add 25 ml of 2% glucose solution to the flask and start stirring.
6. Tightly close the flask with the stopper.
7. Follow the pressure level registered on the screen.
8. Press **Stop** (  ) to stop recording
9. Turn the valve attached to the syringe extender until the pressure in the flask returns to atmospheric levels.
10. During the experiment observe changes in pressure and pH registered on the screen.
11. Save your data by Selecting **Save** (  ).

## Data Analysis

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

1. Calculate the changes in pressure and pH in the flask. What were the initial pressure and pH values? What were the final values? What was the difference between the initial and final values?
2. Compare the changes 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 CO<sub>2</sub> release, apply a linear fit to the Pressure graph:
  - a. Use one cursor to select the beginning of the plot line and a second to select the end.
  - b. Select **Linear fit**. The fit equation will be displayed below the x-axis.
  - c. The slope of the fit line is the rate of CO<sub>2</sub> 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

1. How does the pressure generated during the experiment relate to the CO<sub>2</sub> release associated with yeast fermentation?
2. What is the optimal pH range for yeast fermentation? Base your conclusions on the results you obtained in the experiment.
3. Explain how the decrease in pH during the initial part of the experiment affects the rate of CO<sub>2</sub> dissolution in water. Suggest an experiment to test your hypothesis.
4. Temperature rise in the flask during the experiment can affect the rate of CO<sub>2</sub> release in two different ways: solubility of CO<sub>2</sub> in water and rate of fermentation. Explain these two effects.



## Further Suggestions

1. Add increasing amounts of yeast to the flask and observe the rate of CO<sub>2</sub> release in each case.
2. Calculate the reaction rate obtained in each experiment.
3. Compare the effect of different sucrose concentrations on the rate of fermentation.
4. Compare different types of six-carbon sugars (glucose, fructose, galactose) to disaccharides (lactose, sucrose) and calculate the rate of fermentation obtained with each sugar.
5. Perform the fermentation experiment in a buffer solution (set the pH value to 4.0).

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

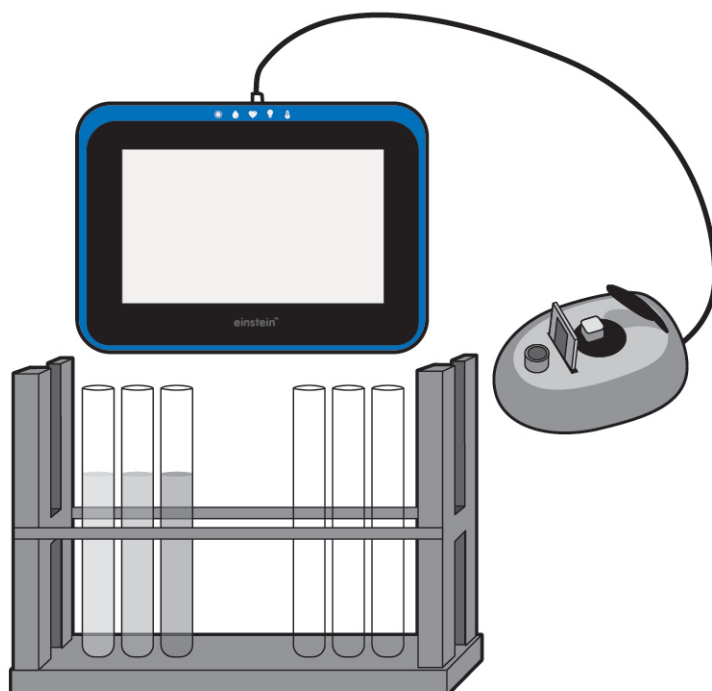


Figure 1



### Introduction

Cell membranes consist of a phospholipid bi-layer 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 outside solution.





## Equipment

- einstein™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- Colorimeter
- sensor cable
- Cuvettes
- Temperature Sensor (-40°C to 140°C)
- Water bath or heating plate
- Stop watch
- Rack with 10 test tubes
- 5 ml pipettes
- 3X100 ml beakers
- 3X50 ml tubes
- 15 beet cylinders (should be freshly prepared just before the experiment)
- Paper towels



## Equipment Setup

1. Launch MultiLab ()
2. Connect the Temperature Sensor to one of the ports of the einstein™ Tablet or einstein™ LabMate.
3. Enable the sensor by selecting the circle () to the left of the appropriate sensor.
4. Assemble the equipment as illustrated in Figure 1.



## Data Logger Setup

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

Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	500 sec

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

Colorimeter	
Rate:	Every second
Duration:	100 sec








## 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 tubes. Add 40 ml tap water.
3. Observe and note the color of the water.
4. Wash the beet cylinders with tap water at least five times until the water remains clear.
5. Mark three 50 ml test tubes A, B and C.
6. Add 20 ml tap water to each tube.
7. Incubate each test tube for four minutes as follows:  
Test tube #1: room temperature (measure using the Temperature Sensor)  
Test tube #2: 70°C to 80°C  
Test tube #3: boiling water
8. Prepare an additional four test tubes in the test tube rack for each temperature.
9. Number them as follows: 1-4 for boiling water 5-8 for 70°C to 80°C  
9-12 for room temperature
10. Start sampling from each of the 50 ml test tubes.
11. Take a sample of 4 ml *every minute*. Put these samples in the test tubes marked 1-12
12. 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.

13. 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.
14. Measure the color in each sample:
  - a. Select **Run** (  ) to begin recording data.
  - b. The setup is manual; therefore you have to Select **Run** (  ) for each sample.
  - c. Select **Tools** on main toolbar, select **Graph title** and enter in the **Graph title** edit box the temperature of the samples.
  - d. Save your data by Selecting **Save** (  ).
  - e. Start a new measurement for each temperature.



## Data Analysis

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

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:

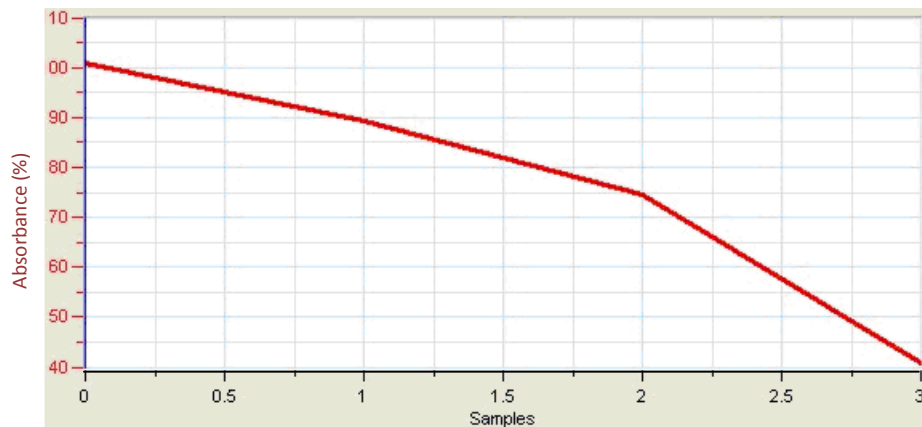


Figure 2

## ? 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

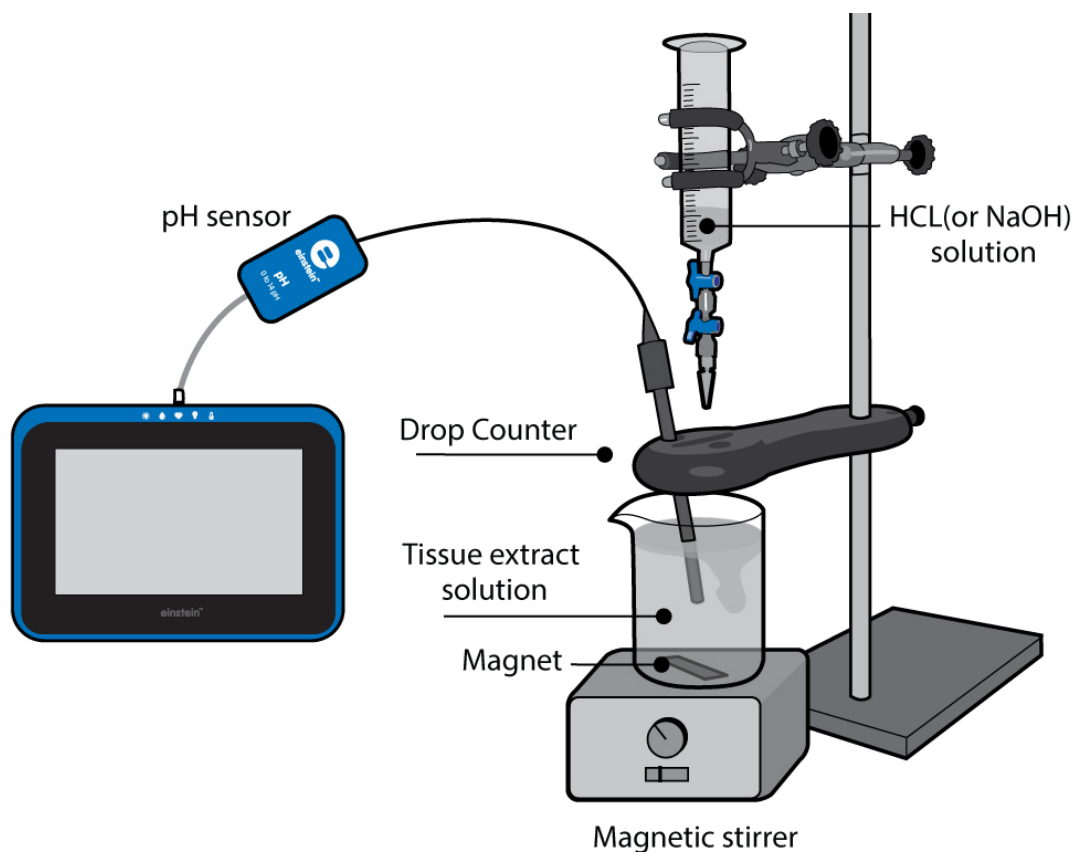


Figure 1



### 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 contains buffers, chemicals that react with acids and bases to maintain stable pH in the cells. Phosphates are the most prominent 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.

**Titration** is a process for determining the concentration of an acidic or basic solution by measuring the minimal volume of acids or bases of known concentration required to be added to neutralize the solution in question.

In this experiment we will be titrating, or determining the pH of tissue extracts from various sources of food: potato, eggs, liver, etc. by adding to them acids or bases of known concentration.





## Equipment

- einstein™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- pH Sensor
- sensor cable
- Temperature Sensor (-40°C to 140°C). The Temperature Sensor should be connected to the einstein™ Tablet or einstein™ LabMate along with the pH Sensor.
- Potatoes, carrots or sour apples
- 100 ml beaker
- 0.5 L beaker
- Drop Counter sensor
- Centrifuge
- Piece of gauze
- Magnetic stirrer
- Small magnet that fits the size of the beaker



## Equipment Setup

1. Launch MultiLab ()
2. Connect the pH electrode to one of the ports of the einstein™ Tablet or einstein™ LabMate.
3. Enable the sensor by selecting the circle () to the left of the appropriate sensor.
4. Assemble the equipment as illustrated in Figure 1.



## Data Logger Setup



pH sensor, Temperature (-40°C to 140°C)	
Rate:	Every 1 sec
Duration:	2000 sec



## Procedure

Prepare 100 ml tissue extract:

1. Use potatoes, carrots or sour apples
2. Crush them using a grater.
3. Place a piece of gauze over a 0.5 L beaker.
4. Collect the tissue extract: Place the crushed tissue on the gauze. Cover it with gauze and press it tightly.
5. Potatoes contain large amounts of starch. To remove the starch, place the extract 1-2 minutes in a table centrifuge for 1-2 minutes. Collect the supernatant.
6. Apple extract must be diluted 1:1 with tap water.
7. For liver extract: Weigh 70 g of chicken liver. Add 150 ml tap water and mix the liver solution in a blender. Use a table centrifuge to separate tissue debris from the extract. Collect the supernatant and add tap water to bring the volume up to 200 ml.
8. Fill the Drop Counter with 0.1 N HCl solution.

9. Making sure that both two-way valves are in the closed position (horizontal), to the plastic reagent reservoir.
10. Tighten the turn screw of the drop counter to the stand, to hold it firmly in place.
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 beaker.
13. Insert the pH electrode into the extract.
14. Turn on the magnetic stirrer and start it very carefully. The magnet must be kept off 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: 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** (  ).



## Data Analysis

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

1. Use the first cursor to read the initial pH of the tissue.
2. Calculate the extent of change in pH obtained in the process and the time range. Use the cursors to find the appropriate values:
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 added base 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  $\text{NaHPO}_4^-$ ).
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

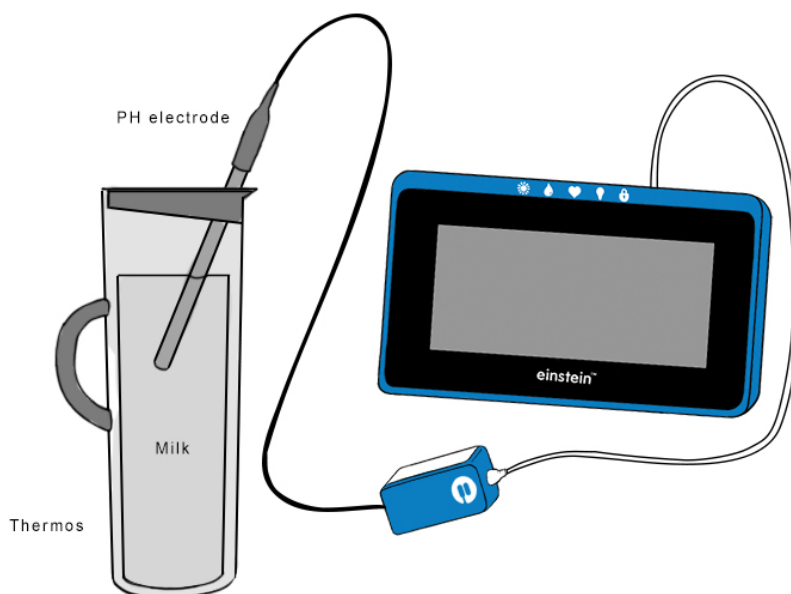


Figure 1



### 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 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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- pH Sensor
- sensor cable
- Temperature Sensor (-40°C to 140°C). A Temperature Sensor should be connected to the data logger along with the pH Sensor.
- 1 liter thermos (with an opening that enables a good seal including the pH cable)
- Milk

## 123 Equipment Setup




**Notes:** This is a long experiment so ensure that the AC/DC adapter is connected to the einstein™ Tablet or einstein™ LabMate™ for the duration of the experiment.

1. Launch MultiLab ()
2. Connect the pH electrode to one of the ports of the einstein™ Tablet or einstein™ LabMate.
3. Ensure that only the pH sensor is selected.
4. Assemble the equipment as illustrated in Figure 1.

## Data Logger Setup

<b>pH</b>	
Rate:	Every 1 min
Duration:	2000 sec
<b>Temperature (-40°C to 140°C)</b>	
Rate:	Every 1 min
Duration:	2000 sec

## 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** () on the main toolbar.
5. After 30 hours of incubation, you can stop data logging by Selecting **Stop** ()
6. Save your data by Selecting **Save** ()

## Data Analysis

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

1. Calculate the extent of change in pH obtained in the process. Use the cursors to mark the start and end of the experiment.
2. Apply a linear fit to the difference graph:
  - a. Use the cursors to mark the start and end of the experiment.
  - b. Select **Linear fit**. The fit equation will be displayed below the x-axis.
  - c. The slope of the fit line is the rate of pH change.

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

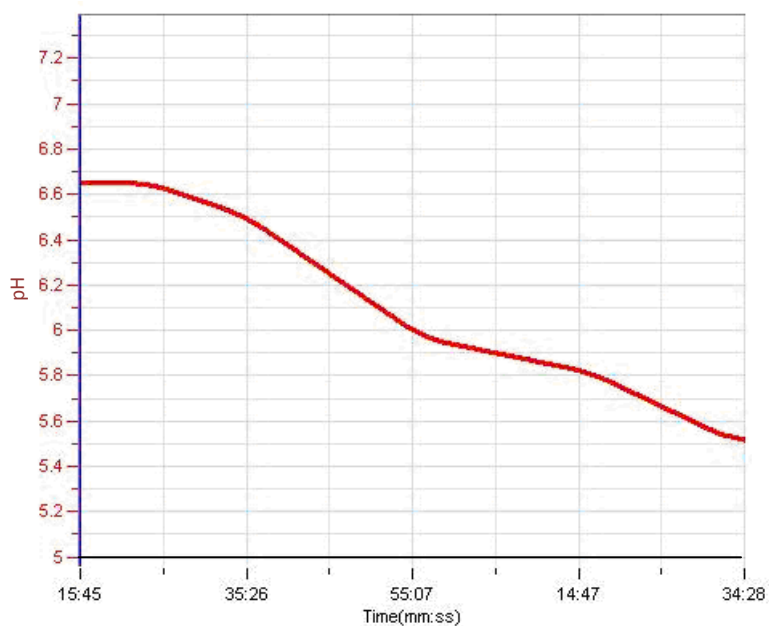


Figure 2



## 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).

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

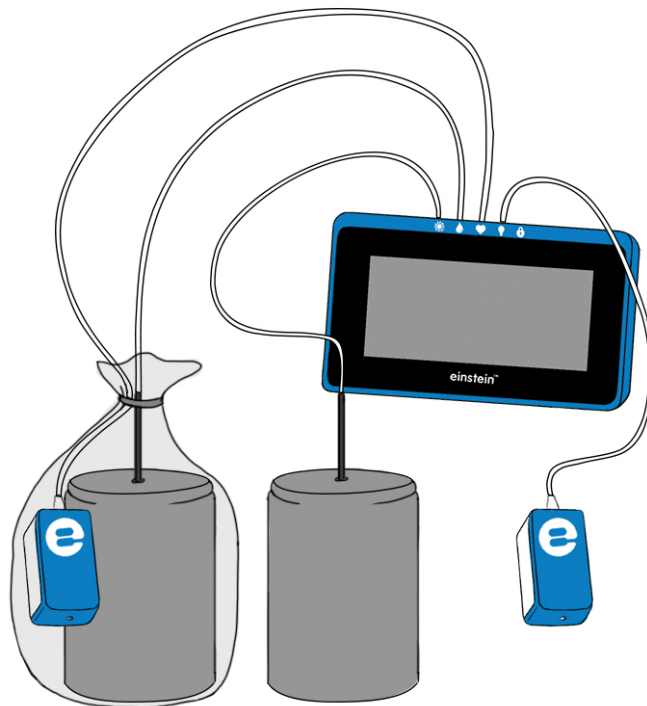


Figure 1



## 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 the loss of heat loss from clay jugs.




## Equipment

- einstein™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 2 Temperature Sensors (-40°C to 140°C)
- 2 Humidity Sensors
- 2 sensor cables
- 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)

123

## Equipment Setup

1. Launch MultiLab ().
2. Connect the Humidity Sensors and the Temperature Sensors to the ports of the einstein™Tablet or einstein™LabMate.
3. Ensure that only the Temperature and Humidity sensors are enabled.
4. Assemble the equipment as illustrated in Figure 1.





## Data Logger Setup

<b>Humidity</b>	
Rate:	Every 1 sec
Duration:	2000 sec
<b>Temperature (-40°C to 140°C)</b>	
Rate:	Every 1 sec
Duration:	2000 sec





## 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 set the number of samples collected, on the appropriate time scale.
10. Save your data by Selecting **Save** (  ).



## Data Analysis

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

1. Use the cursors to mark the course of changes in humidity and temperature in the covered and exposed systems:
2. What was the initial value in each system, the final value, and the difference between the two values?
3. Use the cursors to mark the time interval between the start of the experiment and 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:

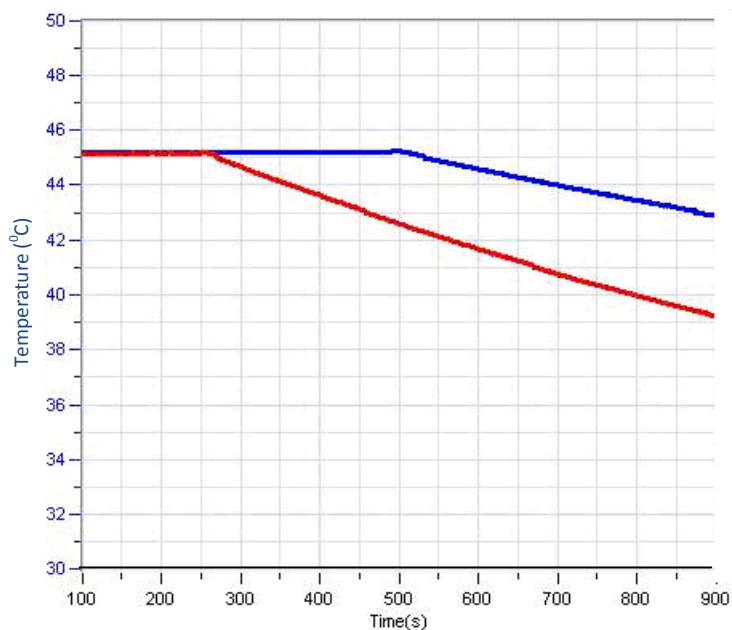


Figure 2



## 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  $1/\Delta T^2$ .

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

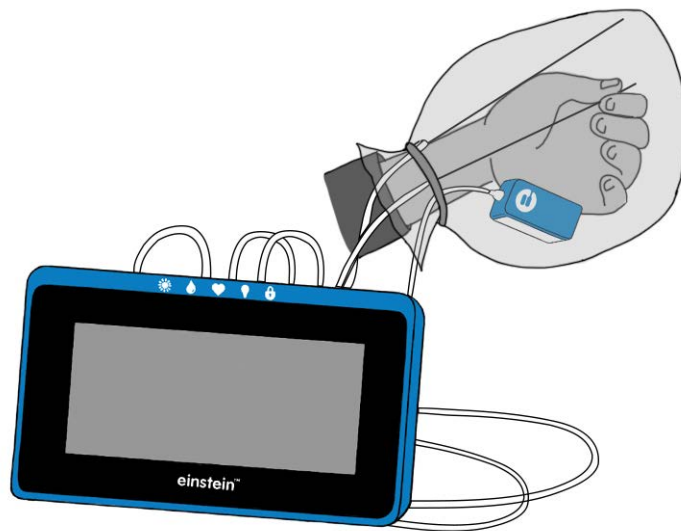


Figure 1



## Introduction

Exposure of our body to high temperature 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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 2 Temperature Sensors (-40°C to 140°C)
- Humidity Sensor
- sensor cable
- Plastic bag



## Equipment Setup

1. Launch einstein™ MultiLab ().
2. Connect the Humidity Sensors and the Temperature Sensors to the ports of the einstein™ Tablet or einstein™ LabMate.
3. Ensure that only the Temperature and Humidity sensors are selected.



## Data Logger Setup

### Temperature (-40°C to 140°C)

Rate: Every 1 sec

Duration: 2000 sec



### Humidity

Rate: Every second

Duration: 2000 sec



## Procedure

1. Attach a Temperature Sensor to the fingers of your right arm, as demonstrated in Figure 1 above.
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. 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** (.



## Data Analysis

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

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?
2. 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):

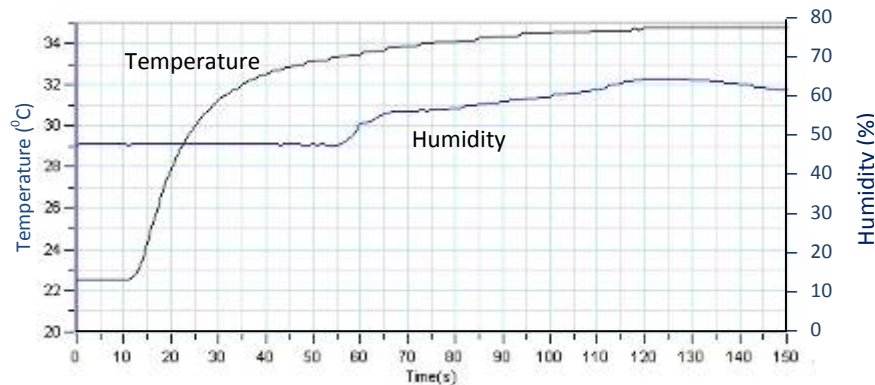


Figure 2

3. 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 and the hand uncovered by the plastic bag.
2. Perform exercise while holding the hand inside the plastic bag, and measure its effect on temperature and humidity.
3. Increase humidity of 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.

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

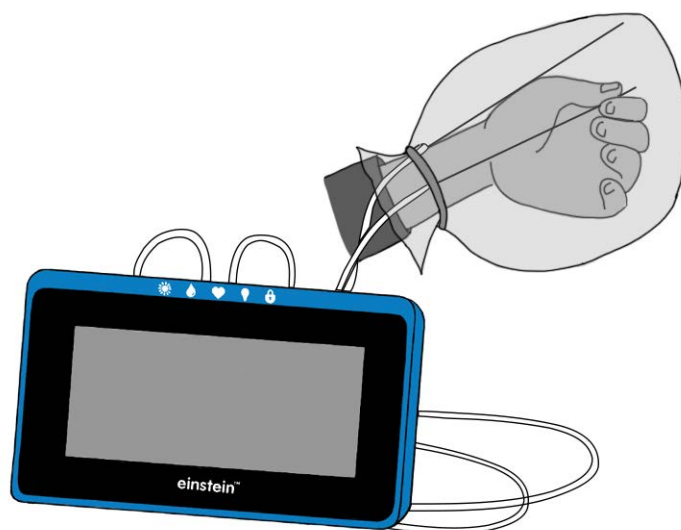


Figure 1

## Introduction



Exposure of our body to high temperature 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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- 2 Temperature Sensors (-40°C to 140°C)
- Plastic bag

## 123 Equipment Setup

1. Launch MultiLab (.
2. Connect the Temperature Sensors to the ports of the einstein™ Tablet or einstein™ LabMate.
3. Enable each sensor by selecting the circle () to the left of the appropriate sensor. .



## Data Logger Setup

### Temperature (-40°C to 140°C)

Rate: Every 1 sec

Duration: 2000 sec

## Procedure

1. Attach one Temperature Sensor to the outside of your hand and another to your fingertips as demonstrated in Figure 1 above.
2. Select **Play** () to begin recording data.
3. Follow temperature changes in your fingertips, registered on the computer's monitor, until it 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** ()

## Data Analysis

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

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

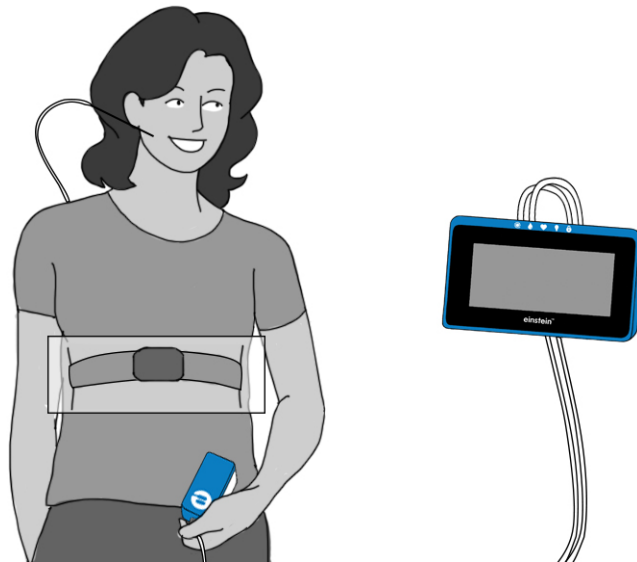


Figure 1



## Introduction

During exercise, your muscles need more energy. They produce this energy by burning glucose or fat which produces heat. Yet, body core 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™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- Surface temperature Sensor (-40°C to 140°C)
- Heart Rate Sensor
- sensor cable
- Saline solution



## 123 Equipment Setup

1. Launch MultiLab ().
2. Connect the Temperature Sensor and the Heart Rate sensor to the ports of the einstein™Tablet or einstein™LabMate.
3. Enable each sensor by selecting the circle () to the left of the appropriate sensor.

## Data Logger Setup

<b>Surface temperature (-40°C to 140°C)</b>	
Rate:	25 samples per second
Duration:	200 sec
<b>Heart Rate (0 – 240 bpm)</b>	
Rate:	25 samples per second
Duration:	200 sec

## 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 on the back side of the belt with 4 drops of saline solution.
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** (.



## 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 CO<sub>2</sub> Exhaled in Human Respiration

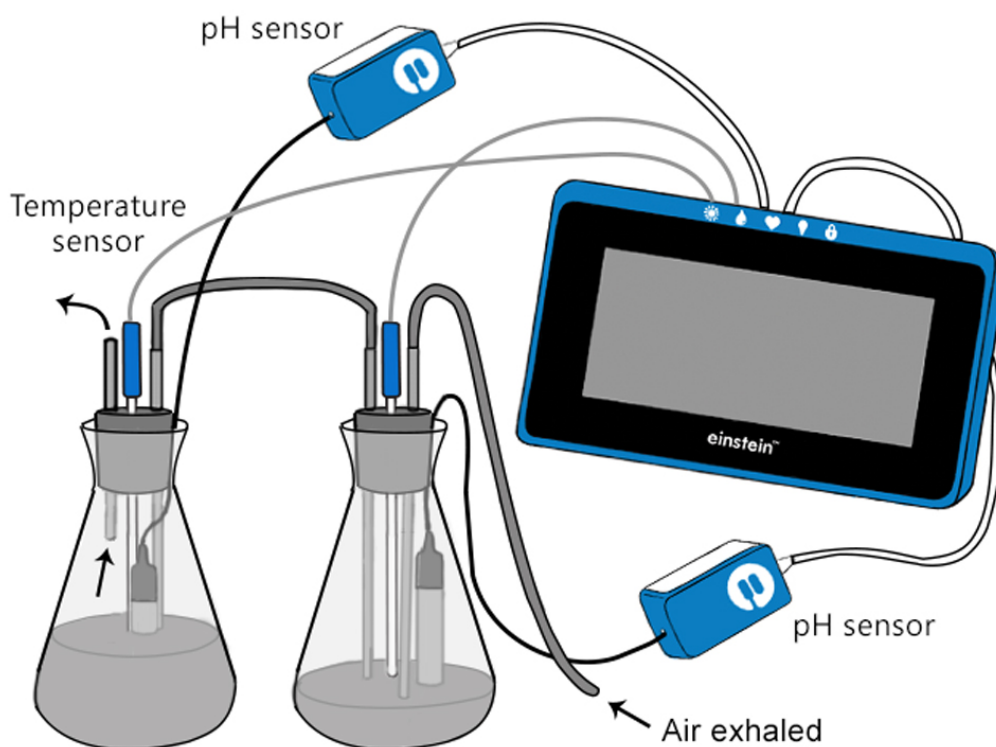


Figure 1



### Introduction

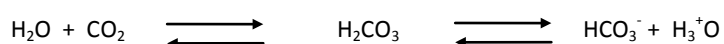
The respiratory system has two main roles: exchanging oxygen for CO<sub>2</sub> in the blood and maintaining stable blood pH through regulation of the CO<sub>2</sub> level.

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 exhale, 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 8L air volume (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.

CO<sub>2</sub> concentration in the atmosphere is very low, only 0.03%. In the lungs, however, the concentration rises up to 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 CO<sub>2</sub> in water leads to the following reaction:



H<sub>3</sub><sup>+</sup>O ions react with the NaOH and change the pH of the solution. The amount of CO<sub>2</sub> exhaled during one minute is determined by using a pH Electrode.




## Equipment

- einstein™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- 2 pH Sensors
- 2 sensor cables
- 2 Temperature Sensors\* (-40°C to 140°C).
- CO<sub>2</sub> Sensor (optional)
- 2X500 ml flasks
- 2 stoppers
- Short tube (6 cm long)
- 2 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)
- 2X30 cm silicon pipes
- 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 MultiLab ()
2. Connect the pH sensors and Temperature sensors to one of the ports of the einstein™Tablet or einstein™LabMate.
3. Ensure that only the Temperature and pH sensors are selected.
4. Add 200 ml tap water to the first flask (the flask into which you directly exhale air).
5. Add 400ml tap water to the second flask (this is a CO<sub>2</sub> trap: CO<sub>2</sub> that does not dissolve in the first flask will reach the second flask through the connecting pipe. This CO<sub>2</sub> will be dissolved in the second flask, containing a larger volume of solution).
6. Add 1 ml of 0.5% phenolphthalein solution to each flask and then 1.0 ml of 0.04% NaOH solution. Mix well.



## Data Logger Setup



<b>pH Sensor</b>	
Rate:	Every 1 sec
Duration:	1000 sec
<b>Temperature Sensor (-40°C to 140°C)</b>	
Rate:	Every 1 sec
Duration:	1000 sec



## Procedure

1. In this experiment, two flasks serve to trap CO<sub>2</sub> exhaled during respiration. Air is exhaled through a silicon pipe directly connected to the first flask. Air exhaled will reach the long tube of this flask through a silicon pipe.
2. The other flask is used to trap CO<sub>2</sub> that did not dissolve in the first flask. The long tube of this flask is connected with a silicon pipe to the short tube of the first flask.
3. A pH electrode is inserted to 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 CO<sub>2</sub> 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 CO<sub>2</sub> Sensor and insert in its groove the pH electrode cable and the long pipe.

Follow changes in the indicator's color in 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 successively for 30 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 CO<sub>2</sub> level with the sensor, when the CO<sub>2</sub> starts to rise), stop breathing through the pipe. Let the pH stabilize in the flasks for about 30 seconds. Then take the stopper and the CO<sub>2</sub> 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). You can use a burette to facilitate the titration of the CO<sub>2</sub> by 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** (  ).



## Data Analysis

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

1. Calculate the pH change obtained in each flask. Use the cursors to find the appropriate values.  
An example of the graph obtained in this experiment is shown below:

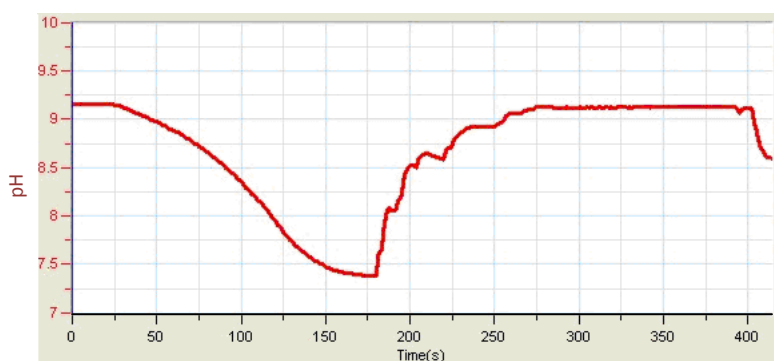


Figure 2

2. To find the amount of CO<sub>2</sub> 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 CO<sub>2</sub>.
3. To calculate the total amount of CO<sub>2</sub> 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 receive the amount of CO<sub>2</sub> exhaled *in one minute*.  
CO<sub>2</sub> exhaled *in one minute* (μmoles) = total volume of 0.04% NaOH x 10 x 2.  
The molecular weight of CO<sub>2</sub> is 44 g.  
Weight of CO<sub>2</sub> exhaled *in one minute* (μg) = Amount of CO<sub>2</sub> in μmoles x 44.  
If CO<sub>2</sub> was released to the free air and measured by the sensor, add this amount to the total amount of CO<sub>2</sub> (400 ppm = 72 μg CO<sub>2</sub>).
4. Calculate an average of your results: the number of times you take a breath in a minute and the amount of CO<sub>2</sub> 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 CO<sub>2</sub> 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 CO<sub>2</sub> exhaled. Explain.



## Further Suggestions

1. Compare the amount of CO<sub>2</sub> 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 CO<sub>2</sub> exhaled by males and females.
3. Compare the amount of CO<sub>2</sub> 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

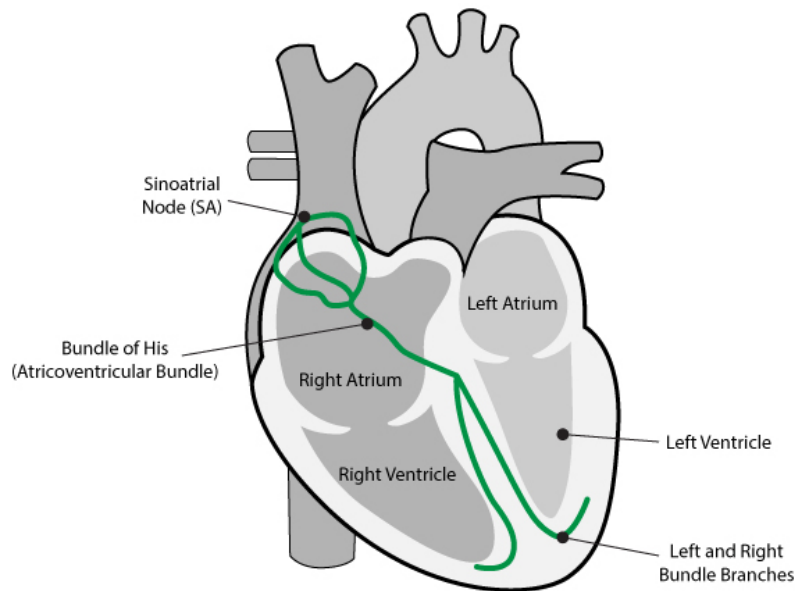


Figure 1



### Introduction

The EKG (Electrocardiogram) is a process 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 arise 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 muscle, and can be seen as muscle artifacts if 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™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- EKG Sensor
- 1 sensor cable
- 3 EKG electrode patches



## Experiment Setup

1. Launch MultiLab ()
2. Connect the EKG Sensor and the Spirometer to the ports of the einstein™Tablet or einstein™LabMate.

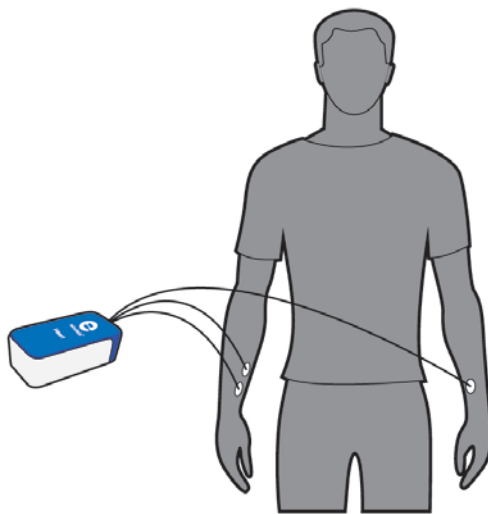
3. Enable each sensor by selecting the circle (●) to the left of the appropriate sensor.

## Data Logger Setup

### EKG (0 - 5 V)

Rate:	100 samples per second
Duration:	50 sec

## Procedure



Apply the three EKG Electrodes:

1. 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.
2. Peel three electrode patches from the backing paper. Firmly place the first electrode on the right wrist.
3. Place a second electrode a few centimeters above the first one.
4. Place a third electrode on the inside of the left wrist.
5. 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.
6. Connect the micro-alligator clips of the three sensor's leads to the tabs on the edges of the electrode patches.
7. Connect the two leads labeled R.A. (right arm) to the right arm electrode patches.
8. Connect the lead labeled L.A. (left arm) to the left arm electrode patch.
9. Assume a comfortable position, so that during measurement you won't need to move. The electrodes are very sensitive to motion.
10. Select **Run** (●) to begin recording data.
11. Save your data by Selecting **Save** (↓).
12. Perform some exercise and then repeat steps 2-9.

## Data Analysis

For more information on working with graphs see: **Working with Graphs in MiLAB**  
See sample graphs below.

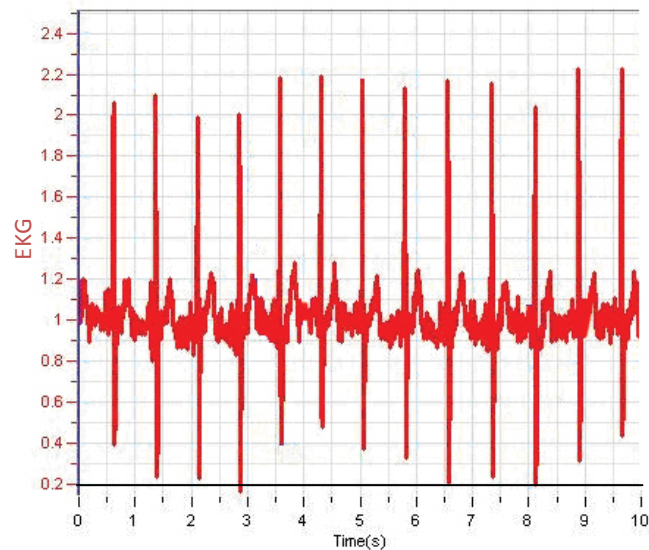


Figure 2

1. Calculate the heart rate in the two positions (*rest* and *after exercise*).  
Place one cursor at the beginning of one heart cycle and a second after 10 heart cycles.

For example, from the graphs in Figure 3 above, we calculated the heart rate in:

**The rest position:**

$$1/dt = 0.13 \text{ Hz} \times 600 = 78 \text{ beats/min}$$

**And in the after exercise position:**

$$1/dt = 0.19 \text{ Hz} = 114 \text{ beats/min}$$

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

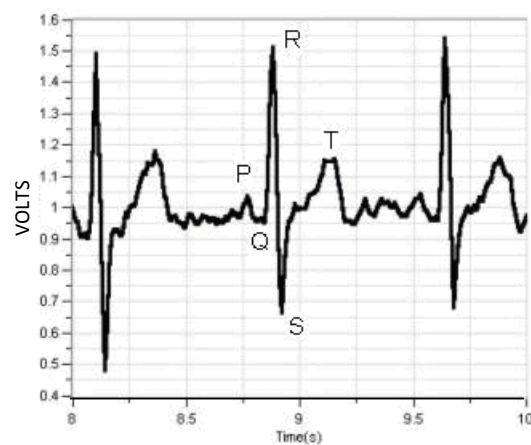


Figure 4

With the aid of the cursors make the following measurements (see Figure 4):

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 bodies during the activities.

## Impact of Crowded Urban Areas on Microclimate

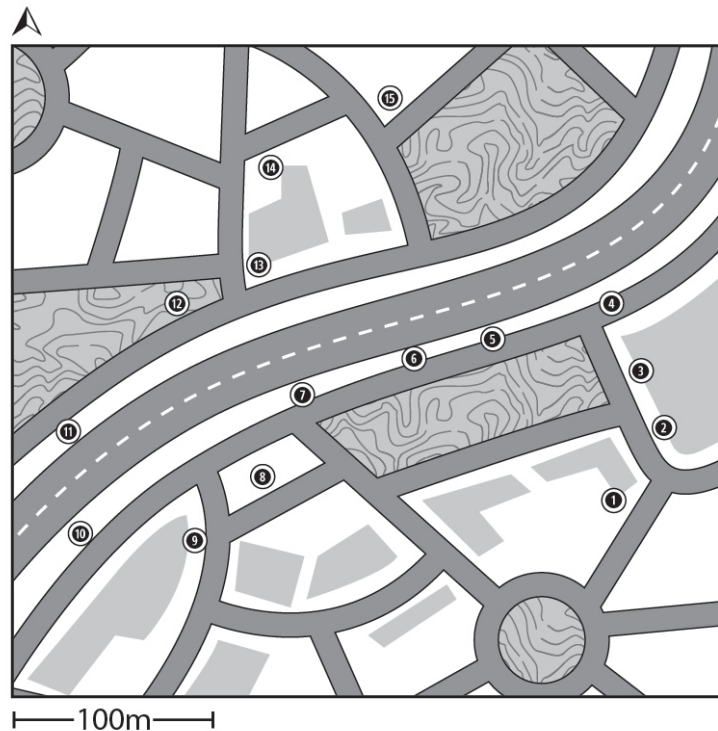


Figure 1: Route and Stops on a park map



### 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 the effects crowded urban areas with heavy traffic and compare them to urban parks in terms of temperature and relative humidity.




## Equipment

- einstein™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- Temperature Sensor (-40°C to 140°C)
- Humidity Sensor
- 2 sensor cables
- 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 Temperature and Humidity Sensors inside the Radiation Shield.
2. Attach the Radiation Shield to the top end of the pole.
3. Launch MultiLab ()
4. Connect the Humidity Sensor and the Temperature Sensor to the ports of the einstein™Tablet or einstein™LabMate.
5. Ensure that only the Humidity sensor and Temperature sensor are enabled.





## Data Logger Setup

<b>Humidity</b>	
Rate:	10 / sec
Duration:	1 sec
<b>Temperature (-40°C to 140°C)</b>	
Rate:	10 / sec
Samples:	1 sec



## Procedure

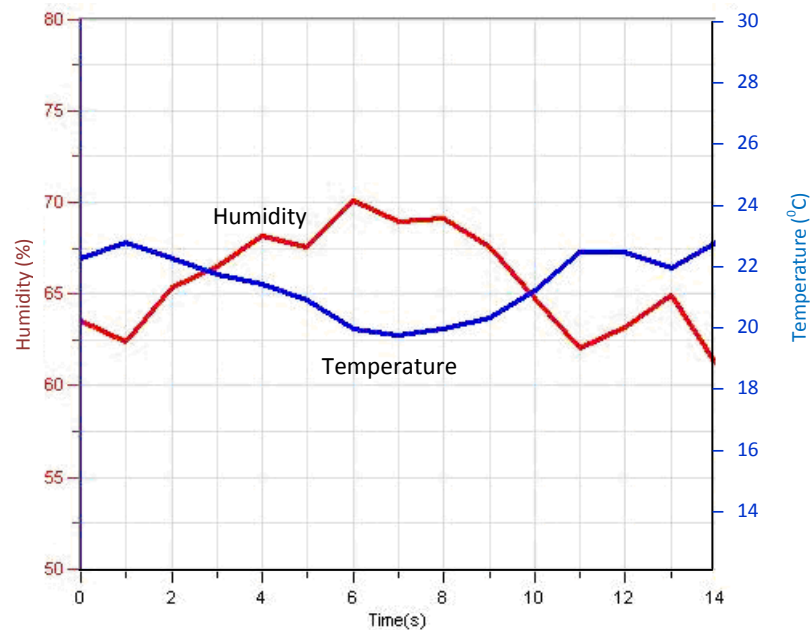
1. Choose at least two sites at the outskirts of the city or by the seashore.
2. On the map, draw a route that passes through a built-up area on either side of the green area and also through the center of the green area itself. The line need not be straight. It could, for example, follow a road. In 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. Wait 60 seconds and Select **Run** () to collect the first data sample.
5. Walk to *Location #2*. Wait 60 seconds and collect the second data sample: Select **Run** ()

6. Repeat the manual recording procedure for each location. Wait 60 seconds and Select **Run** (🎮) to record the data sample.
7. After recording data at the last station Select **Stop** (⏏) to stop the data recording.
8. Save your data by Selecting **Save** (💾).

## Data Analysis

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

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. road canyons, junctions, main road, side road, grass, trees, etc.
3. Compare the results of 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 residence 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 Thermocouple Temperature Sensor and change the recording rate to 1/s. 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 Thermocouple Temperature Sensor and change the recording rate to 1/s. Walk slowly and stand on the doorstep of an air-conditioned store. Move close to the outlet 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

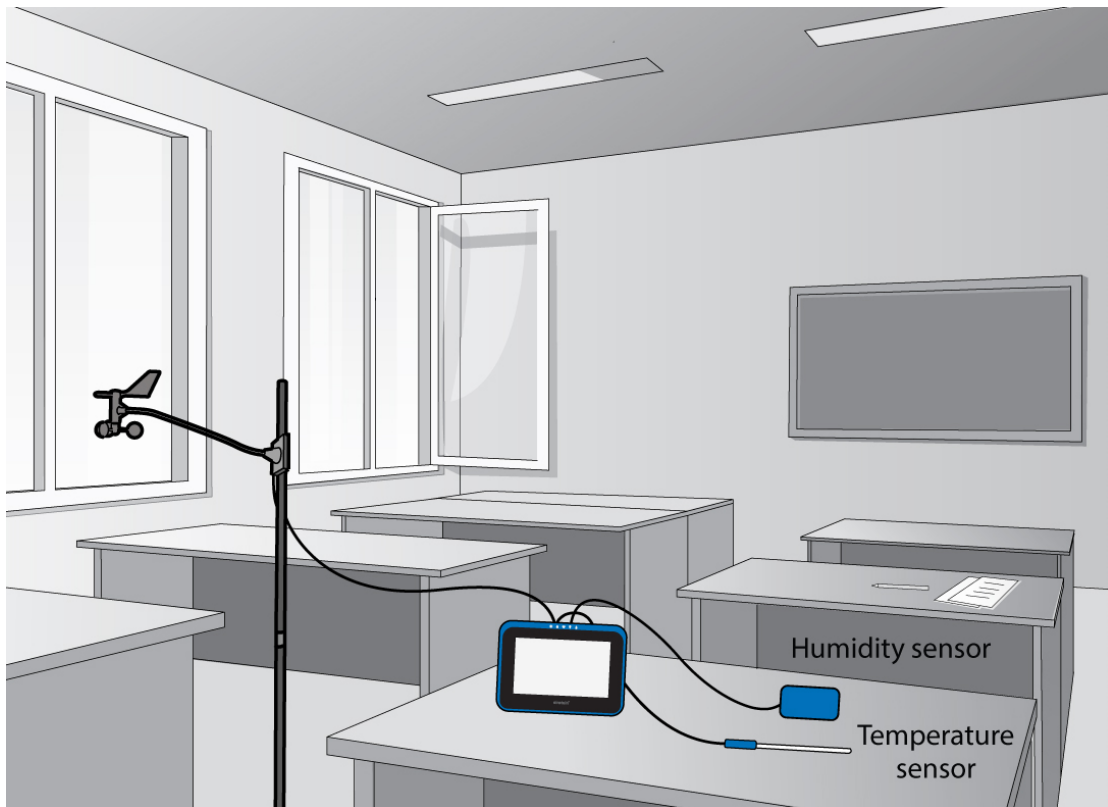


Figure 1: meteorological station situated in a suitable classroom



## 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™ Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™ LabMate
- Temperature Sensor (-40°C to 140°C)
- Humidity Sensor
- 4 cable sensors
- Anemometer




## 123 Equipment Setup

1. Choose a classroom that has at least two openings 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 MultiLab ()
5. Connect the Humidity and Temperature sensor to the ports of the einstein™ Tablet or einstein™LabMate.
6. Ensure that only the Temperature, Humidity and Anemometer sensors are enabled.

## Data Logger Setup

<b>Humidity</b>	
Rate:	Every 1 min
Duration:	6000 sec
<b>Temperature (-40°C to 140°C)</b>	
Rate:	Every 1 minute
Samples:	6000 sec

## 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** ()

## Data Analysis

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

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:  

$$(\text{Dry bulb temperature} + \text{wet bulb temperature}) / 2$$
 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™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- 2 Thermocouple Sensors (T/C-K, 0°C to 1250°C)
- 2 sensor cables
- White sticky tape

123

## Equipment Setup

**Note:** If only one einstein™Tablet or 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 AC/DC adapter is connected to the einstein™Tablet or 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 a Thermocouple Temperature Sensor in the center of each exterior and interior wall. Use the white sticky tape to keep it in place.
3. Connect the AC/DC adapter to the einstein™Tablet or einstein™LabMate.
4. Launch MultiLab ()
5. Connect the two Thermocouple sensors to the ports of the einstein™Tablet or einstein™LabMate.
6. Ensure that only the Thermocouple sensors are enabled.



## Data Logger Setup




Temperature (T/C-K, 0°C to 1250°C)

Rate: Every 10 min

Duration: 60000 sec



## Procedure

1. Select **Run** (  ) to begin recording data.
2. After six hours, stop recording. Select **Stop** (  ).
3. Save your data by Selecting **Save** (  ).
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 MiLAB**

1. Label the curves for the interior and exterior measurements on each of the three graphs that have been produced:
  - a. Choose each curve with the cursor.
  - b. Select **New annotation** and in the **Edit caption** edit box enter the name of the curve and Select **OK**.
2. Analyze these graphs with the help of the cursors.
3. 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

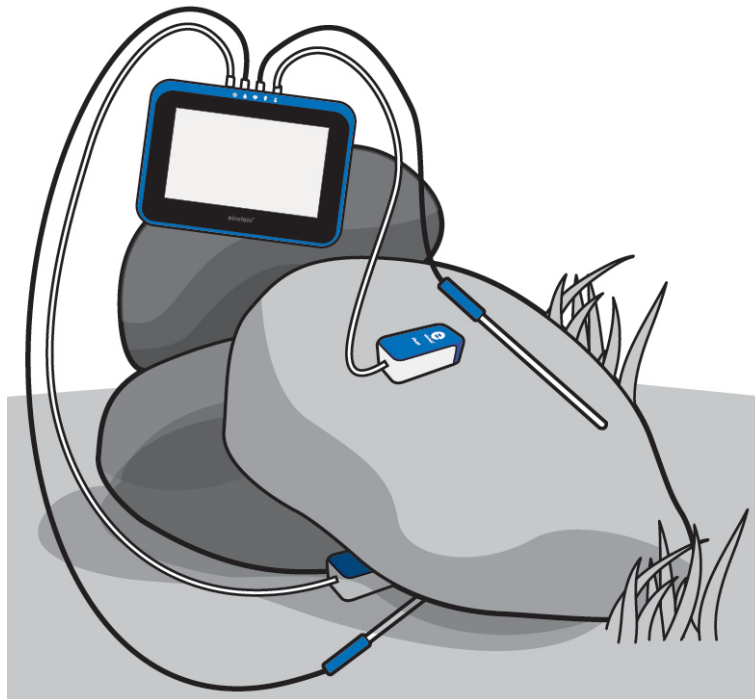


Figure 1



## 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™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- 2 Temperature Sensors (-40°C to 140°C)
- 2 Triple Range Light Sensors
- 2 sensor cables
- Adhesive tape
- Tape measure



## Equipment Setup

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

1. Launch MultiLab (.
2. Connect the Temperature sensors and the Light Sensors to the ports of the einstein™Tablet or einstein™LabMate™.
3. Ensure that only the light and Temperature sensors are enabled.
4. Assemble the equipment as illustrated in Figure 1.

**Note:** Dangerous animals, such as poisonous snakes and spiders maybe present in the habitat being studied.  
Don't place the Light Sensor under the rock.  
Take security and safety precautions when leaving the einstein™Tablet or einstein™LabMate in the field.



## Data Logger Setup




<b>Temperature (-40°C to 140°C)</b>	
Rate:	Every 10 sec
Duration:	5000 sec
<b>Triple Range Light</b>	
Rate:	Every 10 sec
Samples:	5000 sec





## Procedure

While surveying the area where you are going to perform this experiment, look for a rock with these characteristics:

1. The rock's length and width should be 20 – 40 cm.
2. The rock should not be tightly lodged in the soil.
3. The base should consist of small hollows that can easily support the necessary sensors.
4. It should be exposed to direct light radiation.
5. Turn the rock over and quickly place the Temperature Sensor (connected to the einstein™Tablet or einstein™LabMate ports) beneath it. Put the rock back in its initial position. Place the Light Sensor (connected to the einstein™Tablet or einstein™LabMate ports) on the ground near, but not under the rock.
6. Attach the additional Temperature sensor and Light sensor to the surface of the rock (connected to the einstein™Tablet or einstein™LabMate ports). Use adhesive strips of tape to ensure stable positioning of the sensors.
7. The actual Temperature Sensor is located in the tip of the probe. Make sure this part of the probe touches the surface of the rock.
8. Attach the Light sensor to the rock in the direction in which maximal readings are obtained.
9. Place your Tablet or einstein™LabMate in a stable position.
10. Select **Run** (  ).
11. While running the data logger, 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.
12. After 45 minutes to an hour, when sufficient data is collected, Select **Stop** (  ) to stop logging data.
13. Save your data by Selecting **Save** (  ).



## Data Analysis

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

1. Mark the course of changes in temperature and light intensity occurring on the surface and beneath the rock. Use the cursors 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 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 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.

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

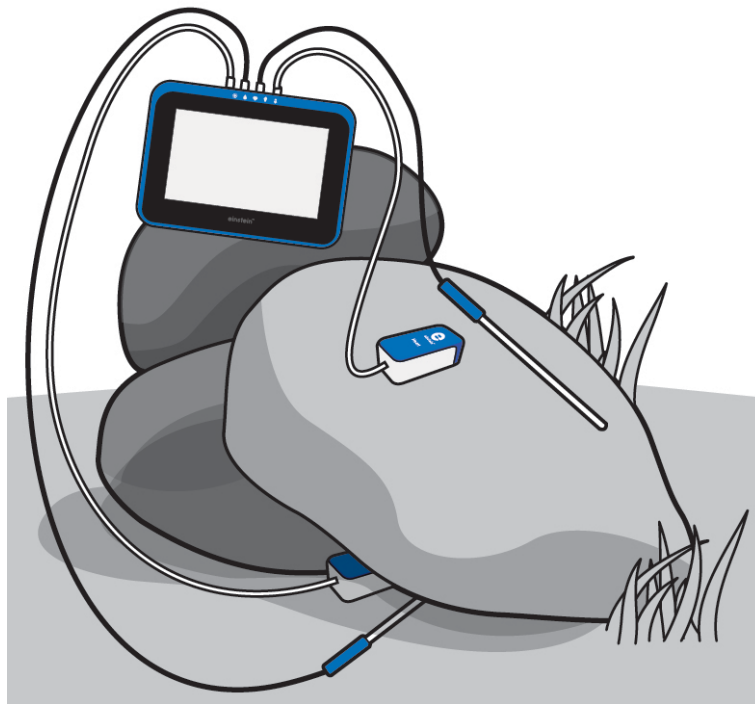


Figure 1



## 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 diurnally 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™Tablet with MiLAB or Android /IOS Tablet with MiLAB and einstein™LabMate
- 2 Temperature Sensors (-40°C to 140°C)
- 2 Humidity Sensors
- 2 sensor cables
- Adhesive tape
- Tape measure




## Equipment Setup

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

1. Launch MiLAB (.
2. Connect the Temperature Sensors and the Humidity Sensors to the ports of the einstein™Tablet or einstein™LabMate.
3. Ensure that only the Temperature and Humidity sensors are enabled.
4. Assemble the equipment as illustrated in Figure 1.

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

Enable each sensor by selecting the circle () to the left of the appropriate sensor. Then, choose the appropriate rate & samples as specified below.



## Data Logger Setup

### Temperature (-40°C to 140°C)

Rate: Every 10 sec

Duration: 10000 sec




### Humidity

Rate: Every 10 sec

Samples: 10000 sec



## 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 (connected to the einstein™Tablet or einstein™LabMate port) beneath it. Make sure to return the rock to its initial position. Place the Humidity Sensor (connected to the einstein™Tablet or einstein™LabMate port) on the ground near but not under the rock.
3. Attach the additional Temperature Sensor and Humidity Sensor (connected to the einstein™Tablet or einstein™LabMate ports) to the top of the rock. Use adhesive strips of tape to ensure stable positioning of the sensors.
4. The actual Temperature Sensor is located in the tip of the probe. Make sure this part of the probe touches the surface of the rock.
5. Place the einstein™Tablet or einstein™LabMate in a stable position.
6. Select **Run** (  ).
7. While running the data logger, 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.
8. When sufficient data is collected, Select **Stop** (  ) to stop logging data.
9. Save your data by Selecting **Save** (  ).



## Data Analysis

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

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](http://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](http://www.FourierEdu.com)

[Info@fourierEdu.com](mailto:Info@fourierEdu.com)