

Chapter 8

The Use of Macintosh Computers and Maclab Data Acquisition Units in a Human Cardiovascular Lab.

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Notes for the Instructor

Introduction

The first part of the present laboratory uses spirometry to examine the effects of gravity on student lung volumes. It is designed to show the larger tidal volume when the student is standing (compared with laying down) due to the closing of capillaries in the apex of the lung. This exercise is used in laboratories for non-science majors and for science majors in introductory animal or human physiology courses; the major constraint is equipment availability.

The second part of the laboratory attempts to correlate heart activity with breathing. Cardiac function can be monitored by measuring the student's electrocardiogram or finger pulse. The latter gives the advantage that the students can also examine the effects of gravity on peripheral blood flow by measuring the flow volume with the hand at the hip and heart level, and elevated above the head. The second portion of the laboratory is open-ended, and allows students to examine topics like the effects of breathing rate and depth on heart function, the effects of exercise, and the effects of re-breathing air—extreme caution should be used by students who elect to breath air with increased carbon dioxide and decrease oxygen levels.

Materials

MacLab data acquisition unit
 Bellows with disposable mouthpieces.
 Displacement transducer
 Bridge preamplifier
 Differential amplifier, set of EKG leads and cream, or plethysmograph

Student Outline

Objectives

The present laboratory exercise introduces certain physiological properties of human breathing. In addition to measuring the influence of body position on the different lung volumes, you will study the effects of exercise on the rate and depth of breathing, and the changes in heart rate during respiration.

Background

Respiration is the process by which gasses are exchanged between the environment and the cell. In animals, respiration involves acquiring oxygen and the expulsion of carbon dioxide. The term respiration can be applied to a single cell in the body or to the body as a whole. In the present laboratory you will examine certain physiological properties of the human respiratory system.

The human respiratory system consists of a series of tubes which branch and terminate as clusters of small membranous air sacs or alveoli. Gaseous exchange takes place across the alveolar wall; according to Fick's Law the structure of the alveoli make them ideal for diffusion. Ventilation of the human lung is achieved by muscular activity, which changes the volume of the thoracic cavity. This change in thoracic volume is conveyed to the lungs by the fluid-filled pleural cavity.

Breathing is controlled by the "Respiratory Control Center" located in the medulla of the brain. The rate and depth of breathing can be altered by many factors including changes in the levels of oxygen and carbon dioxide, and pH of the arterial blood. These factors combine to control the rate and depth of ventilation.

It is important to remember that ventilation is a major factor affecting body oxygen and carbon dioxide levels and it can quickly change blood pH. Ventilation rate can be influenced by many factors, including emotion, speech, disease, and our position relative to gravity. This latter factor will be examined in the present lab exercise. Furthermore, the effects of exercise on breathing rate and depth will be studied, as well as the variation in the heart rate during the breathing cycle and during times of respiratory distress (optional).

Equipment

The following equipment will be used in the present experiment:

MacLab data acquisition unit

Bellows with a disposable mouthpieces.

Displacement transducer

Bridge preamplifier

Differential amplifier, set of EKG leads and cream, or plethysmograph

Equipment set-up

Set-up the equipment as shown in Figure 8.1:

1. Use a BNC cable to connect the output of the bridge amplifier to channel 1 (+) on the MacLab unit.
2. Connect the displacement transducer to the input of the bridge amplifier.
3. Connect the movable arm of the displacement transducer to the bellows.
4. Connect the Mac to the MacLab and to the printer.
5. Plug in and turn on the MacLab and the bridge preamplifier.

Opening MacLab CHART

Before starting the experiment, proceed as follows:

1. Click on the "Chart" button (in lower left margin of the computer screen) to open the CHART program.
2. CHART has been set up so that:
 - only channels 1 & 2 are open.
 - the range (gain) of Channel 1 is 2V (range)
 - the chart speed is 2 sec/Div
 - the Samples/Div is 200.
3. In the FILE menu, drag to SAVE AS and name your file and click on save.
4. Drag to HyperCard in the *Applications* icon to display the instructions.

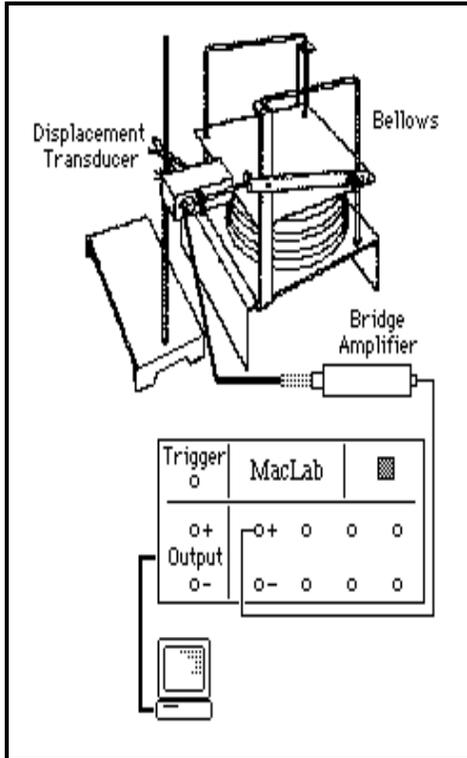


Figure 8.1. the Equipment.

Methods

This section is divided into FIVE parts:

1. Helpful hints and practice
2. Calibration of the bellows
3. Pulmonary volumes—measurement and effects of body position:
 - a. Respiratory rate and tidal volume
 - b. Expiratory Reserve Volume
 - c. Inspiratory Reserve Volume
 - d. Vital capacity
4. Exercise
5. Breathing and heart function
 - a. Heart rate and the breathing cycles
 - b. Heart rate and O_2 availability

NOTE: In this exercise one of your group will be the “subject” and the other will be the experimenter.

Please do NOT volunteer if you have any respiratory or cardiac problems, or if you are not feeling well.

Helpful Hints.

1. Start all experiments with the bellows half inflated.
2. The subject should NOT look at CHART during the experiment.
3. Unless instructed otherwise, do NOT breathe into the bellows for more than 1 minute.
4. Use the Input Amplifier (Figure 8.2) to practice the experiment. When you are comfortable with the procedure make a record in CHART

NOTE: this procedure will decrease “unwanted” data from your recordings.

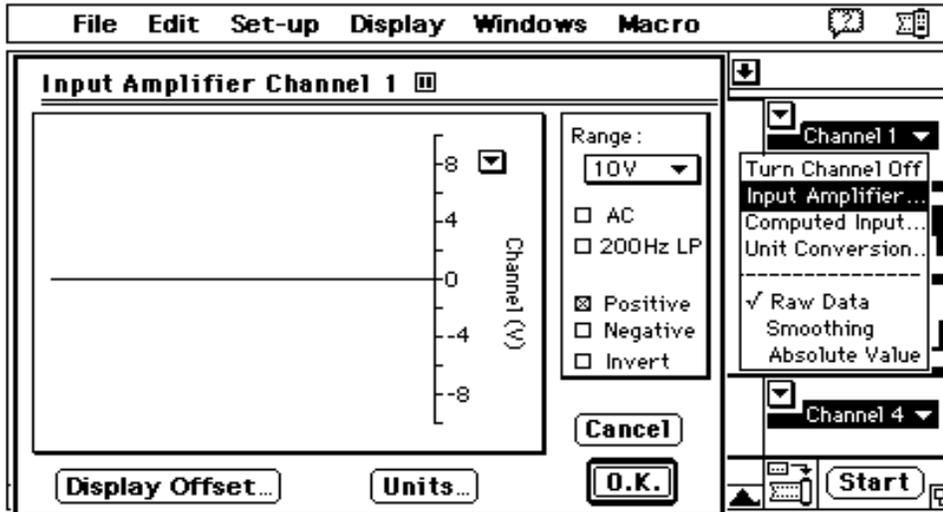


Figure 8.2. The Input Amplifier in CHART. 1) Click in the arrow to the RIGHT of the Channel title (“Channel 1” in the above diagram) and drag to Input Amplifier; 2) The Input Amplifier window shows a trace that can not be saved; 3) This option is useful for just looking at the trace or performing a “dry-run” prior to recording.

Calibration of the Bellows

1. Drag to CHART in the *Applications* icon to display your file on the screen.
2. Open the Input Amplifier (Figure 8.2) and adjust the POSITION control on the bridge amplifier to position the trace in the center of the screen.
3. Click on “OK” and then on “START”.
4. Blow 4 liters of air into the bellows using the scale on side of bellows—type “4 liter calibration”, depress RETURN on the keyboard and then click on “STOP”.
5. Scroll back through the record (using the arrows in the lower margin) and measure the deflection—it should between 800 and 1500 mV.

NOTE: The technique to make measurements is described in Appendix A

6. If the deflection is less than 800 mV, you may wish to change the length of the displacement arm and recalibrate the bellows system.

7. In the FILE menu, drag to SAVE and then drag to HyperCard in the *Applications* icon to display instructions.

The calibration for your system is

$$1 \text{ liter} = \frac{\text{trace deflection (volts)}}{4}$$

– make a note of this value.

Pulmonary Volumes—Measurement and Effects of Body Position:

A. Respiratory Rate and Tidal Volume.

1. Have the subject stand quietly for a few minutes.
2. Drag to CHART in the *Applications* icon.
3. Click on “START”, type “standing breathing” and depress RETURN. Record normal breathing for at least 5 complete respiratory cycles—it MAY be necessary to adjust the gain. Click on “STOP”.
4. Repeat with the subject lying on the bench—type “lying breathing” and depress return; click on “STOP”.
5. Make measurements as follows:
 - Scroll through your data to find the appropriate section or use the comments option in the WINDOWS menu—for both standing and lying.
 - Use the mouse to drag across and select a section of data.
 - Drag to Zoom Window in the WINDOWS menu (Figure 8.3).
 - Use the Marker and Cursor (Appendix A) to measure:
 - i. The time interval between successive waves; this represents the time interval between breaths. Calculate your breathing rate at rest.
 - ii. The amplitude of each wave (in millivolts); use your calibration and convert to volume—this is your tidal volume.
 - iii. Place the marker and cursor on a reasonably straight portion of the trace during inspiration. Read the voltage and time values. Convert the voltage value to volume and calculate the rate of air movement/second during inspiration.

Repeat for expiration; make these measurements for standing and lying.

6. In the FILE menu, drag to SAVE and then drag to HyperCard in the *Applications* icon to display instructions.

Questions:

- Is the tidal volume the same for the different body positions?
For each body position, calculate the amount of air passing through the lungs per minute as follows:
Tidal volume (liters/breath) \times Breathing rate (breaths/minute)
- Does the breathing rate compensate for the differences in tidal volume?
i.e. do you breathe faster in the body position with the lower tidal volume so that the amount of air passing through the lungs each minute is the same in each body position?

B. Expiratory Reserve Volume.

1. Have the subject stand quietly for a few minutes.
2. Drag to CHART in the *Applications* icon.
3. Click on “START”, type “exp. res. vol. - standing” and depress RETURN. The subject should breath normally for 3 respiratory cycles and then on the fourth should expire as much as possible. Click on “STOP”.
4. Repeat with the subject lying on the bench—type “exp. res. vol. - lying” and depress RETURN; click on “STOP”.

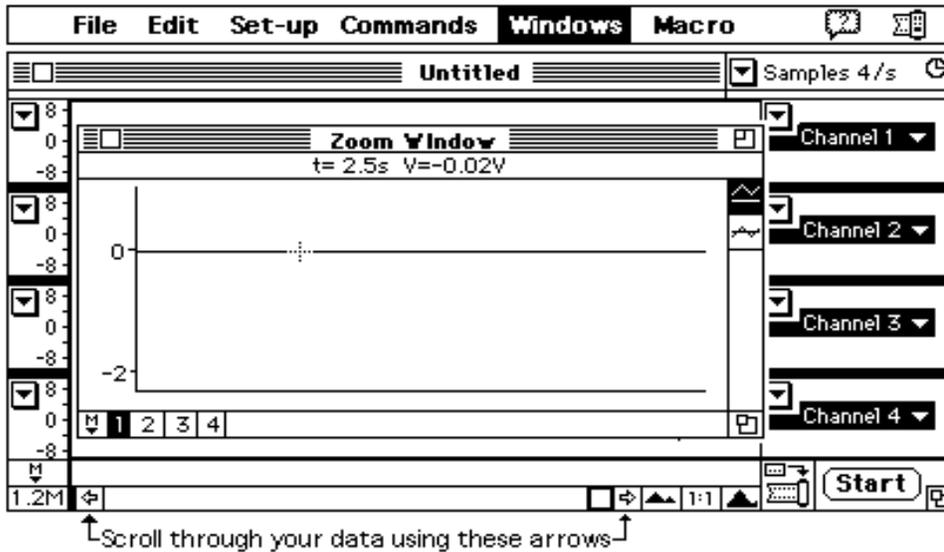


Figure 8.3. The Zoom Window in CHART. Selecting “Copy Zoom Window” in the Edit menu allows a “screen shot” to be pasted directly into word processing program.

5. Make measurements as follows:

- Scroll through your data to find the appropriate section or use the comments option in the WINDOWS menu—for both standing and lying.
- Use the mouse to drag across and select a section of data.
- Drag to Zoom Window in the WINDOWS menu (Figure 8.3).
- Use the Marker and Cursor (Appendix 1) to measure the amplitude of the expiratory reserve volume—from the expiration of the tidal volume to the fully expired level. Use the calibration and convert to volume—this is your expiratory reserve volume.

6. In the FILE menu, drag to SAVE and then drag to HyperCard in the *Applications* icon to display instructions.

Question: Is the expiratory reserve volume the same in the two body positions?

C. Inspiratory Reserve Volume.

1. Have the subject stand quietly for a few minutes.
2. Drag to CHART in the *Applications* icon
3. Click on “START”, type “insp. res. vol. - standing” and depress RETURN. The subject should breath normally for 3 respiratory cycles and then on the fourth should inhale as much as possible. Click on “STOP”.
4. Repeat with the subject lying on the bench—type “insp. res. vol. - lying” and depress RETURN; click on “STOP”.
5. Make measurements as follows:
 - Scroll through your data to find the appropriate section or use the comments option in the WINDOWS menu—for both standing and lying.
 - Use the mouse to drag across and select a section of data.
 - Drag to Zoom Window in the WINDOWS menu (Figure 8.3).
 - Use the Marker and Cursor (Appendix 1) to measure the amplitude of the inspiratory reserve volume—from the inspiration of the tidal volume to the fully inspired level. Use the calibration and convert to volume—this is your inspiratory reserve volume.

6. In the FILE menu, drag to SAVE and then drag to HyperCard in the *Applications* icon to display instructions.

Question: Is the inspiratory reserve volume the same in the two body positions?

D. Vital capacity

For each body position, calculate the vital capacity (add tidal volume, inspiratory reserve volume and expiratory reserve volume).

Now, directly measure vital capacity:

1. Have the subject stand quietly for a few minutes.
2. Drag to CHART in the *Applications* icon
3. Click on “START”, type “vital cap. - standing” and depress RETURN. The subject should breath normally for 3 respiratory cycles and then on the fourth should inhale and then expire as much as possible. Click on “STOP”.
4. Repeat with the subject lying on the bench—type “vital cap. - lying” and depress RETURN click on “STOP”.
5. Make measurements as follows:
 - Scroll through your data to find the appropriate section or use the comments option in the WINDOWS menu—for both standing and lying.
 - Use the mouse to drag across and select a section of data.
 - Drag to Zoom Window in the WINDOWS menu (Figure 8.3).
 - Use the Marker and Cursor (Appendix 1) to measure the amplitude of the expiratory reserve volume—from the expiration of the tidal volume to the fully expired level. Use the calibration and convert to volume—this is your expiratory reserve volume.
6. In the FILE menu, drag to SAVE and then drag to HyperCard in the *Applications* icon to display instructions.

Questions: Is the vital capacity you measured the same as the calculated value? Does this tell you anything about the accuracy of your measurements?

Exercise.

In this section you will measure whether the increase in air flow immediately after exercise is produced by increasing breathing rate, breathing depth, or both.

1. Have the subject stand quietly for a few minutes.
2. Drag to CHART in the *Applications* icon.
3. Click on “START”, type “resting” and depress RETURN. The subject should breath normally for about 5 respiratory cycles. Click on “STOP”.
4. Have the subject exercise to increase their respiration rate. Repeat #3 (above) but type “after exercise” and depress RETURN. Click on “STOP”.
5. Make measurements as follows:
 - Scroll through your data to find the appropriate section or use the comments option in the WINDOWS menu—for both standing and lying.
 - Use the mouse to drag across and select a section of data.
 - Drag to Zoom Window in the WINDOWS menu (Figure 8.3).
 - Use the Marker and Cursor (Appendix 1) to measure:
 - i. The time interval between successive waves; this represents the time interval between breaths. Calculate your breathing rate at rest.
 - ii. The amplitude of each wave (in millivolts); use your calibration and convert to volume—this is your tidal volume at rest.
 - iii. Repeat parts (i) and (ii) for the recording accumulated after exercise.

- In the FILE menu, drag to SAVE and then drag to HyperCard in the *Applications* icon to display instructions.

Questions:

- Does exercise change:
 - tidal volume?
 - breathing rate?
 - the volume of air passing through the air/minute (i.e. tidal volume x breathing rate)?

Examine the rate of air flow:

- at rest, does air flow faster during inspiration or expiration—from your knowledge of how you breath and gravity explain your results.
- are flow rates changed by exercise? Does one (inspiration or expiration) change more than the other compared with rest?

Breathing and Heart Function.

In this section you will correlate heart rate with breathing.

NOTE: This last section of the laboratory is designed to be open ended and encourages you to design your own experiments.

It is very important that you are careful. The bellows represents a potentially lethal hazard, since you are rebreathing air which has a higher level of CO₂ and a lower level of O₂ than fresh air.

EKG Equipment

- Use a BNC cable to connect the preamplifier output to Channel 2 (+) on the MacLab unit.
- Set the low frequency filter on the preamplifier to 0.1Hz, ∞100 gain and select AC coupling.
- Connect the EKG cable plug to the input on the front panel of the preamplifier. Do not force the plug—it only goes one way!
- Removing all jewelry and watches from the subject's hands and arms.
- Attach the three electrodes (metal plates) to the subject using the rubber straps as follows:
 - Place a small amount of EKG cream on a metal electrode—the cream helps conduction.
 - Attach the rubber strap to the electrode.
 - Attach an electrode to the UNDERSIDE of the left wrist (Figure 8.4).

Note: electrodes must be in contact with BARE SKIN—not over clothing!.

Repeat, to attach an electrode to the underside of the right wrist and to the left ankle.

- Attach the plugs on the end of the three wires as shown in Figure 8.4.
- Plug in and switch on the preamplifier.

Heart Rate and the Breathing Cycles

- Have the subject stand quietly for a few minutes.
- Drag to CHART in the Applications icon
- Select the Input Amplifier for Channel 2 and monitor the electrocardiogram (EKG)—adjust the range if necessary. Click on O.K.
- Click on START, type “breathing and EKG” and depress RETURN. The subject should breath SLOWLY and DEEPLY into the bellows.

Notice that the heart rate varies during the breathing cycle.

Type comments on the keyboard and depress the return.

- Other ideas:

try holding your breath when fully inspired.

try holding your breath when fully expired.

try breathing out, hold breath and depress the diaphragm—thus producing a large negative pressure in the thorax.

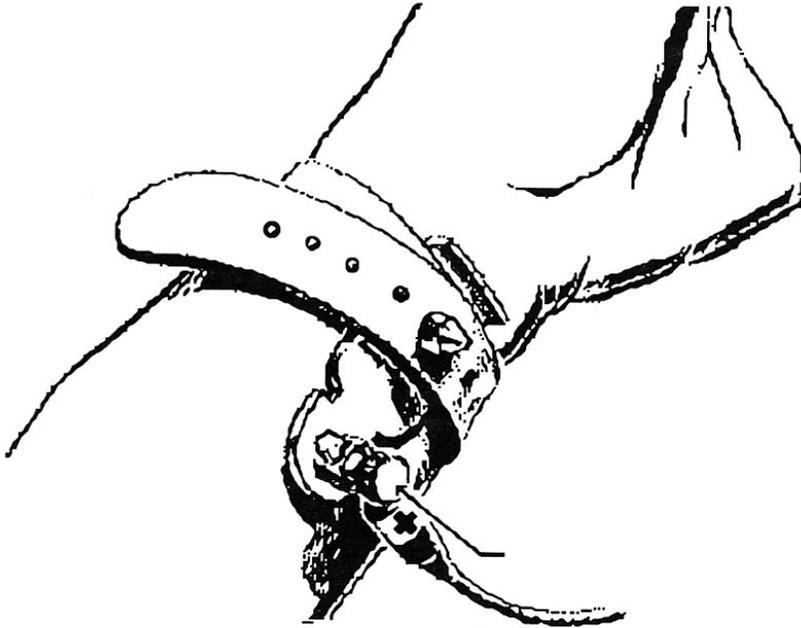


Figure 8.4. Attaching a Metal Electrode to the Wrist. Place the electrode pin through the hole and rotate the screw (arrow) until the pin is held securely in place.

Type comments on the keyboard and depress the return while recording data.

6. Click on "STOP" to stop the CHART.
7. Make measurements from your data to show how heart rate varies with breathing rate etc. Select regions of data and drag to Zoom Window in the Windows menu; Copy Zoom Window in the Edit menu and paste the "screen shot" into your word processing program (laboratory report). Use sufficient screen shots to illustrate any statements you make.
8. In the FILE menu, drag to SAVE and then drag HyperCard in the Applications icon to display instructions.

Heart Rate and O₂ Availability.

NOTE: The bellows is a closed system so the level of oxygen will slowly decrease and the level of carbon dioxide will slowly increase.

- This part of the experiment is *optional*.
- Do NOT perform if you have had problems.
- *Terminate immediately* if dizzy or sick.
- *Do not over achieve*.

1. Have the subject stand quietly for a few minutes.
2. Drag to CHART in the *Applications* icon
3. Type "rebreathing and EKG" and depress RETURN. The subject should breath normally into the bellows.

You should look for changes in heart rate and breathing rate and depth.

4. Click on "STOP" to stop CHART.
5. In the FILE menu, drag to SAVE and then drag to HyperCard in the *Applications* icon to display instructions.

Data Analysis and Presentation

In this section you can repeat or make measurements from the data in your file. At any stage, help can be found by clicking on the “MacLab analysis” button in the left margin of the computer screen. If you elected to perform data analysis at a time after the laboratory session, be aware that you can open your CHART file using any Macintosh computer with the appropriate software—the MacLab data acquisition unit is not required to open the file.

Pulmonary Volumes

Make a table or a graph to illustrate the different lung volumes and the effect of gravity.

Exercise

Make a table or a graph to illustrate the effect of exercise on breathing rate and depth. Also, calculate the volume of air exchanged/minute when at rest and after exercise.

Breathing and Heart Function

Show representative records of your data and explain why your heart rate changes under the imposed conditions.

Questions

1. Explain why average pulmonary volumes and capacities change with body position. Why do most values decrease when a person lies down?
2. Compare the vital capacity measurement you made with the value calculated from (expiratory reserve volume + tidal volume + inspiratory reserve volume). Are these values identical; if not, what does this tell you about measurement error?
3. What is the relationship between respiratory rate and tidal volume?
4. What type of factors would you expect to effect inspiratory and expiratory reserve volumes? What diseases might decrease these values?
5. Explain why changes are observed in respiratory rate during the rebreathing exercise. Did you observe changes in tidal volume? Explain.
6. What is the relationship between respiratory rate and heart rate?
7. How do blood gas levels relate to and effect respiratory and cardiac rates?
8. What happens to tidal volume, breathing rate, rate of expiration, rate of inspiration and heart rate during exercise? Can you explain why these changes take place?
9. Why are values obtained standing and lying not the same?

APPENDIX A
Making Measurements From CHART

Accurate measurements can be made with the marker and the cursor in either the CHART or the ZOOM Windows:

1. Drag the marker (M) in the lower left corner of the window (Figure 8.3) to a chosen point on the trace.
2. Move the mouse so that the cross-hairs of the cursor are on the second chosen point on the trace.
3. Read the difference in voltage and time (in the top margin of the Zoom Window or over the Channel title in the Chart Window).

The numbers represent the difference in voltage (vertical) and time (horizontal) between the two points.