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Biopac Student Lab® Lesson 8
RESPIRATORY CYCLE I
Introduction
Rev. 01152013

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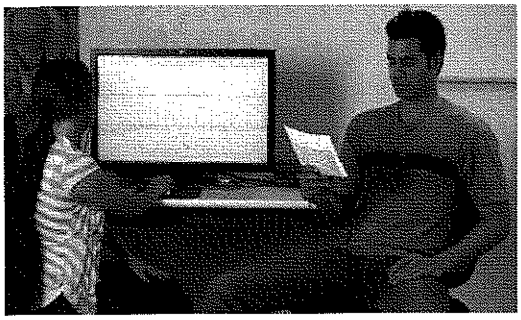

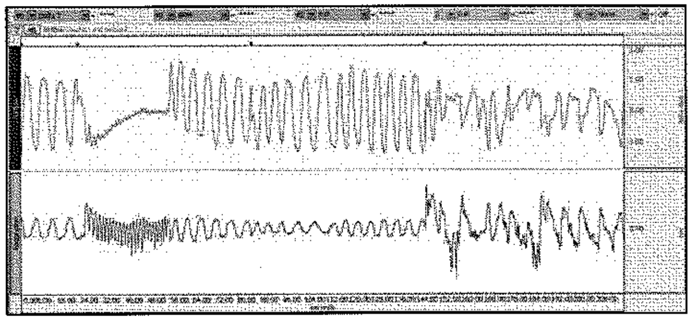

I. INTRODUCTION

Three primary functions of the respiratory system are to provide oxygen for the body's energy needs, provide an outlet for CO_2, and help maintain the pH of the blood plasma. The respiratory cycle serves these multiple purposes in conjunction with the circulatory system.

The mechanics of the respiratory cycle consists of alternating processes of **inspiration** and **expiration**. During inspiration, skeletal muscles (such as the diaphragm and external intercostals) contract, thereby increasing volume within the thoracic cavity and lungs. The increased volume creates less pressure within the lungs than the atmosphere, so air rushes into the lungs. During resting expiration, the inspiratory muscles relax, causing the volume of the thoracic cavity and the lungs to be reduced. This reduction forces gas back into the atmosphere. Normally, unlabored expiration at rest is a passive event determined by relaxation of inspiratory muscles. During exercise or during forced exhalation, e.g., coughing, expiration becomes an active event dependent upon contraction of expiratory muscles that pull down the rib cage and compress the lungs.

During inspiration, oxygen drawn into the lungs diffuses to the pulmonary capillaries and is transported to cells via erythrocytes (red blood cells). The cells use oxygen to supply energy for metabolic processes. When producing energy, these cells then release carbon dioxide as a waste product. Some of the carbon dioxide reacts with water in the body to form carbonic acid, which then dissociates to H^+ and bicarbonate. The erythrocytes transport CO_2 and H^+ back to the lungs. Once in the lungs, the H^+ and HCO_3^- recombine to form water and CO_2 (Fig. 8.1).

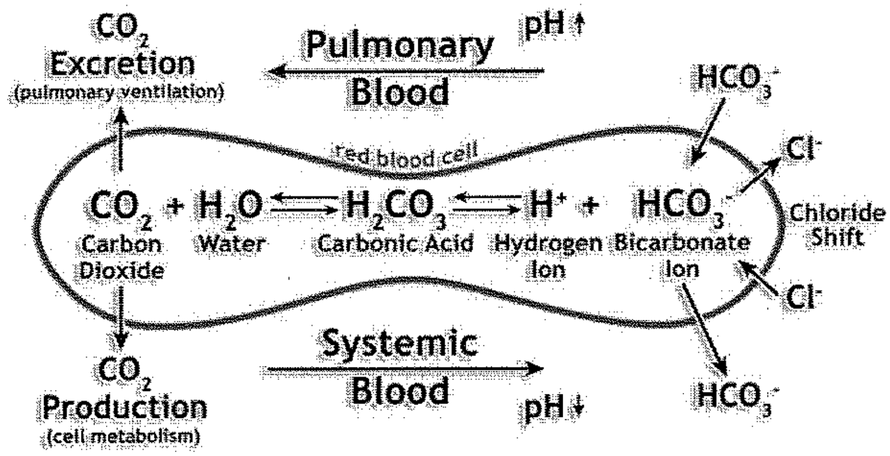

Fig. 8.1

Many factors are involved in the regulation of **ventilation**, the rate and depth of breathing. The basic **rhythm** of breathing is established by **inspiratory** and **expiratory** respiratory centers in the medulla.

- The inspiratory center initiates inspiration via activation of the inspiratory muscles. During normal, quiet breathing at rest (**eupnea**,) the average respiratory rate (RR) is 12-14 cycles/minute. The inspiratory center always acts to produce an active inspiration.
- In contrast, the expiratory center acts to limit and then inhibit the inspiratory center, thereby producing a passive expiration.

This basic breath pattern is affected by:

a) Higher centers in the brain.

b) Feedback from peripheral and central **chemoreceptors** in the arterial system and medulla, respectively.

c) Stretch receptors in the lungs.

d) Other sensory receptors in the body.

For example, cerebral control of the medullary respiratory centers is observed when a subject attempts to thread a needle. The cycle temporarily ceases in order to minimize body movement so that the needle may be threaded more easily. Cerebral control is also evident during speech, which requires expiratory air to pass over the vocal cords.

The separate chemoreceptors sense O_2, CO_2 and H^+ levels in the blood and in the cerebrospinal fluid of the medulla. In ***hyper*ventilation** (excess ventilation,) the breathing rate and depth is increased so that the lungs rid the body of carbon dioxide faster than it is being produced. Hydrogen ions are removed from body fluids and the pH becomes elevated. This tends to depress ventilation until normal carbon dioxide and hydrogen ion levels are restored. The temporary cessation of breathing after voluntary hyperventilation is known as *apnea vera*.

In ***hypo*ventilation** (insufficient ventilation - shallow and/or slow breathing) the lungs gain carbon dioxide in body fluids (*hypercapnia*) since the lungs fail to remove carbon dioxide as rapidly as it is being formed. The increased formation of carbonic acid results in a net gain of hydrogen ions, lowering pH in body fluids. The chemoreceptor feedback causes ventilation to increase until carbon dioxide levels and extracellular fluid pH return to normal.

In this lesson, you will measure ventilation by recording the rate and depth of the breathing cycle using a **pneumograph transducer**. This transducer converts changes in chest expansion and contraction to changes in voltage, which will appear as a waveform. One respiratory cycle will then be recorded as an increasing voltage (ascending segment) during inspiration and a decreasing voltage (descending segment) during expiration.

You will also use a temperature transducer to indirectly measure airflow from one nostril. Each inhale brings cooler air across the transducer, and each exhale blows warmer air across the transducer. The temperature of the air passing by the temperature probe is inversely related to the expansion or contraction of the Subject's chest. This indirect method is efficient when rate and relative amplitude measurements are all that's required; a direct airflow measurement requires more complicated equipment and data processing.

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II. EXPERIMENTAL OBJECTIVES

1) To record and measure ventilation utilizing pneumograph and air temperature transducers.
2) To show how ventilation relates to temperature changes in airflow through one nostril.
3) To observe and record chest expansion and contraction and modifications in the rate and depth of the breathing cycle due to cerebral influence and chemoreceptor influence on the medullary control centers.

III. MATERIALS

- BIOPAC Respiratory Transducer SS5LB (or older SS5LA or SS5L)
- BIOPAC Temperature Transducer SS6L
- BIOPAC Single-sided (surgical) tape (TAPE1)
- Chair without armrests
- Biopac Student Lab System: BSL 4 software, MP36 or MP35 hardware
- Computer System (Windows 8, 7, Vista, XP, Mac OS X 10.5 – 10.8)

IV. EXPERIMENTAL METHODS

A. SETUP

FAST TRACK Setup

1. Turn the computer **ON**.
2. If the MP36/35 unit is on, turn it **OFF**.
3. **Plug the transducers in** as follows:
   Respiratory* (SS5LB) — CH 1

   Temperature (SS6L) — CH 2
4. Turn **ON** the MP36/35 unit.
5. **Attach** the Respiratory Transducer (SS5L) around the **Subject's** chest (Fig. 8.3).

Setup continues...

Detailed Explanation of Setup Steps

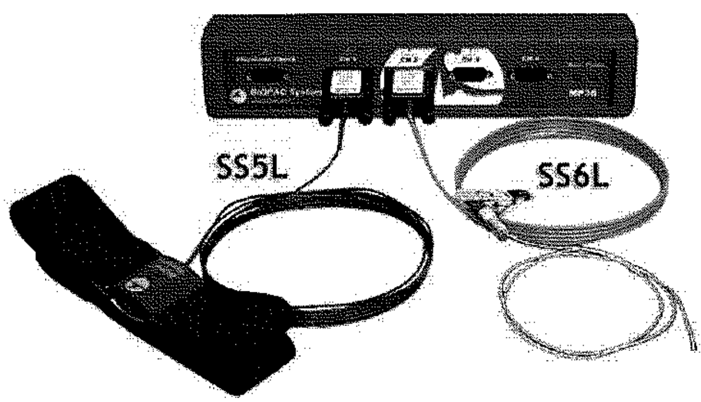

Fig. 8.2

* **Note**: The SS5LA Respiratory Transducer is shown in Fig. 8.2. You may have the SS5LB or SS5L, which both look a little different but function identically.

Transducer should be placed below the armpits and above the nipples.

Important: The tension must be slightly tight at the point of maximal expiration (chest contracted).

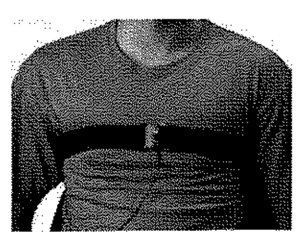

Fig. 8.3 SS5L Placement

If using the SS5LA, loop the nylon straps through the corresponding slots in the transducer to hold it in place when tightened (Fig. 8.4).

IMPORTANT:

The SS5LA is fragile. Do not pull hard on the ends of the rubber portion.

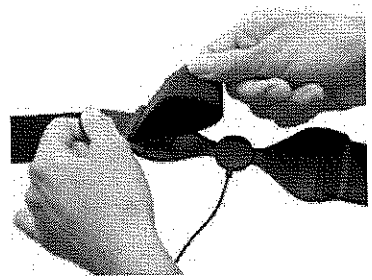

Fig. 8.4 SS5LA

6. **Attach** Temperature Transducer (SS6L) under **Subject's** nostril, taped to face (Fig. 8.5).

Place it such that the sensor tip is close to the nostril but not touching the skin. Create a small loop in the wire to help secure it when taped to the face.

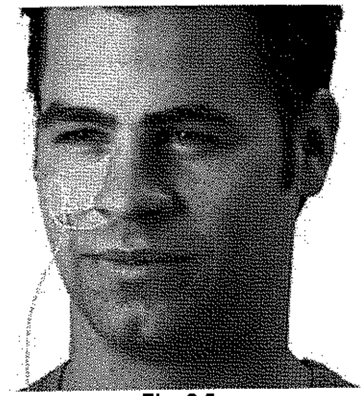

Fig. 8.5

7. **Start** the Biopac Student Lab Program.
8. Choose lesson **"L08 – Respiratory Cycle I"** and click **OK.**
9. Type in a unique **filename** and click **OK**.

Start Biopac Student Lab by double-clicking the Desktop shortcut.

No two people can have the same filename, so use a unique identifier, such as **Subject's** nickname or student ID#.

A folder will be created using the filename. This same filename can be used in other lessons to place the **Subject's** data in a common folder.

Important: The Respiratory Transducer model number must be specified in Lesson Preferences or the recorded signal may be out of too low or too high. See steps below.

10. *Optional*: Set Preferences.
    - Choose File > **Lesson Preferences**.
    - Select an option.
    - Select the desired setting and click **OK**.

This lesson has optional Preferences for data and display while recording. Per your Lab Instructor's guidelines, you may set:

Grids: Show or hide gridlines

Respiratory Transducer: Specify the model as SS5LB, SS5LA, or SS5L.

Lesson Recordings: Specific recordings may be omitted based on instructor preferences.

END OF SETUP

B. CALIBRATION

The Calibration procedure establishes the hardware's internal parameters (such as gain, offset, and scaling) and is critical for optimal performance. **Pay close attention to Calibration.**

FAST TRACK Calibration

1. **Subject** is seated and relaxed, breathing normally through nose (Fig. 8.6).
2. Click **Calibrate**.
3. Wait for Calibration to stop.
4. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to Data Recording.
   - If necessary, click **Redo Calibration**.

END OF CALIBRATION

Detailed Explanation of Calibration Steps

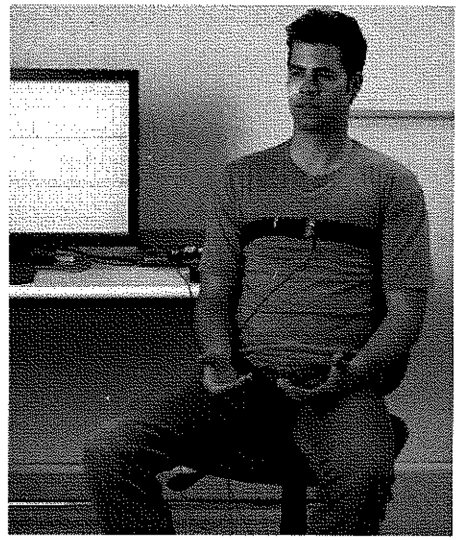

Fig. 8.6 Positioning

Subject must be seated in a chair, arms at side of body, hands apart in lap and knees flexed with feet supported.

Subject remains seated and relaxed, breathing through nose.

Calibration lasts eight seconds.

Both channels should show variations in the data.

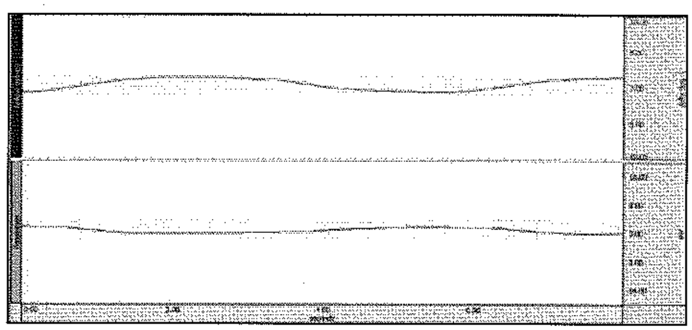

Fig. 8.7 Example Calibration data

If recording does not resemble Example Data…

- If data is noisy or flatline, check all connections to MP unit.
- If the "Airflow (temp)" channel does not show any variation, position Temperature Transducer closer to **Subject's** nostril.
- If Respiration channel does not show variation, verify Respiratory Transducer has not slipped and that strap is snug.

C. DATA RECORDING

FAST TRACK Recording

1. **Subject** is seated, relaxed, breathing through nose.
   - **Review** recording steps.

Detailed Explanation of Recording Steps

Four conditions will be recorded*: Normal breathing, Hyperventilation and recovery, Hypoventilation and recovery, and Coughing and then reading aloud.

*IMPORTANT
This procedure assumes that all lesson recordings are enabled in lesson Preferences, which may not be the case for your lab. Always match the recording title to the recording reference in the journal and disregard any references to excluded recordings.

Hints for obtaining optimal data:

- The Respiratory Transducer should fit snugly when the chest is contracted.
- Make sure the Temperature Transducer is firmly attached and does not move during recordings.
- Subject must sit upright with back straight.

Eupnea

2. Click **Record**.
3. Record for 20 seconds.
4. Click **Suspend**.
5. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to the next recording.
   - If necessary, click **Redo**.
   - If all required recordings are completed, click **Done**.

Subject remains seated, relaxed and breathing through nose.

Both channels should show cyclical variations in the data.

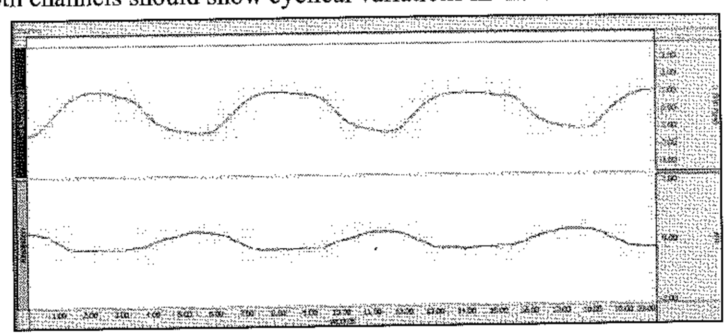

Fig. 8.8 Example Eupnea data

If recording does not resemble Example Data…

- If data is noisy or flatline, check all connections to MP unit
- If the "Airflow (temp)" channel does not show variation, verify Subject is breathing through nose. Reposition the Temperature Transducer if necessary.
- If Respiration channel does not show variation, verify Respiratory Transducer has not slipped and that strap is snug.

Click **Redo** and repeat Steps 2 – 5 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Recording continues…

Hyperventilation and recovery

- **Subject** remains seated and relaxed.
- **Review** recording steps.

6. Click **Record**.
7. **Subject** hyperventilates for 30 seconds, breathing rapidly and deeply through mouth and nose.

Record both hyperventilation and the initial recovery period.

8. **Subject** resumes breathing normally through nose.
9. Record for 30 seconds.

> **WARNING:**
> The **Director** must watch the **Subject** and stop the procedure if **Subject** starts to feel sick or excessively dizzy.

10. Click **Suspend**.
11. Verify recording resembles the Example Data.
    - If similar, click **Continue** and proceed to the next recording.

Use the horizontal scroll bar to look at different portions of the recording.

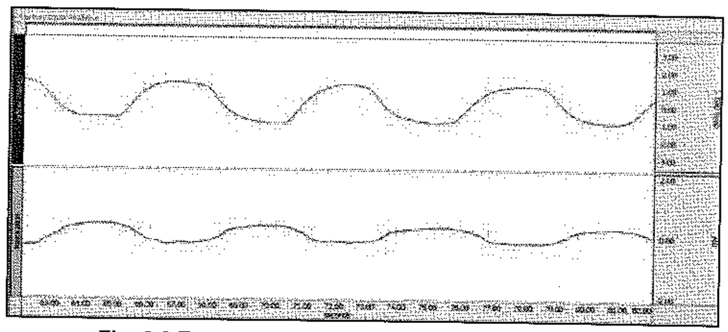

Fig. 8.9 Example Hyperventilation and recovery data

- If necessary, click **Redo**.
- If all required recordings have been completed, click **Done**.

The data might be different for the reasons detailed in Step 5.

Click **Redo** and repeat Steps 6 – 11 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Hypoventilation and recovery

- **Review** recording steps.

Important! **Subject** should NOT perform the next section until breathing has returned to normal.

12. Click **Record**.
13. **Subject** hypoventilates for 30 seconds.
14. **Subject** resumes breathing normally through nose.
15. Record for an additional 30 seconds.

Subject should breathe slowly and shallowly through the nose for a maximum of 30 seconds. Then, resume breathing nasally until a normal breathing pattern is reestablished.

Record both hypoventilation and the initial recovery period.

> **WARNING**
> The **Director** should watch **Subject** and stop the procedure if **Subject** starts to feel sick or excessively dizzy.

Recording continues…

16. Click **Suspend**.
17. Verify recording resembles the Example Data.
    - If similar to Fig. 8.10, click **Continue** and proceed to the next recording.

Use the horizontal scroll bar to view different portions of the data recording.

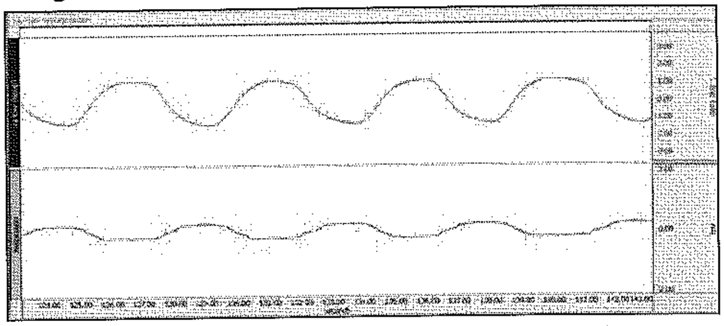

Fig. 8.10 Example Hypoventilation & recovery data

- If necessary, click **Redo**.
- If all required recordings have been completed, click **Done**.

The data might be different for the reasons detailed in Step 5.

Click **Redo** and repeat Steps 12 – 17 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Coughing and reading aloud

- **Director** provides reading material, such as Lab Manual.
- **Review** recording steps.

Important! **Subject** should NOT perform the next section until breathing has returned to normal.

18. Click **Record**.
19. **Subject** coughs once.
20. **Subject** reads aloud from provided material.
21. Record until **Subject** has finished reading.

After coughing, **Subject** continues to read aloud until finished.

- **Subject** must remain seated and still while reading.
- Respiration Transducer must fit snugly across chest.
- Verify Temperature Transducer does not move.

22. Click **Suspend.**
23. Verify recording resembles example data, with a downward spike present when **Subject** coughed. (Scroll to beginning of recording to locate the spike.)
    - If similar, click **Continue** to proceed to optional recording section, or **Done** to finish the lesson.

Use the horizontal scroll bar to view different portions of the data.

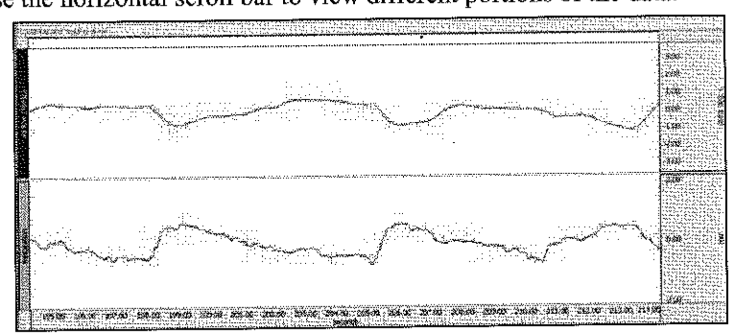

Fig. 8.11 Example Coughing and reading aloud data

- If necessary, click **Redo**.

The data might be different for the reasons detailed in Step 5.

Click **Redo** and repeat Steps 18 – 23 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Recording continues…

OPTIONAL ACTIVE LEARNING PORTION

With this lesson you may record additional data by clicking **Continue** following the last recording. Design an experiment to test or verify a scientific principle(s) related to topics covered in this lesson. Although you are limited to this lesson's channel assignments, the electrodes or transducers may be moved to different locations on the subject.

Design Your Experiment

Use a separate sheet to detail your experiment design, and be sure to address these main points:

A. ***Hypothesis***

Describe the scientific principle to be tested or verified.

B. ***Materials***

List the materials you will use to complete your investigation.

C. ***Method***

Describe the experimental procedure—be sure to number each step to make it easy to follow during recording.

Run Your Experiment

D. ***Set Up***

Set up the equipment and prepare the subject for your experiment.

E. ***Record***

Use the **Continue**, **Record** and **Suspend** buttons to record as much data as necessary for your experiment.

Click **Done** when you have completed all of the recordings required for your experiment.

Analyze Your Experiment

F. Set measurements relevant to your experiment and record the results in a Data Report.

24. After clicking **Done**, choose an option and click **OK**.

After clicking **Done**, a dialog with options will be generated. Make a selection, and continue as directed.

If choosing the **Record from another Subject** option:

- Repeat Setup Steps 5 – 6, and then proceed to Calibration.

25. Remove the respiration and temperature transducers.

END OF RECORDING

V. DATA ANALYSIS

FAST TRACK Data Analysis

1. Enter the **Review Saved Data** mode.
   - Note Channel Number (CH) designations:

Channel	*Displays*
CH 2	**Airflow (temp)**
CH 40	**Respiration**

   - Note measurement box settings:

Channel	*Measurement*
CH 40	**Delta T**
CH 40	**BPM**
CH 40	**p-p**
CH 2	**p-p**

2. **Zoom** in to select about four respiration cycles in the "**Eupnea**" data.
3. Use the **I-Beam** cursor to select the area of inspiration.

   A

Data Analysis continues…

Detailed Explanation of Data Analysis Steps

Enter the **Review Saved Data** mode from the Lessons menu.

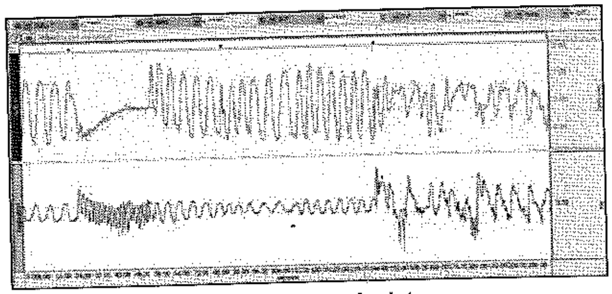

Fig. 8.12 Example data

The measurement boxes are above the marker region in the data window. Each measurement has three sections: channel number, measurement type (tool,) and measurement result. The first two sections are pull-down menus that are activated when you click them.

Brief definition of measurements:

Delta T: Measures the difference in time between the end and beginning of the selected area.

BPM: The **B**eats **P**er **M**inute measurement first calculates the difference in time between the beginning and end of the selected area (seconds/beat,) and divides this value into 60 seconds/minute.

P-P (Peak-to-Peak)**:** Subtracts the minimum value from the maximum value found in the selected area.

The "selected area" is the area selected by the **I-Beam** tool (including endpoints).

Note: The append event markers ◆ mark the beginning of each recording. Click on (activate) the event marker to display its label.

Useful tools for changing view:

Display menu: Autoscale Horizontal, Autoscale Waveforms, Zoom Back, Zoom Forward

Scroll Bars: Time (Horizontal); Amplitude (Vertical)

Cursor Tools: Zoom Tool

Buttons: Overlap, Split, Show Grid, Hide Grid, -, +

Hide/Show Channel: "Alt + click" (Windows) or "Option + click" (Mac) the channel number box to toggle channel display.

In the following example, the Respiration data (bottom, CH 40) is used. The start of inspiration is where the data begins to trend upward and the end of inspiration is at the next peak. The ΔT measurement is the duration of inspiration.

TIP: It may be helpful to hide CH 2 Airflow (temp) to avoid confusion.

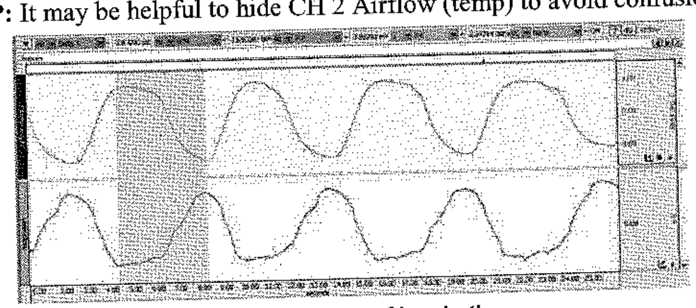

Fig. 8.13 Area of Inspiration

4. Select the area of expiration.

   A

5. Select the area that includes both the inspiration and expiration data used in Steps 3 and 4, and measure the total duration, the breathing rate (BPM) and the relative ventilation amplitude (depth).

   A, C

6. Repeat Steps 3-5 for two other respiratory cycles in the "**Eupnea**" data recording.

   A, C

Example of selecting area of expiration using Respiration data (CH 40).

- The **start** of expiration is where the data begins to trend downward from the peak.
- The **end** of expiration is when the data returns to its basline value.

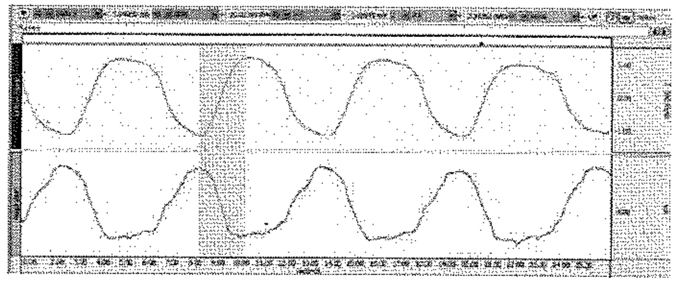

Fig. 8.14 Area of Expiration

7. Find the total duration, breathing rates and relative ventilation amplitude within the "**Hyperventilation and recovery**," "**Hypoventilation and recovery**," and "**Coughing and reading aloud**" data recordings as needed to fill in the Data Report tables.

   B, C

Example of selecting one complete respiration cycle (inspiration + expiration data). From the measurements, obtain the total duration (CH 40 Delta T,) the breathing rate (CH 40 BPM,) and relative ventilation depth (CH 40 P-P).

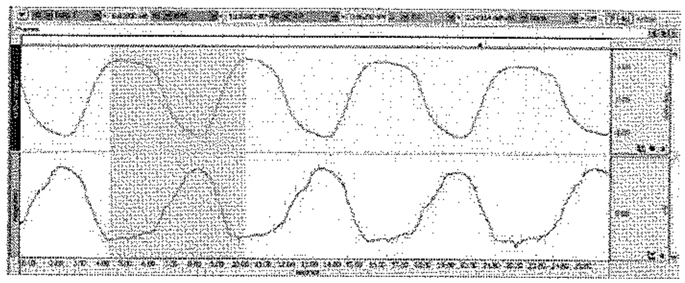

Fig. 8.15 One complete respiration cycle selected

Note: '**Coughing and reading aloud**' recording only requires one measurement. (Cough data should show downward spike when **Subject** coughed.)

8. Using the **I-Beam** cursor, select the interval between the maximal inspiration (Respiration -CH 40) and maximal Airflow (temp) – CH 2 for each data recording needed to complete the table.

   D

9. Answer the questions at the end of the Data Report.
10. **Save** or **Print** the data file
11. **Quit** the program.

Record the Delta T (time interval) between the two peaks and the **P-P** [CH 2] (temperature amplitude).

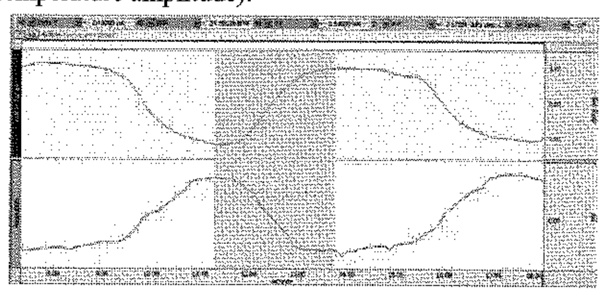

Fig. 8.16 Area from max. Respiration to max. Airflow

An electronically editable **Data Report** is located in the journal (following the lesson summary,) or immediately following this Data Analysis section. Your instructor will recommend the preferred format for your lab.

END OF DATA ANALYSIS

END OF LESSON 8

Complete the Lesson 8 Data Report that follows.

RESPIRATORY CYCLE I

DATA REPORT

Student's Name: ______________________________

Lab Section: ______________________________

Date: ______________________________

I. Data and Calculations

Subject Profile

Name: ______________________________ Height: ______________

Age: ______________ Gender: Male / Female Weight: ______________

A. Eupnea (Normal Breathing)

Complete Table 8.1 with values for each cycle and calculate the Means.

Table 8.1

Measurement	Rate	Cycle 1	Cycle 2	Cycle 3	Mean
40 Delta T	**Inspiration Duration**				
	Expiration Duration				
	Total Duration				
40 BPM	**Breathing Rate**				

B. Comparison of Ventilation Rates (hyperventilation, hypoventilation, cough, read aloud)

Complete Table 8.2 with measurements from CH 40 for three cycles of each recording and calculate the Means where indicated. Note: Delta T is total duration, BPM is breathing rate, and Cough has only one cycle.

Table 8.2

Rate	40 Delta T			*Calculated* Mean	40 BPM			*Calculated* Mean
	Cycle 1	Cycle 2	Cycle 3		Cycle 1	Cycle 2	Cycle 3	
Hyperventilation								
Hypoventilation								
Cough								
Read Aloud								

C. **Relative Ventilation Depths (all recordings)**

Table 8.3

Depth	40 P-P Cycle 1	Cycle 2	Cycle 3	Mean *Calculated*
Eupnea				
Hyperventilation				
Hypoventilation				
Cough		//////	//////	//////

D. **Association of Respiratory Depth and Temperature (eupnea, hyperventilation, hypoventilation)**

Table 8.4

Measurement		Eupnea	Hyperventilation	Hypoventilation
2 P-P	*Peak DeltaTemp*			
40 Delta T	*Delta T between Max inspiration and Peak Delta Temp*			

II. Questions

E. If the subject held breath immediately after hyperventilation and hypoventilation, would the subject hold breath longer after hyperventilation or hypoventilation? Why?

____

____

____

____

F. After a brief period of hyperventilation, "apnea vera" occurs.

i. Define hyperventilation.

____

____

____

ii. Define apnea vera.

____

____

____

iii. Describe the feedback loop causing apnea vera.

____

____

____

G. i. What changes occur in the body with hypoventilation?

____

____

____

ii. How does the body adjust rate and depth of ventilation to counteract the effects of hypoventilation?

____

____

____

H. In which part of the respiratory cycle is temperature:

Highest?______________________ Lowest?________________________

Explain why temperature varies with the respiratory cycle.

I. Describe or define cough in terms of modification of the breathing cycle.

J. What modifications of the breathing cycle occur when reading aloud? Why?

K. Refer to Table 8.1 data: During eupnea, did the subject inspire immediately after the end of expiration or was there a pause? Explain the stimulus and mechanism to initiate inspiration.

L. Referring to Table 8.3 data: Are there differences in the relative ventilation depths?

III. OPTIONAL Active Learning Portion

A. ***Hypothesis***

B. ***Materials***

C. ***Method***

D. ***Set Up***

E. ***Experimental Results***

End of Lesson 8 Data Report