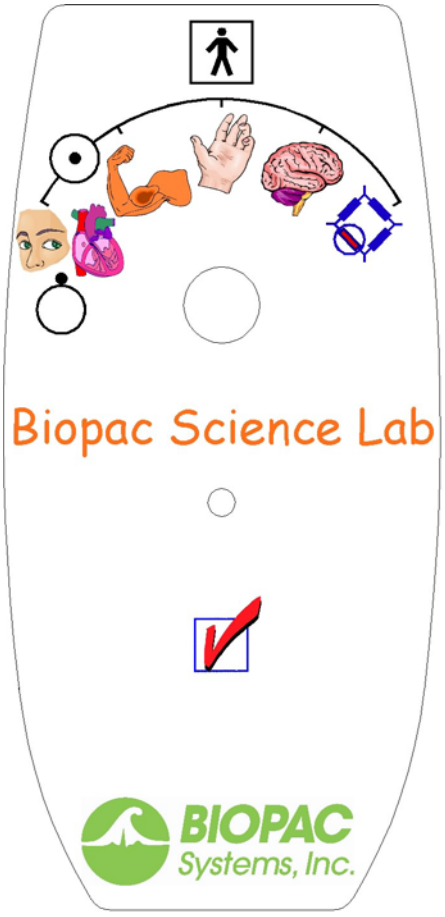
Physiology Lessons
for use with the
Biopac Science Lab MP40

PC running Windows® XP
or Mac® OS X 10.3-10.4

BIOPAC SCIENCE LAB

Lesson 12 Respiration 1

Apnea



Lesson Revision 3.15.2006

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Lesson 12 The Respiratory Cycle

I. Scientific Principles

All body cells require oxygen for metabolism and produce carbon dioxide as a metabolic waste product. The respiratory system supplies oxygen to the blood for delivery to cells, and removes carbon dioxide added to the blood by the cells. Cyclically breathing in and out while simultaneously circulating blood between the lungs and other body tissues facilitates the exchange of oxygen and carbon dioxide between the body and the external environment. This process serves cells by maintaining rates of oxygen delivery and carbon dioxide removal adequate to meet the cells' metabolic needs.

The breathing cycle, or respiratory cycle, consists of inspiration during which new air containing oxygen is inhaled, followed by expiration during which old air containing carbon dioxide is exhaled. Average adult people at rest breathe at a frequency of 12 to 15 breaths per minute (BPM), and with each cycle, move an equal volume of air, called tidal volume (TV), into and back out of the lungs. The actual value of tidal volume varies in direct proportion to the depth of inspiration. During normal, quiet, unlabored breathing (eupnea) at rest, adult tidal volume is about 450 ml to 500 ml.

The rate at which air is moved into and out of the respiratory system is called pulmonary ventilation (PV) or respiratory minute volume (RMV). Mathematically, respiratory minute volume is the product of tidal volume and the respiratory cycle frequency:

$$RMV = (TV \times BPM)$$

A normal adult value for RMV is (500 mL/breath) x (12 breaths/minute) = 6 L/min.

Respiratory minute volume varies with the body's need for oxygen and the need for excreting carbon dioxide. During strenuous exercise, oxygen consumption and carbon dioxide production increase, and in order to meet the body's needs, both tidal volume and frequency may increase five-fold or more over resting values, exceeding 100 L/min.

The changes in lung volume that occur during inspiration and expiration are produced by contraction and relaxation of skeletal muscles of the thorax. The rate and strength of contraction of respiratory muscles, and hence the rate and depth of respiration, are controlled by primary respiratory centers (inspiratory and expiratory) located in the medulla oblongata at the base of the brain stem (Fig. 12.1).

The primary centers are inherently rhythmic, alternating their activity to produce inspiration and then expiration. However, their rhythm may be altered by inputs from other neural centers in the brain including voluntary control areas of the cerebral cortex.

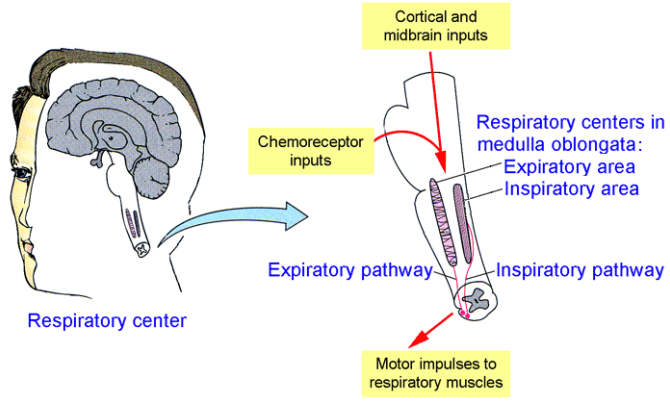


Fig 12.1 Primary respiratory centers in the medulla oblongata

- For example, the track athlete positioned on starting blocks and awaiting the signal from the starter's gun may begin to breathe faster and more deeply in anticipation of the race before the actual need occurs to increase oxygen delivery and carbon dioxide removal in skeletal muscles.

Other modifications of the respiratory cycle occur as a result of metabolic changes in oxygen, carbon dioxide, or hydrogen ion concentrations in systemic arterial blood. Blood bathes chemical sensors, called chemoreceptors, located in the walls of the aorta and carotid arteries. Chemoreceptors sense changes in systemic arterial carbon dioxide concentration, hydrogen ion concentration, and oxygen concentration, and send impulses to the respiratory centers in the medulla oblongata. The following increases (↑) and/or decreases (↓) in the partial pressure of carbon dioxide (PCO_2), the hydrogen ion concentration ([H+]), and the partial pressure of oxygen (PO_2) in systemic arterial blood alter respiratory minute volume:

$\uparrow PCO_2$, ↑[H+], and/or $\downarrow PO_2$ increase rate and depth of respiration

$\downarrow PCO_2$, ↓[H+], and/or ↑ PO_2 decrease respiratory rate and depth

Carbon dioxide in blood and in cerebrospinal fluid bathing the brain is the principal chemical stimulus to the respiratory centers for maintaining and for increasing respiratory minute volume. The level of carbon dioxide can be altered by changing the ratio of the volume of CO_2 excreted per minute to the volume of CO_2 produced per minute. A person at rest can voluntarily breathe faster and more deeply to rid the body of carbon dioxide faster than it is being produced. This is called voluntary hyperventilation and produces a condition known as hypocapnia, a lower than normal blood carbon dioxide level, which reduces respiratory drive. When voluntary hyperventilation ceases, breathing temporarily ceases for several seconds because the principal chemical stimulus for breathing (CO_2) has been lowered.

The cessation of breathing allows the blood carbon dioxide level to return to normal, and with it the desire to resume breathing. The temporary cessation of breathing following a brief period of voluntary hyperventilation is known as apnea vera (*apnea*–without breath, *vera*–true).

A person may also voluntarily hold their breath and experience a voluntary apnea for a short period of time. However, the cessation of breathing results in hypercapnia, a condition in which blood carbon dioxide levels rise above normal, producing a stronger chemical stimulus to the respiratory centers that overcomes the cerebral breath-holding input and initiates breathing. Thus, the child who holds his breath to spite his parents will, if ignored, begin to breathe anyway. Immediately after voluntary apnea ends, breathing resumes at a higher than resting rate and depth, producing an involuntary hyperventilation to quickly rid the body of excess carbon dioxide. As blood carbon dioxide level is returned to normal, breathing frequency and depth decrease to normal resting values.

In this lesson you will observe physiologic modifications of the respiratory cycle associated with voluntarily increasing and decreasing blood carbon dioxide content. You will qualitatively determine changes in respiratory minute volume by recording and analyzing EMGs from respiratory muscles of the thorax.

II. Experimental Objectives

1) To observe and record EMGs from thoracic respiratory skeletal muscle during eupnea, or normal unlabored breathing at rest.
2) To record changes in the EMG associated with modifications in the rate and depth of the respiratory cycle that occur before, during, and after periods of apnea vera and voluntary apnea and to compare those changes to eupnea.

III. Materials

- Biopac Science Lab system (MP40 and software) on computer running Windows XP or Mac OS X
- Electrode lead set (40EL lead set)
- Disposable vinyl electrodes (EL503); three electrodes per subject
- *Optional*: Nose clip (AFT3)

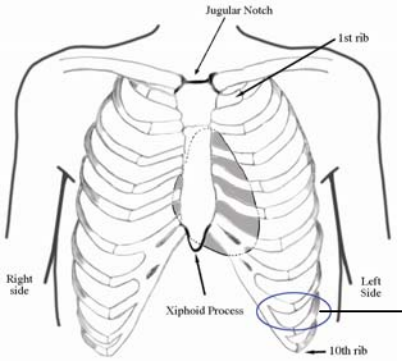
IV. Experimental Methods

A. Set Up

Equipment

Fig. 12.2 MP40 with 40EL connected

Subject



white lead – intercostal

red lead – intercostal

black lead (ground) – where convenient

Fig. 12.3 Electrode placement and lead connections

FAST TRACK	**Details**
1. Turn the computer **ON**.	
2. Set the MP40 dial to **OFF**.	
3. **Plug the equipment in** as follows: Electrode leads (40EL) → MP40	
4. **Attach three electrodes** to the **Subject** as shown in Fig. 12.3.	Attach three electrodes to the Subject (Fig. 12.3): a) Attach two electrodes (WHITE and RED) between the eighth and ninth ribs. ▪ Locate the lower margin of the ribcage, about 15 cm to the right and 15 cm above the navel (where the 10th rib articulates with costal cartilage). ▪ Count up to locate the ninth rib and mark the location above it (below the eighth rib). ***Note*** If you have trouble locating particular ribs, just make sure to place the electrodes over the lower portion of the rib cage. b) Attach one electrode where convenient (BLACK).
WARNING Any person with a history of heart failure, epilepsy, or respiratory conditions, such as asthma, should not be a **Subject**.	
5. Connect the electrode leads (40EL) to the electrodes, matching lead color to electrode position as shown above.	*Optional placement guidelines*: The electrodes should be positioned to capture maximum muscle activity during normal, resting breathing, and spaced so that the contact points are minimally 7.6 cm (3") apart, with proportionally increased spacing for larger body types such that spacing is approximately 15% of total ribcage circumference. ▪ As a rough example, for a ribcage circumference of 100 cm (39"), electrode contacts should be spaced approximately 15 cm (5.75").
IMPORTANT Clip each electrode lead color to its specified electrode position.	
6. **Start** the Biopac Science Lab software.	
7. Choose lesson **L12-Respiration-1** and click **OK**.	
8. Type in a unique **file name**.	No two people can have the same file name, so use a unique identifier, such as the subject's nickname or student ID#.
9. Click **OK**.	This ends the Set Up procedure.

B. Check

FAST TRACK

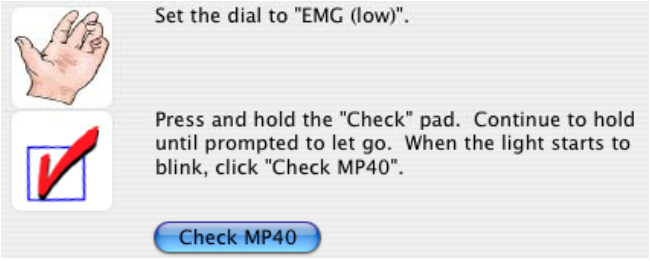
MP40 Check

1. Set the MP40 dial to  EMG (low).
2. Press and hold the  **Check** pad on the MP40.
3. Click  when the light is flashing.
4. Wait for the MP40 check to stop.
5. Let go of the  **Check** pad.
6. Click **Continue**.

Signal Check

7. Click **Check Signal**.
8. Wait for the Signal Check to stop**.**
9. Review the data.
   - If correct, go to the Record section.
   - If incorrect, click  .

Details



Continue to hold the pad down until prompted to let go.

The MP40 check procedure will last five seconds.

The light should stop flashing when you let go of the **Check** pad.

When the light stops flashing, click **Continue**.

Subject should be comfortably seated with good posture, facing away from the computer monitor. With mouth open, Subject should consciously control breathing to produce regular, periodic breath cycles of about 4-5 seconds (12-15 breaths per minute).

Note Inspiration must be active, but expiration should be passive (simply relax inspiratory muscles). Breathe with chest muscles, not abdominal muscles.

The 16-second Signal Check recording should resemble Fig. 12.4.

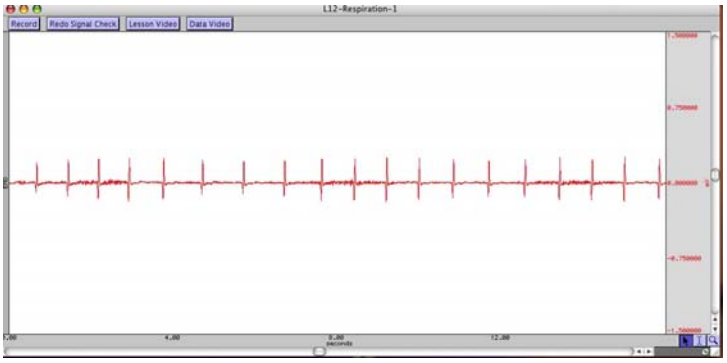


Fig. 12.4

If the recording check does not match, click **Redo Signal Check**.

C. Record

FAST TRACK

1. Prepare for the recording. Have the **Subject** sit, relax, and breathe normally with mouth open.

IMPORTANT
This lesson requires significant attention to detail. To work efficiently, read this entire section so you will know what to do before recording.

Details

Watch the Help menu videos to prepare for the recording.

You will record the Subject under the following conditions:

a) breathing normally with mouth open
b) during and after hyperventilation
c) holding breath
d) holding breath after hyperventilation

For "normal breathing," Subject should be comfortably seated with good posture. With mouth open, Subject should consciously control breathing to produce regular, periodic breath cycles of about 4-5 seconds (12-15 breaths per minute). Subject should breathe with chest muscles, not abdominal muscles and should not speak during recording.

Stop each recording segment as soon as possible so you don't waste recording time (time is memory).

SEGMENT 1 — Eupnea

Subject will breathe normally during recording

2. Click Record.

When you click **Record**, the recording will begin, and an append marker labeled **Eupnea** will automatically be inserted.

3. Record for 20 seconds.

Subject breathes normally through the mouth (with no talking) while sitting with arms relaxed, preferably in a chair with armrests, and facing away from the monitor.

Note Inspiration must be active, but expiration should be passive (simply relax inspiratory muscles).

4. Click **Suspend**.

When you click **Suspend**, the recording will halt, giving you time to review the data and prepare for the next recording segment.

5. Review the data.
   - If correct, go to **Step 6**.
   - If incorrect, click **Redo**.

The segment should resemble Fig. 12.5.

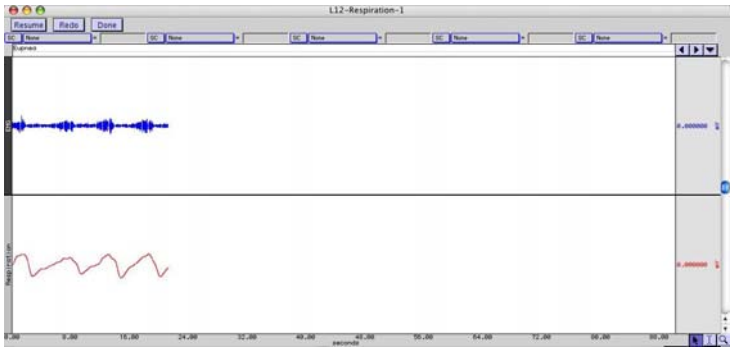


Fig. 12.5 Eupnea recording segment

The recording should show about four or five peaks. If the data is incorrect, click **Redo** and repeat Steps 2-5; the last data segment you recorded will be erased.

SEGMENT 2 — Apnea Vera

Subject will hyperventilate BEFORE and during recording and then return to normal breathing

6. **Subject** sits, relaxes, and hyperventilates (breathes in and out as deeply as possible).

Subject sits with arms relaxed, preferably in a chair with armrests, and facing away from the computer monitor. Director records time as Subject breathes in and out as deeply as possible (each breath cycle should last about 3-4 seconds) for 75 seconds. Inspiration and expiration should be active for hyperventilation.

Note Subject will hyperventilate for a total of 90 seconds, but do not record the first 75 seconds.

7. After 75 seconds of hyperventilation, click **Resume** and have **Subject** continue to hyperventilate.

A marker labeled **Apnea vera** will automatically be inserted when you click **Resume**, and the recording will continue from the point it left off. Subject must breathe as deeply as possible.

8. After 15 seconds of recorded hyperventilation, insert a marker (**F9** or **Esc**) and have the **Subject** stop hyperventilating.

    ∇ *Label marker*: Stop hyperventilation

Recorder will announce change at 15 seconds and insert marker; Subject should stop hyperventilating and attempt to resume normal breathing. To insert a marker, press **F9** (Windows) or **Esc** (Mac). Continue to record for 30 seconds.

9. After 30 seconds of hyperventilation recovery, click **Suspend**.

When you click **Suspend**, the recording will halt, giving you time to review the data and prepare for the next recording segment.

10. Review the data.
    - If correct, go to **Step 11**.
    - If incorrect, click **Redo**.

The data should resemble Fig. 12.6.

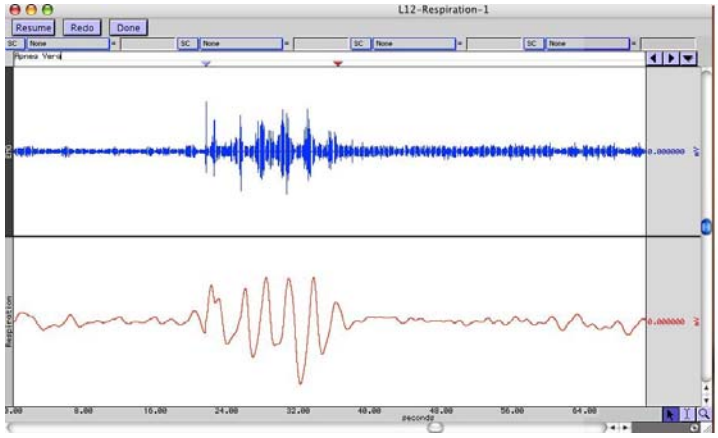


Fig. 12.6 Apnea vera recording segment

If the data is incorrect, click **Redo** and repeat Steps 6-10; the last data segment you recorded will be erased.

SEGMENT 3 — Voluntary Apnea

Subject will breathe normally, hold breath after an inspiration, and then return to normal breathing

Optional: Subject should clip nose (AFT3). Subject should breathe normally while sitting with arms relaxed, preferably in a chair with armrests.

11. Have **Subject** clip nose (optional), sit, relax, and breathe normally.

12. Click **Resume**.

A marker labeled **Voluntary apnea** will automatically be inserted when you click **Resume**, and the recording will continue from the point it left off.

13. Record **Subject** in the following conditions and insert a marker at each change:

Duration	*Condition*
20 seconds	normal breathing
varies	holding breath **after a normal resting inspiration**
20 seconds	breathing normally

    Recorder inserts an event marker (**F9** or **Esc**) at each change. There should be two new markers when this segment is completed.

    ∇ *Label marker*: Start hold

    ∇ *Label marker*: Stop hold

Recorder will time conditions and insert markers at each change. To insert a marker, press **F9** (Windows) or **Esc** (Mac).

Subject should breathe normally for 20 seconds and then clip nose with fingers (if not already clipped with AFT3) and hold breath *after a normal resting inspiration.* Continue to hold for as long as possible.

Continue to record for 20 seconds after holding breath.

14. After the 20 seconds of normal breathing, click **Suspend**.

When you click **Suspend**, the recording will halt, giving you time to review the data and prepare for the next recording segment.

15. Review the data.
    - If correct, go to **Step 16**.
    - If incorrect, click **Redo**.

The data should resemble Fig. 12.7.

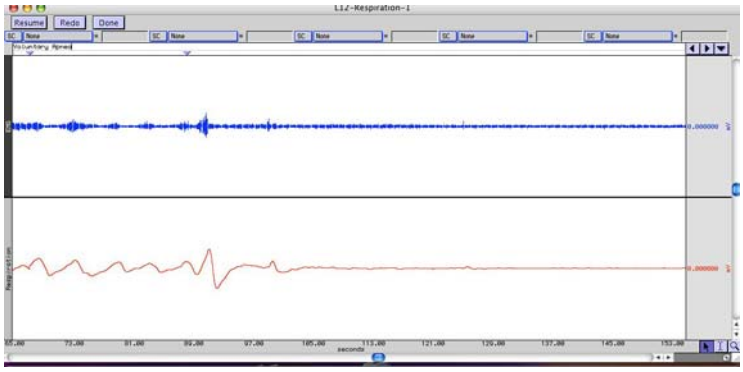


Fig. 12.7 Voluntary apnea recording segment

It is normal to see a spike at the start of respiration If the data is incorrect, click **Redo** and repeat Steps 11-15; the last data segment you recorded will be erased.

SEGMENT 4 — Voluntary Apnea After Hyperventilation

Subject will hyperventilate and hold breath following an inspiration BEFORE recording starts, then hold breath as long as possible, and then return to normal breathing

During 20-second hyperventilation, Subject breathes in and out as deeply as possible (each breath cycle should last about 3-4 seconds) with active inspirations and expirations. Subject should then clip nose with AFT3 (optional) or fingers, hold breath, and continue to hold for as long as possible.

16. **Subject** should hyperventilate for 20 seconds (breathe as deeply as possible) and then clip nose (with AFT3 or fingers) and hold breath.

17. Click **Resume** as quickly as possible after the **Subject** holds breath.

A marker labeled **Voluntary apnea after hyperventilation** will automatically be inserted when you click **Resume**, and the recording will continue from the point it left off.

18. When **Subject** can no longer hold breath and resumes breathing, click **Suspend**.

When you click **Suspend**, the recording will halt, giving you time to review the data and prepare for the next recording segment.

19. Review the data.
    - If correct, go to **Step 20**.
    - If incorrect, click **Redo**.

The data should resemble Fig. 12.8.

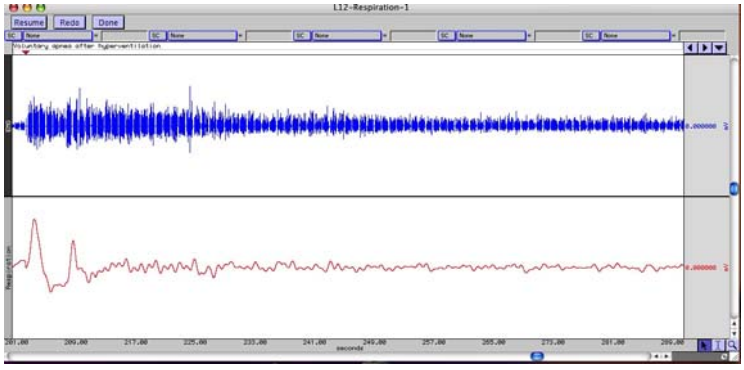


Fig. 12.8 Voluntary apnea after hyperventilation recording segment

If the data is incorrect, click **Redo** and repeat Steps 16-19; the last data segment you recorded will be erased.

20. *Optional:* Click **Resume** to record additional segments.

Optional: You can record additional segments by clicking **Resume** instead of **Done**. A time marker will be inserted at the start of each added segment.

21. Click **Done**.

A pop-up window with options will appear. Click **Yes** (or **No** if you want to redo the last segment).

22. Click **Yes**.
23. Choose an option and click **OK**.

When you click **Yes**, a dialog with options will be generated. Make your choice, and click **OK**.

- If you choose **Analyze current data file**, go to the Analyze section for directions.

24. Remove the electrodes.

Unclip the electrode leads and peel off the electrodes. Throw out the electrodes (BIOPAC electrodes are not reusable).

END OF RECORDING

V. ANALYZE

FAST TRACK

1. Enter the **Review Saved Data** mode and choose the correct file.

Note Channel Number (CH) designations:

Channel	*Displays*
CH1	**EMG**
CH2	**Respiration**

All measurements in this analysis are on the Respiration channel so EMG is hidden in the sample data figures.

To show/hide a channel:

Windows: Ctrl-click channel box

Mac: Option-click channel box

2. Set up the measurement boxes as follows:

Channel	*Measurement*
CH2	**BPM**
CH2	**Delta T**
CH2	**P-P**

3. Set up the display window for optimal viewing of Segment 1 (**Eupnea**).
4. Using the I-Beam tool, select one full respiratory cycle (valley to valley).

A

5. Repeat **Step 4** on three additional cycles.

A

Details

To review saved data, choose **Analyze current data file** from the Done dialog after recording data, or choose **Review Saved Data** from the **Lessons** menu and browse to the required file.

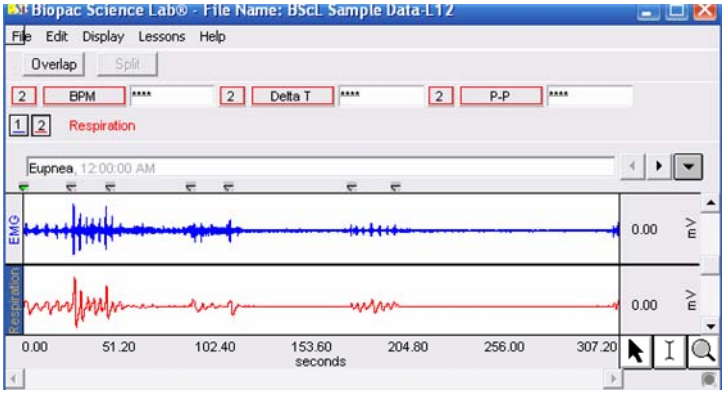


Fig. 12.9 Lesson 12 data

Bursts in the data reflect respiratory effort: a burst represents inspiration, and end of burst to start of next burst represents expiration. Measurements can be taken on either channel.

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

A brief description of these measurements follows.

BPM: (breaths per minute): calculates the difference in time between the end and beginning of the selected area (same as Delta T), and divides this value into 60 seconds/minute.

Delta T: displays the amount of time in the selected area (the difference in time between the endpoints).

P-P: Peak-to-Peak measurement shows the difference between the maximum amplitude value in the selected range and the minimum amplitude value in the selected area. In this lesson, P-P is used as an index of the strength of muscle contractions.

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

The BPM measurement result is only accurate when the selected area extends over exactly one respiration cycle.

Segment 1 begins at the marker labeled **Eupnea**.

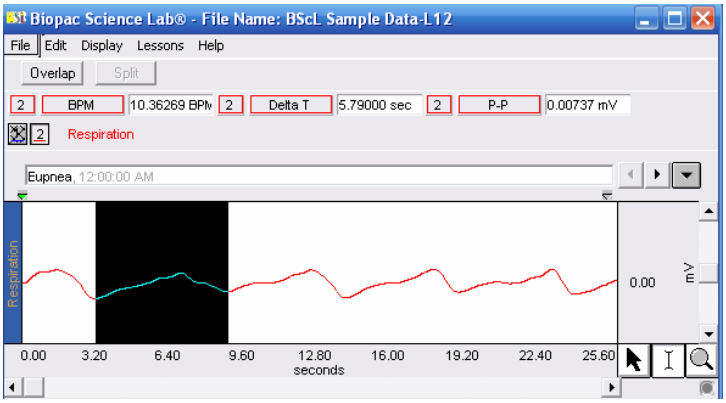


Fig. 12.10 One full respiratory cycle selected in Eupnea.

The following tools help you adjust the data window:

Autoscale Horizontal	Horizontal (Time) Scroll Bar
Autoscale Waveforms	Vertical (Amplitude) Scroll Bar
Zoom	Zoom Previous/Back
Overlap	Split

6. Set up the display window for optimal viewing of the hyperventilation section of Segment 2 (**Apnea Vera**).

Segment 2 begins at the marker labeled **Apnea Vera** and extends to the first event marker that you inserted (**Stop hyperventilation)** in the section.

7. Using the I-Beam tool, select one respiratory cycle (valley to valley).

B

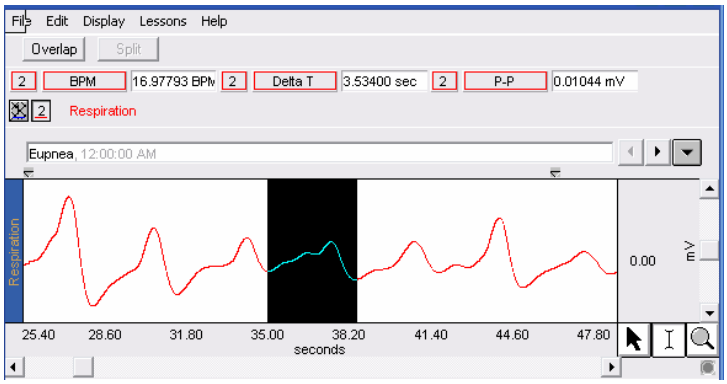


Fig. 12.11 Segment 2 hyperventilation

8. Scroll to the period of apnea vera in Segment 2 and insert a marker at the end of the period.
   - ∇ Label the marker: **AV end**

Apnea vera should occur between the **Stop hyperventilation** marker and the point where the Subject resumed breathing.

To insert a marker after acquisition, click in the gray area beneath the marker label bar.

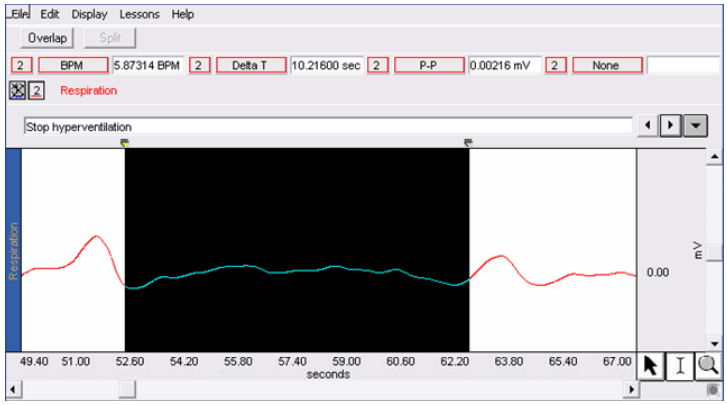


Fig. 12.12 Apnea vera period

9. Select the period of apnea vera.

C

Select the area from the **Stop hyperventilation** event marker that you inserted during recording to the **AV end** marker that indicates the point where the Subject resumed breathing.

10. Scroll to the data following apnea vera (after the marker you inserted labeled **AV end**) to the end of Segment 2.
11. Using the I-Beam tool, select one respiratory cycle (valley to valley).

B

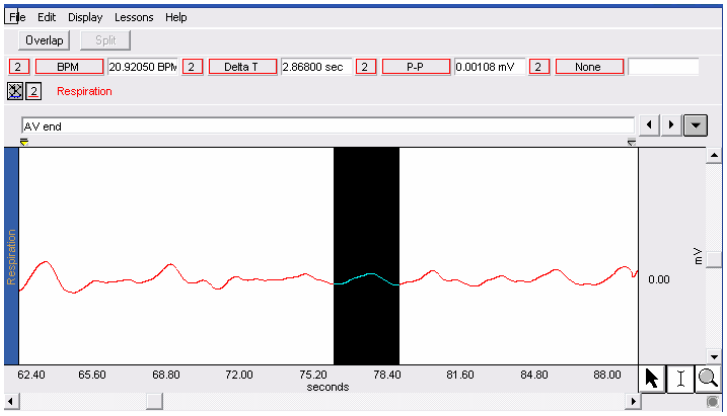


Fig. 12.13 Sample data following apnea vera

12. Scroll to the area of normal breathing between the start of Segment 3 (**Voluntary apnea**) and the start of voluntary apnea.
13. Using the I-Beam tool, select one cycle (valley to valley).

    D
14. Repeat the measurements taken in **Step 13** for a different cycle in the same area.

    D

This section begins at the marker labeled **Voluntary apnea** and extends to the marker you inserted labeled **Start hold**.

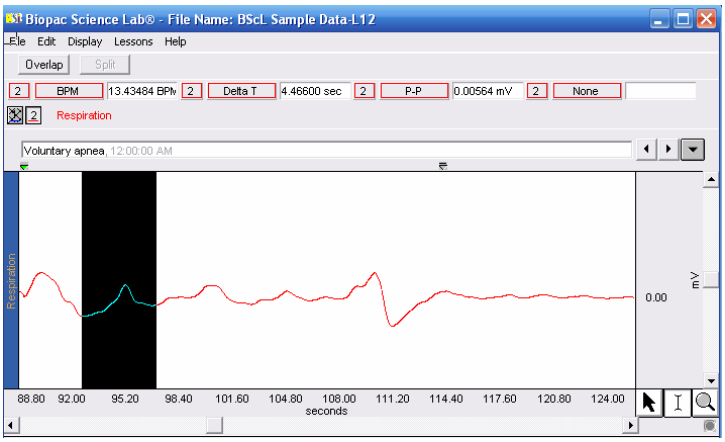


Fig. 12.14 Sample data before voluntary apnea

15. Using the I-Beam tool, select the entire period of voluntary apnea.

    E

The voluntary apnea period of Segment 3 (**Voluntary apnea**) begins at the first marker (**Start hold)** that you inserted in the segment and extends to the second marker (**Stop hold**) that you inserted in the segment.

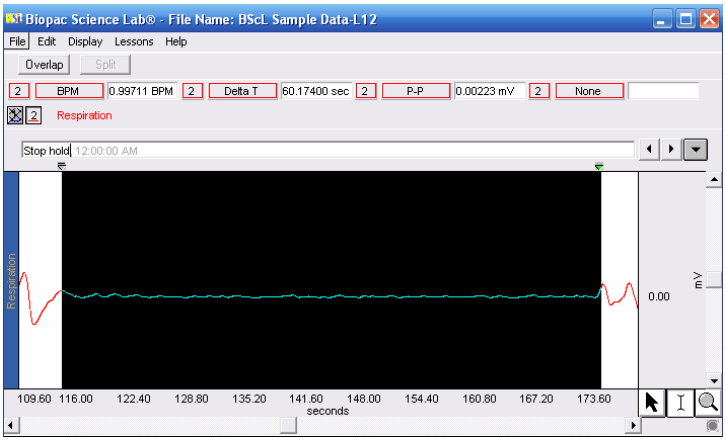


Fig. 12.15 Sample data during voluntary apnea

16. Scroll to the area of recovery from voluntary apnea in Segment 3.
17. Using the I-Beam tool, select one cycle (valley to valley).

    D
18. Repeat the measurements taken in **Step 17** for a different cycle in the same area.

    D

Recovery from voluntary apnea in Segment 3 begins at the second event marker (**Stop hold**) that you inserted and extends to the end of the segment.

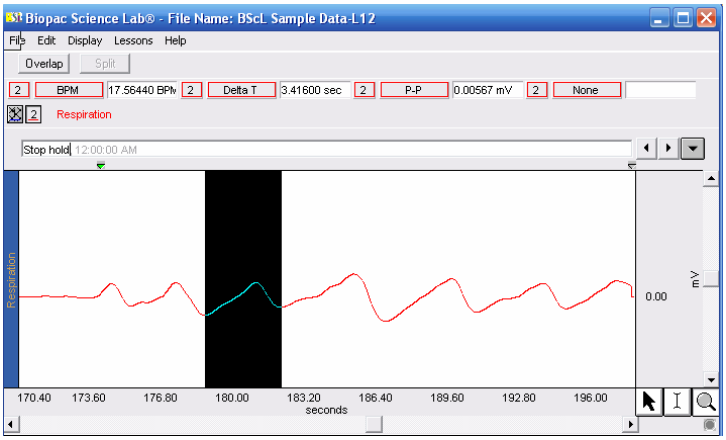


Fig. 12.16 Sample data after voluntary apnea

19. Set up the display window for optimal viewing of Segment 4 (**Voluntary apnea after hyperventilation**).

Segment 4 begins at the marker labeled **Voluntary apnea after hyperventilation**.

20. Using the I-Beam tool, select the period of voluntary apnea.

    E

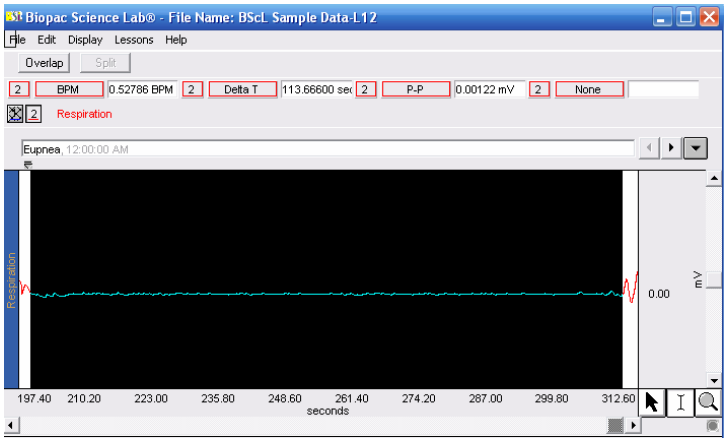


Fig. 12.17

21. Save or print the data file.
22. Exit the program.
23. Set the MP40 dial to **Off**.

You may save the data, save notes that are in the journal, or print the data file.

END OF LESSON 12

Complete the Lesson 12 Data Report that follows.

The Data Report starts on the next page.

Lesson 12 RESPIRATION 1
Apnea

These are sample questions. You should amend, add, or delete questions to support your curriculum objectives.

DATA REPORT

Student's Name: _____

Lab Section: _____

Date: _____

I. Data and Calculations

Subject Profile

Name_____ Age_____

Gender: Male / Female Height_____Weight_____

Eupnea

A. Complete Table 12.1 with data from Segment 1 (Eupnea). Measure two cycles of data from the beginning of the segment and two cycles from the end, and then manually calculate the average for each measurement.

Table 12.1 Eupnea

Cycle	Breaths per Minute [CH2 BPM]	Respiratory Effort [CH2 P-P]	Cycle Interval [CH2 Delta T]
1			
2			
3			
4			
Average *(calculate manually)*			

* CH2 will indicate relative effort; use CH1 for a more precise EMG (muscle) measurement, if preferred.

Apnea Vera

B. Complete the following Table 12.2 with data from Segment 2 (Apnea Vera).

Table 12.2 Hyperventilation and recovery

Selected Area	Breaths per Minute [CH2 BPM]	Respiratory Effort [CH2 P-P]
During Hyperventilation		
After Apnea Vera		

C. Measure the duration of apnea vera in Segment 2 (Apnea Vera): CH2 Delta T = _____

Voluntary Apnea

D. Complete Table 12.3 with data from Segment 3 (Voluntary Apnea). Select one cycle from the beginning and end of each section, and then manually calculate the averages.

Table 12.3 Comparison of eupnea and apnea recovery

Cycle	BEFORE APNEA		AFTER APNEA	
	Breaths per Minute [CH2 BPM]	Respiratory Effort [CH2 P-P]	Breaths per Minute [CH2 BPM]	Respiratory Effort [CH2 P-P]
1				
2				
Average *(calculate manually)*				

Duration of Apnea

E. Complete Table 12.4 with data from Segment 3 (Voluntary Apnea) and Segment 4 (Voluntary Apnea after Hyperventilation).

Table 12.4 Hyperventilation's effect on voluntary apnea

Selected Area	Voluntary Apnea (Seg 3) [CH2 Delta T]	Voluntary Apnea After Hyperventilation (Seg 4) [CH2 Delta T]
Duration of Apnea		

II. Data Summary and Questions

F. Compare the respiratory cycle frequency (BPM) and depth (P-P) during eupnea in Segment 1 to the frequency and depth immediately after the period of apnea vera in Segment 2. Are the values for frequency and depth slightly lower immediately after apnea vera? If so, account for the difference in terms of blood carbon dioxide content.

G. Examine the data from segments 1 and 2 and compare the length (Delta T), frequency (BPM), and depth (P-P) of the respiratory cycles during voluntary hyperventilation versus during eupnea. Does the length of the respiratory cycle shorten as breathing frequency increases? Why? Describe the changes in respiratory rate and depth that occurred during voluntary hyperventilation.

H. It is possible to increase the frequency of breathing while simultaneously developing hypocapnia. Explain how this is possible.

I. What is the cause of apnea vera and how does it differ from the cause of voluntary apnea?

J. Examine the data from segments 3 and 4. Is the duration (Delta T) of voluntary apnea longer if it is preceded by a period of hyperventilation? Give a physiological reason explaining why or why not.

K. Physiologically, the duration of voluntary apnea is limited by involuntary respiratory center controls. Explain how the control system limits the duration of apnea.

L.

M. Define the following terms:

i. hypocapnia

ii. hypercapnia

iii. tidal volume

iv. respiratory minute volume

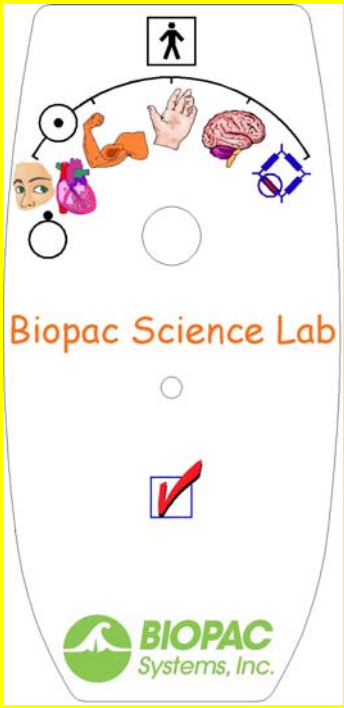
N. Explain the effects each of the following has on respiratory cycle frequency and depth:

i. increased blood concentration of carbon dioxide

ii. increased blood concentration of hydrogen ion

iii. decreased blood concentration of oxygen

End of Biopac Science Lab Lesson 12 Data Report



VI. Active Learning Lab

Design a new experiment to test or verify the scientific principle(s) you learned in the Biopac Science Lab recording and analysis segments.

- ***For this lesson***, you might see how hypoventilation influences apnea.

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 will you 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.

- See the **Set Up** section or Help > About Electrodes for electrode placement guidelines.

Run Your Experiment

D. ***Set Up***

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

E. ***Record***

Use the **Record**, **Resume**, and **Suspend** buttons in the Biopac Science Lab program to record as many segments as necessary for your experiment.

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

Analyze Your Experiment

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