Richard Pflanzer, Ph.D.
Associate Professor Emeritus
Indiana University School of Medicine
Purdue University School of Science

William McMullen
Vice President, BIOPAC Systems, Inc.

II. EXPERIMENTAL OBJECTIVES

1. To listen to human heart sounds and describe them qualitatively in terms of intensity or loudness, pitch, and duration.
2. To correlate the human heart sounds with the opening and closing of cardiac valves during the cardiac cycle and with systole and diastole of the ventricles.
3. To determine the nature of the change in the relationship between electrical and mechanical events of the cardiac cycle as heart rate increases.

III. MATERIALS

- BIOPAC Stethoscope (SS30L)
- BIOPAC Electrode Lead Set (SS2L)
- BIOPAC Disposable Electrodes (EL503,) 3 electrodes per Subject
- BIOPAC Electrode Gel (GEL1) and Abrasive Pad (ELPAD)
- Biopac Student Lab System: BSL 4 software, MP36, MP35 or MP45 hardware
- Computer System (Windows 8, 7, Vista, XP, Mac OS X 10.5 – 10.8)
- *Optional:* BIOPAC Headphones (OUT1/OUT1A for MP3X or 40HP for MP45)

IV. EXPERIMENTAL METHODS

A. SETUP

FAST TRACK Setup

1. Turn the computer **ON**.
   - If using an MP36/35 unit, turn it **OFF**.
   - If using an MP45, make sure USB cable is connected and "Ready" light is **ON**.
2. **Plug the equipment in** as follows:
   Stethoscope (SS30L) — CH 1
   Electrode lead set (SS2L) — CH 2
3. Turn **ON** the MP36/35 unit.

OPTIONAL – BSL 4.0.2 and higher:
Heart sounds from the SS30L stethoscope may also be heard via the following MP headphone connections:

- OUT1 headphones into Analog Out (MP35).
- OUT1 headphones into Analog Out or OUT1A into the headphone output jack (MP36).
- 40HP headphones into the headphone output jack (MP45).

This can be useful when a second observer wishes to monitor the stethoscope output.

Setup continues…

Detailed Explanation of Setup Steps

Fig. 17.5 MP3X (top) and MP45 (bottom) equipment connections

4. Select a **Subject**, a **Recorder** and, if appropriate in your lab group, a **Director**.

CAUTION!
Subject selected must not have had or now have any disorder, hypertension, heart surgery, stroke, or any history of cardiovascular degeneration.

This lesson teaches the clinical detection of heart sounds, which are monitored in four positions on the upper chest (between ribs two and six).

Normally, this involves one person (**Director**) listening to the heart sounds of another individual (**Subject**). However, in a lab setting this may not be comfortable or appropriate due to gender differences and personal preference. In such cases:

- **Subject** may listen to his/her own heart sounds by acting as and following instructions for the **Director**.
- When a **Subject** listens to his/her own heart sounds, it is imperative that the right arm remains relaxed so EMG artifact does not corrupt the ECG signal.—this means that Subject must hold the stethoscope with the left hand.

Subject should not have consumed caffeine, smoked, or performed heavy exercise within one hour of the recording.

A **Recorder** is always required to run the lesson and insert event markers.

5. Clean and abrade skin.

If the skin is oily, clean electrode sites with soap and water or alcohol before abrading.

If electrode is dry, apply a drop of gel.

Remove any jewelry on or near the electrode sites.

6. Attach three electrodes and clip leads in Lead II setup.
   - RIGHT forearm = WHITE lead
   - RIGHT leg = BLACK lead (Ground)
   - LEFT leg = RED lead

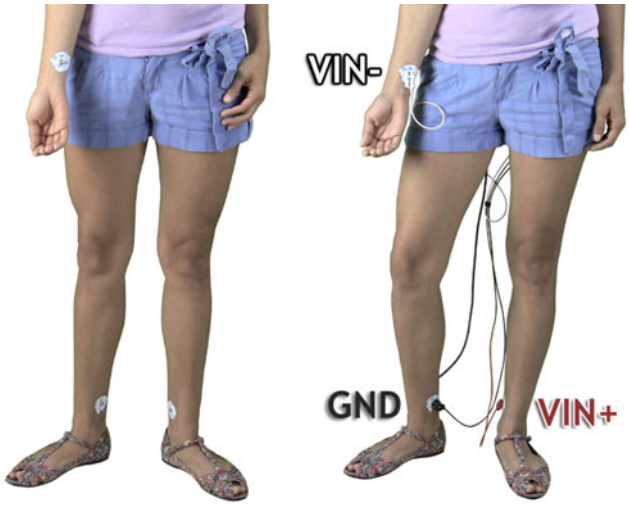

Fig. 17.6 Electrode placement & lead attachment

Details

- Place one electrode on the medial surface of each leg, just above the ankle. Place the third electrode on the right anterior forearm at the wrist (same side of arm as the palm of hand).
- Lead II is WHITE = right wrist, BLACK = right ankle, RED = left ankle.
- The pinch connectors work like a small clothespin, but will only latch onto the nipple of the electrode from one side of the connector.
- For optimal electrode contact, attach all electrodes to Subject at least five minutes prior to recording.

7. **Subject** gets in a seated, relaxed, position.

Subject should sit with arms relaxed at side of body and hands apart in lap, with legs flexed at knee and feet supported.

Position the cables and leads such that they do not pull on the electrodes; connect the electrode cable clip to a convenient location on **Subject's** clothes.

Setup continues…

Fig. 17.7 Calibration Positioning

8. Clean the stethoscope earpieces and diaphragm.

Clean each earpiece with rubbing alcohol and allow it to dry completely. You should also clean the surface of the stethoscope diaphragm (the part that comes in contact with the skin) for each new **Subject**.

9. **Start** the Biopac Student Lab Program.

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

10. Choose lesson "**L17 – Heart Sounds"** and click **OK**.
11. **Type** in your filename and click **OK**.

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.

12. ***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

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

END OF SETUP

B. CALIBRATION

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

FAST TRACK Calibration

1. **Subject** remains seated, relaxed and still.
2. Click **Calibrate**.
3. Lightly tap the stethoscope diaphragm twice.
4. Wait for Calibration to stop.
5. Verify recording resembles the example data.
   - If similar, proceed to next step.
   - If necessary, click **Redo Calibration**.

END OF CALIBRATION

Detailed Explanation of Calibration Steps

Subject must remain relaxed and still throughout calibration to minimize baseline shift and EMG artifact.

Calibration will stop automatically after 8 seconds.

The stethoscope data must show clear spikes to indicate when it was tapped. There should be a recognizable ECG waveform with baseline at or near 0 mV with no large baseline drift and no significant EMG artifact.

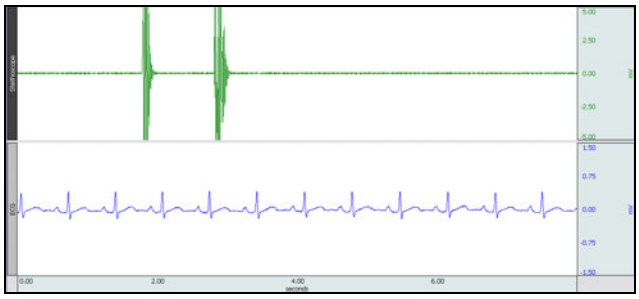

Fig. 17.8 Example Calibration data

If recording does not resemble the Example Data.

- If the data is noisy or flatline, check all connections to the MP unit.
- If the ECG displays baseline drift or excessive EMG artifact:
  - Verify all electrodes are making good contact with the skin and that the leads are not pulling on the electrodes.
  - Make sure the **Subject** is in a relaxed position. (Fig. 17.7)

POSITIONING THE STETHOSCOPE

- **Director** determines optimal stethoscope diaphragm position for listening to heart sounds 1 and 2 ("lub-dub",) and should mark the location with a water-soluble pen.
- For suggested stethoscope placements, see the **Stethoscope Position Reference** below.
- If not performing the optional Note Sounds setup, click **Continue** to proceed to the Data Recording section.

OPTIONAL: "NOTE SOUNDS" SETUP

OPTIONAL: Click Note Sounds to enter detailed descriptions of heart sounds at each valve position.

- Refer to **Stethoscope Position Reference** (below) OR Help menu Valve Positions.
- After completing descriptions, click **Continue** to proceed with the recording.

Stethoscope Position Reference

(Fig. 17.11)

END OF NOTE SOUNDS SETUP

- **For greater stethoscope comfort**, rotate the Eartubes slightly forward.

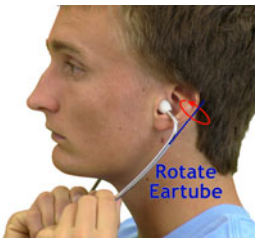

Fig. 17.9 Rotate Eartube for comfort

- Refer to the Stethoscope Position Reference section below.
- The best stethoscope position may be the one that produces the loudest sounds, but it is important that heart sounds 1 and 2 ("lub-dub") are recorded. This may only be possible by "trial and error" after reviewing the first data recording and redoing if necessary.

The **Director** should describe the sound as to its pitch, loudness, and duration, and the **Recorder** types in the description. Begin with the aortic valve and compare it to the others.

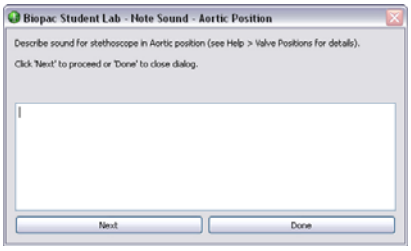

Fig. 17.10 Sound description entry dialog

Click **Next** to proceed to the next valve position, and repeat the description/entry process. Repeat for all valve positions then click **Done**. (All descriptions will appear in the Journal when the lesson is reviewed in Analysis mode.)

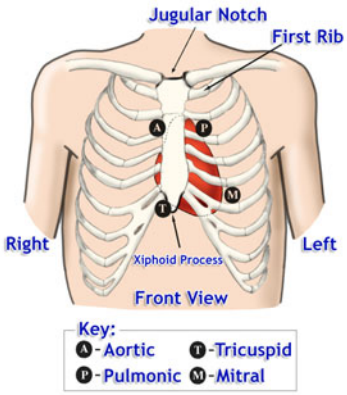

Fig. 17.11 Heart valve position and corresponding stethoscope placement

Aortic and Pulmonic positions: Follow the collarbone to the jugular (supraclavicular) notch, which is a little depression just below the Adam's apple. Go down vertically 64 mm (2.5") and 38 mm (1.5") to the right for Aortic or 38 mm (1.5") to the left for Pulmonic. Position stethoscope between the ribs. Note that this description only works on adults.

Tricuspid position: Just to the right of the tip of the sternum (xiphoid process) immediately below the rib cage.

Mitral position: Roughly on the same horizontal plane as the tricuspid position to the left of the tip of the sternum (xiphoid process) between the fifth and sixth ribs.

C. DATA RECORDING

FAST TRACK Recording

1. Prepare for the recording.
   - **Subject** remains seated, relaxed, breathing normally (Fig. 17.7).
   - **Review** recording steps before proceeding.

Seated, at rest

2. **Recorder** clicks **Record**.
   - **Subject** remains seated relaxed, breathing normally.
   - Stethoscope diaphragm is held in optimal position.
3. Record for 20 seconds.
4. After 20 seconds, **Subject** begins a slow, deep inhale/exhale cycle.
   - **Recorder** presses **F4** at start of inhale and **F5** at start of exhale.
   - Wait for deep exhale to complete.
5. Click **Suspend**.
6. Verify that recording resembles the example data.
   - If similar, proceed to Step 7.
   - If different, click **Redo**.

Recording continues…

Detailed Explanation of Recording Steps

Two data recordings will be acquired*: One with **Subject** at rest and one after moderate exercise.

***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:

- If Subject is holding the stethoscope diaphragm, it must be held in left hand, with right hand relaxed in order to minimize EMG artifact.
- To avoid noise artifact, the stethoscope must be held still.
- The room should be quiet in order to easily hear sounds through the stethoscope.

If the Stethoscope data displays very low amplitude, you can choose **Display > Autoscale Waveforms** DURING the recording.

Subject begins a slow, deep inhalation, hold for one second and continue with a slow exhalation, then return to normal breathing.

- Subject should breathe through the nose. Recorder should listen and watch the Subject to detect the start of inhale and exhale.
- To minimize baseline shift and EMG artifact, do not inhale or exhale quickly and try to minimize chest expansion.

The heart sounds should be clearly seen in the stethoscope data. The ECG data should show little baseline drift or EMG artifact except during the deep breathing portion. The two event markers must be present.

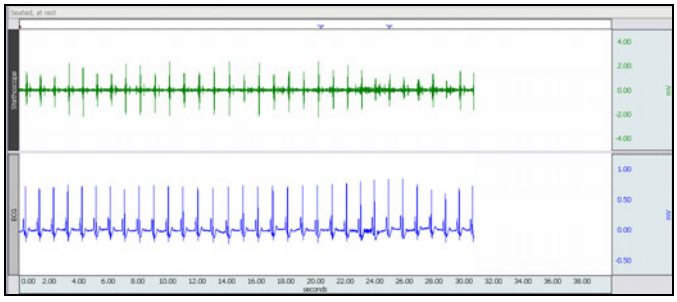

Fig. 17.12 Example data

If recording does not resemble the Example Data…

- If the data is noisy or flatline, check all connections to the MP unit.
- If the stethoscope data is of very low amplitude, choose Display > Autoscale Waveforms. If the heart sounds are not distinguishable from baseline noise, redo and try a different diaphragm position and/or apply more pressure to the stethoscope diaphragm. If the diaphragm position changes, make sure to mark it with a water-soluble pen.
- If there is too much noise artifact in the stethoscope data, make sure to hold the stethoscope with constant pressure and to minimize movement.
- If the ECG displays baseline drift or excessive EMG artifact:
  - Verify all electrodes are making good contact with the skin and that the leads are not pulling on the electrodes.
  - Make sure the **Subject** is in a relaxed position (Fig. 17.7).
- If event markers are missing, redo and remind Recorder to press F4 and F5 at the appropriate times.

Click **Redo** and repeat Steps 1 – 6 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

7. Zoom in to verify heart sounds 1 and 2 are recorded.
   - If heart sounds 1 and 2 are present, proceed to next recording.
   - If necessary, click **Redo**.
   - If all required recordings have been completed, click **Done**.

Zoom in to see the details of the cardiac cycles. All four heart sounds may be seen in your data, but it is important that at least heart sounds 1 and 2 are recorded for proper data analysis.

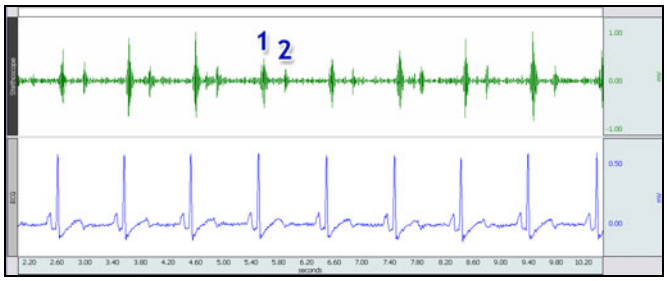

Fig. 17.13 Zoom to verify heart sounds 1 and 2 are recorded

If only one heart sound is recorded, **Redo** and try a slightly different diaphragm position and/or apply more pressure to the stethoscope diaphragm.

After exercise

8. Unclip electrode leads from **Subject**.

Subject must be able to move about freely to exercise and elevate the heart rate.

9. **Subject** exercises to elevate heart rate to 1.5 x resting HR and then sits down to recover.

The exercise required will vary depending on **Subject** and the level of physical fitness. Generally, 20 – 30 push-ups/jumping-jacks or running in place for 25 – 40 steps will suffice. After exercise, **Subject** sits down and remains relaxed and still.

10. Check that electrodes are still making good contact with skin and re-clip leads in Lead II configuration.

Check electrode adhesion and reconnect leads after exercise. Pay attention to the lead color for proper placement, as shown in Fig. 17.6.

11. **Subject** places stethoscope in same optimal position as previous recording.
12. Click **Record**.
    - **Subject** remains seated, recovering from exercise.
    - Stethoscope diaphragm is held in optimal position.

Recording continues…

13. Record for 20 seconds.
14. Click **Suspend**.
15. Verify recording resembles the example data.
    - If similar, click **Continue** and proceed to optional recording section, or **Done** to finish the lesson.
    - If necessary, click **Redo**.

The heart sounds should be clearly seen in the stethoscope data and will typically be of greater amplitude than the last recording (at rest). The ECG may show more baseline drift or EMG artifact than in the first recording.

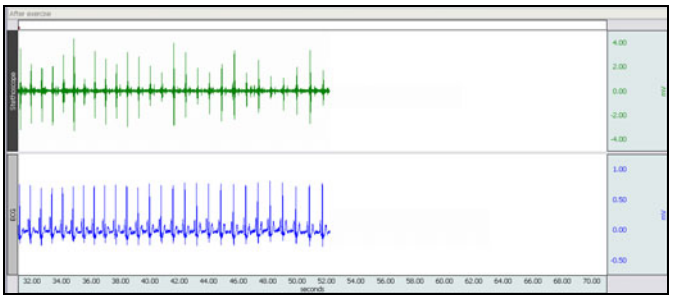

Fig. 17.14 Post-Exercise example data

Click **Redo** and repeat Steps 8 – 15 if necessary.

Note that when **Redo** is clicked, the most recent recording will be erased.

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.

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

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

- Repeat Setup Steps 4 – 8, and then proceed to Calibration.

17. Remove the electrodes.

Remove the electrode cable pinch connectors and peel off all electrodes. Discard the electrodes. (BIOPAC electrodes are not reusable.) Wash the electrode gel residue from the skin, using soap and water. The electrodes may leave a slight ring on the skin for a few hours which is quite normal.

END OF RECORDING

V. DATA ANALYSIS

FAST TRACK Data Analysis

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

Channel	*Displays*
CH 1	**Stethoscope**
CH 2	**ECG**

   - Note measurement box settings:

Channel	*Measurement*
CH 1	**P-P**
CH 1	**Delta T**
CH 1	**BPM**

2. Set up the display window for optimal viewing of the first recording.

3. **Zoom** in on an area of two complete cardiac cycles, prior to the start of deep inhalation.

4. Use the **I-Beam** cursor to select the area from one R-wave to the next R-wave.

   Note the **BPM** measurement.

   A

Data Analysis continues…

Detailed Explanation of Data Analysis Steps

If entering **Review Saved Data** mode from the Startup dialog or Lessons menu, make sure to choose the correct file.

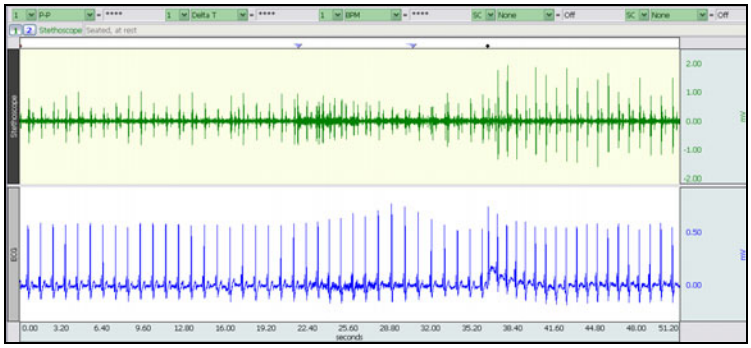

Fig. 17.15 Example data

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.

Brief definition of measurements:

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

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

BPM: Calculates the difference in time between the first and last selected points and then divides this value into 60 seconds/minute.

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.

Note: Try and choose two cardiac cycles that have clearly defined ECG components and whose corresponding hear sounds have minimal noise artifact. Scroll to other cardiac cycles if necessary.

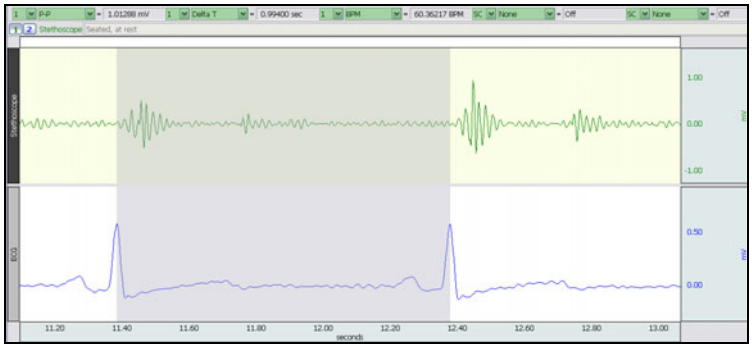

Fig. 17.16 R-R interval

5. Use the **I-Beam** cursor to select an area from the start of the 2nd heart sound to the start of the 1st heart sound of the next cardiac cycle. (Refer to Stethoscope data only (CH1); do not use the ECG channel for this portion of the experiment.)

   Note the **Delta T** measurement.

   A

Heart Sounds in Stethoscope channel (CH1) will lag slightly behind the R-wave (ECG CH2).

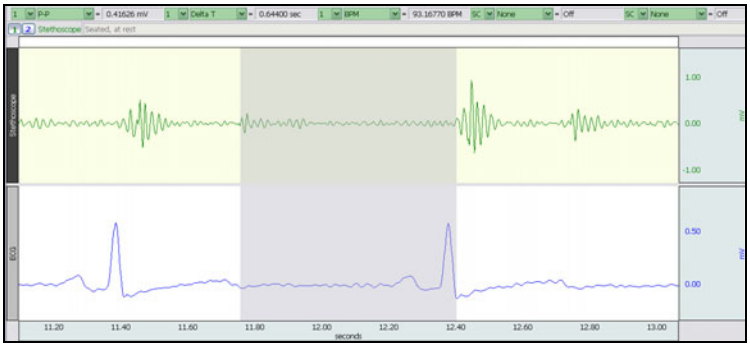

Fig. 17.17 2nd heart sound to 1st heart sound of next cardiac cycle

6. Zoom in on an area of one complete cardiac cycle.

7. Use the **I-Beam** cursor to select an area from the R-wave peak to the start of the 1st heart sound.

   Note the **Delta T** measurement.

   A

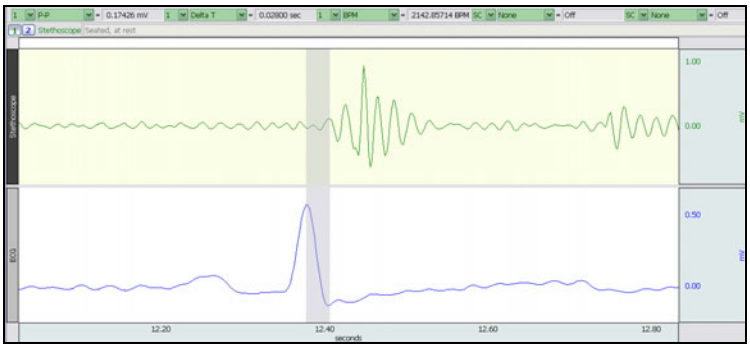

Fig. 17.18 R-wave to 1st heart sound

8. Use the **I-Beam** cursor to select an area from the R-wave peak to the start of the 2nd heart sound.

   Note the **Delta T** measurement.

   A

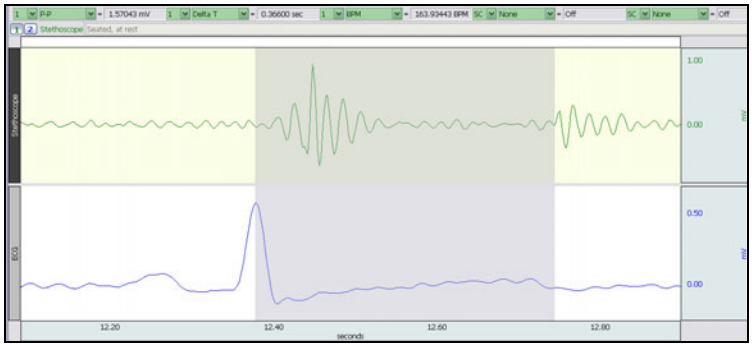

Fig. 17.19 R-wave to 2nd heart sound

9. Use the **I-Beam** cursor to select an area that encompasses the 1st heart sound.

   Note the **P-P** measurement.

   A

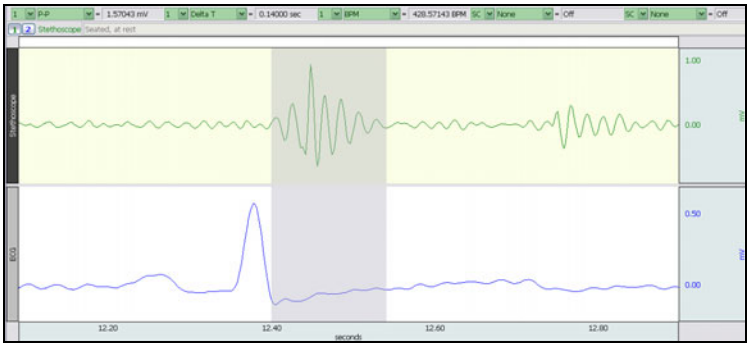

Fig. 17.20 1st heart sound interval

10. Use the **I-Beam** cursor to select an area that encompasses the 2nd heart sound.

    Note the **P-P** measurement.

    A

Data Analysis continues…

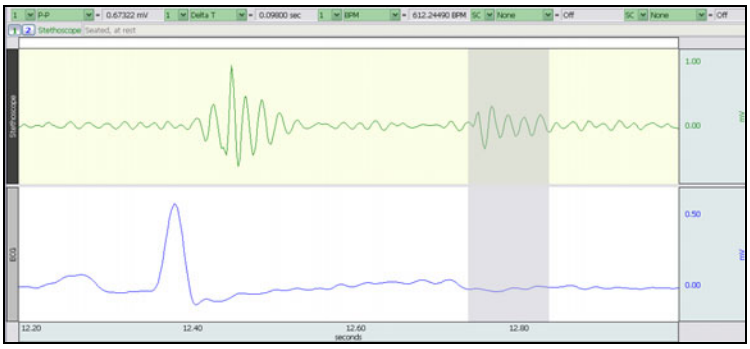

Fig. 17.21 2nd heart sound interval

11. Scroll to the Inhale interval of the "Seated, at rest" recording and take the measurements described above (in Steps 3 – 10) as required to complete Table 17.1.

    A

    This interval begins with the event marker labeled "Inhale." Choose cardiac cycles that are a few cycles after the event marker.

12. Scroll to the **Exhale** interval of the first recording and take the measurements described above (in Steps 3 – 10) as required to complete Table 17.1.

    A

    This interval begins with the event marker labeled "Exhale." Choose cardiac cycles that are a few cycles after the event marker.

13. Scroll to the "**After exercise"** recording and take the measurements described above (in Steps 3 – 10) as required to complete Table 17.1.

    A

    This recording begins with the append event marker labeled "After exercise."

    Note: The ECG data may contain more baseline drift and/or EMG artifact than the first recording and the stethoscope data may contain more noise artifact. It may be necessary to scroll through the data until acceptable cardiac cycles and corresponding heart sounds are found.

14. Answer the questions at the end of the Data Report.

    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.

15. **Save** or **Print** the data file.
16. **Quit** the program

END OF DATA ANALYSIS

END OF LESSON 17

Complete the Lesson 17 Data Report that follows.

HEART SOUNDS

- *Cardiac valve functions*
- *Relationship between electrical and mechanical events of the cardiac cycle*

DATA REPORT

Student's Name: _____

Lab Section: _____

Date: _____

Subject Profile

Name:_____ Height:_____ Gender: Male / Female

Age:_____ Weight:_____

Note: This Data Report assumes that all lesson recordings were performed, which may not be the case for your lab. Please disregard any references to excluded recordings.

I. Data and Calculations

A. Heart Sound Measurements

Complete Table 17.1 with **"Seated, at rest"** and "**After exercise"** data and complete the required calculations.

Table 17.1

Selected area	Measurement	Seated, at rest			After exercise
		At Rest	Inhalation	Exhalation	
R-wave to next R-wave	1 BPM				
R-wave to 1st heart sound	1 Delta T				
R-wave to 2nd heart sound	1 Delta T				
1st to 2nd heart sound	1 Delta T				
2nd sound to next 1st sound	1 Delta T				
1st heart sound interval	1 P-P				
2nd heart sound interval	1 P-P				

B. Description of Heart Sounds

Note: You may copy and paste descriptions from the Lesson 17 journal below.

Describe the sounds of each of the following heart valves in terms of intensity (loudness,) pitch (frequency) and duration (length). Begin with the aortic valve and compare others to it. This is a subjective description.

Aortic _____

_____

Pulmonic _____

_____

Tricuspid _____

_____

Mitral _____

II. Questions

1. Relative to the electrical and mechanical events of the cardiac cycle, what do each of the measurements in *Table 17.1* represent?

   BPM: _____

   Delta T: R-wave to 1st sound _____

   R-wave to 2nd sound _____

   1st to 2nd _____

   2nd sound to next 1st sound _____

   P-P: 1st sound _____

   2nd sound _____

2. Note whether the measured values in *Table 17.1* increased, decreased or did not change from the resting value when heart rate increased.

Table 17.2

Measured Value		Increased	Decreased	No Change
BPM				
Delta T	R-wave to 1st sound			
	R-wave to 2nd sound			
	1st to 2nd			
	2nd sound to next 1st sound			
P-P	1st sound			
	2nd sound			

3. Explain why each of these would change.

4. Briefly describe the cause of the turbulence associated with each of the four heart sounds:

   1st sound _____

   2nd sound _____

   3rd sound _____

   4th sound _____

5. Which of the four heart sounds is loudest? Give a reason.

6. Does ventricular ejection occur during ventricular depolarization or during ventricular repolarization? Refer to your experimental record before you answer, and explain your answer.

7. Which cardiac valves close during ventricular systole? Which cardiac valves close during ventricular diastole?
   Systole:
   Diastole:

8. Define "**systolic murmur**" and give one example of a cause.

9. Define "**diastolic murmur**" and give one example of a cause.

10. Define "**cardiac cycle**."

11. Briefly characterize the relationship between the electrical events and the mechanical events of the cardiac cycle.

III. OPTIONAL Active Learning Portion

A. ***Hypothesis***

B. ***Materials***

C. ***Method***

D. ***Set Up***

E. ***Experimental Results***

End of Lesson 17 Data Report