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II. EXPERIMENTAL OBJECTIVES

1) To become familiar with the electrocardiograph as a primary tool for evaluating electrical events within the heart.
2) To correlate electrical events as displayed on the ECG with the mechanical events that occur during the cardiac cycle.
3) To observe rate and rhythm changes in the ECG associated with body position and breathing.

III. MATERIALS

- BIOPAC Electrode Lead Set (SS2L)
- BIOPAC Disposable Electrodes (EL503,) 3 electrodes per subject
- BIOPAC Electrode Gel (GEL1) and Abrasive Pad (ELPAD) *or* Skin cleanser or alcohol prep
- Mat, cot or lab table and pillow for Supine position
- 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)

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:
   Electrode Lead Set (SS2L)—CH 1
3. Turn **ON** the MP36/35 unit.
4. Clean and abrade skin.
5. Attach three electrodes on **Subject** as shown in Fig. 5.6.

Setup continues…

Detailed Explanation of Setup Steps

Fig. 5.5 MP3X (top) and MP45 (bottom) hardware connections

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.

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).

For optimal electrode contact, place electrodes on skin at least 5 minutes before start of Calibration.

6. Clip the Electrode Lead Set (SS2L) to the electrodes following the color code (Fig. 5.6).
   - RIGHT forearm = WHITE lead
   - RIGHT leg = BLACK lead (ground)
   - LEFT leg = RED lead

Fig. 5.6 Lead II Setup

The pinch connectors work like a small clothespin, but will only latch onto the nipple of the electrode from one side of the connector.

7. **Subject** gets in supine position (lying down, face up) and relaxes (Fig. 5.7).

Position the electrode cables so that they are not pulling on the electrodes. Connect the electrode cable clip to a convenient location on **Subject's** clothes.

Fig. 5.7 Positioning (supine)

8. Start the BIOPAC Student Lab program.
9. Choose lesson "**L05 – Electrocardiography (ECG) I**" and click **OK**.

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

10. Type in a unique **filename** and click **OK**.
11. ***Optional***: Set Preferences.
    - Choose File > **Lesson Preferences**.
    - Select an option.
    - Select the desired setting 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.

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
ECG filter: Set bandwidth
Heart Rate Data: Calculate and display Heart Rate data
Time Scale: Set the full screen time scale with options from 10 to 20 seconds.
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 supine and relaxed, with eyes closed.
2. Click **Calibrate**.
   - **Subject** remains relaxed with eyes closed.
   - Wait for Calibration to stop.
3. Verify recording resembles example data.
   - If similar, click **Continue** and proceed to Data Recording.
   - If necessary, click **Redo Calibration**.

END OF CALIBRATION

Detailed Explanation of Calibration Steps

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

Calibration lasts eight seconds.

There should be a recognizable ECG waveform with a baseline at or near 0 mV, little EMG artifact and no large baseline drift.

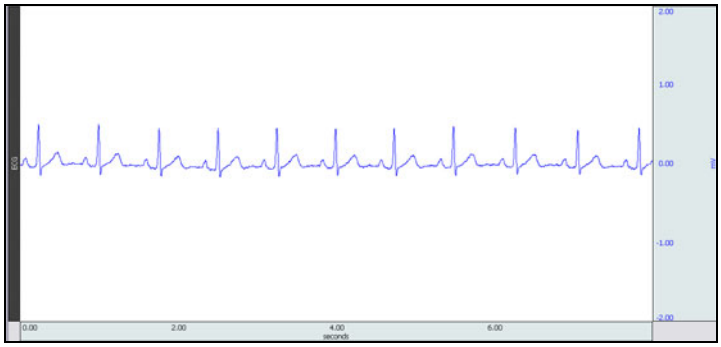


Fig. 5.8 Example Calibration data

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 electrodes are making good contact with the skin and that the leads are not pulling on the electrodes.
  - Make sure Subject is in a relaxed position.

Click **Redo Calibration** and repeat Steps 1 – 3 if necessary.

C. DATA RECORDING

FAST TRACK Recording

1. **Subject** remains supine and relaxed, with eyes closed.
   - **Subject** must remain still.
   - **Review** recording steps.

Detailed Explanation of Recording Steps

Four conditions* will be recorded: Supine, Seated, Breathing deeply, and After exercise. **Subject** performs tasks in the intervals between recordings.

***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:

To minimize EMG artifact and baseline drift:

- **Subject's** arms and legs must be relaxed.
- **Subject** must remain still and should not talk during any recordings.
- Make sure electrodes do not peel up and that the leads do not pull on the electrodes.

Supine

2. Click **Record**.
3. **Subject** remains supine and relaxed, with eyes closed.
4. Record for 20 seconds.
5. Click **Suspend**.
6. Verify recording resembles the example data.
   - If similar, click **Continue** and proceed to next recording.

The ECG waveform should have a baseline at or near 0 mV and should not display large baseline drifts or significant EMG artifact. The Heart Rate (BPM) data will not be accurate until after the first two cardiac (ECG) cycles after which there should not be sporadic variations that go out of the visible range.

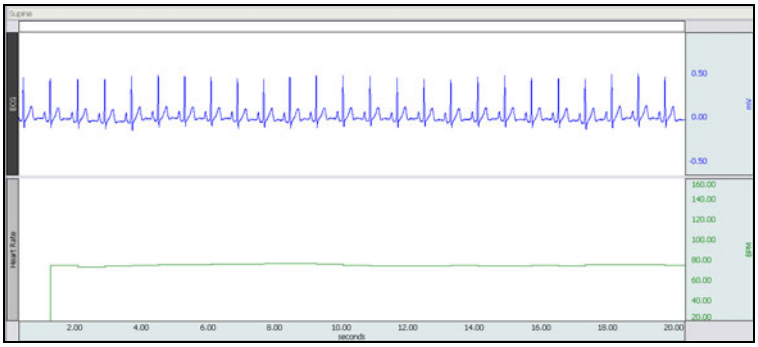


Fig. 5.9 Example Supine data

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

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 excessive baseline drift or EMG artifact, or if the Heart Rate (BPM) data shows sporadic values:
  - Verify electrodes are making good contact with the skin and that the leads are not pulling on the electrodes.
  - Make sure **Subject** is in a relaxed position.
- Click **Redo** and repeat Steps 2 – 6 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

Recording continues…

Seated

- **Review** recording steps.

7. **Subject** gets up quickly and then settles into a seated position (Fig. 5.10).

Subject should sit with arms relaxed at side of body and hands apart in lap, with legs flexed at knee and feet supported for seconds 21 – 40.

Fig. 5.10 Positioning (seated)

8. Once **Subject** is seated and still, click **Record**.
9. Record for 20 seconds.
10. Click **Suspend**.
11. Verify recording resembles the example data.
    - If similar, click **Continue** and proceed to the next recording.

In order to capture the heart rate variation, click Record as quickly as possible after **Subject** sits and relaxes.

Subject remains seated, relaxed, and breathing normally.

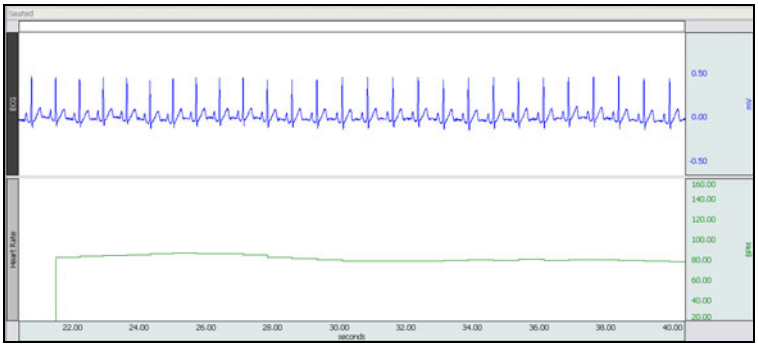


Fig. 5.11 Example Seated data

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

The data description is the same as outlined in Step 6.

Click **Redo** if necessary. The **Subject** must return to the Supine position for at least 5 minutes before repeating Steps 7 – 11.

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

Recording continues…

Deep Breathing

- **Review** recording steps.

12. Click **Record**.
13. **Subject** inhales and exhales slowly and completely as possible for five prolonged (slow) breath cycles.
    - **Recorder** presses F4 at the start of each inhale.
    - **Recorder** presses F5 at the start of each exhale.
14. Click **Suspend**.
15. Verify recording resembles the example data.
    - If similar, click **Continue** and proceed to the next recording.
    - If necessary, click **Redo**.
    - If all required recordings have been completed, click **Done**.

Subject remains seated.

Note It is important to breathe with long, slow, deep breaths to help minimize EMG artifact.

If possible, the **Subject** should breathe through nose so the **Recorder** can clearly observe the start of each inhale and exhale.

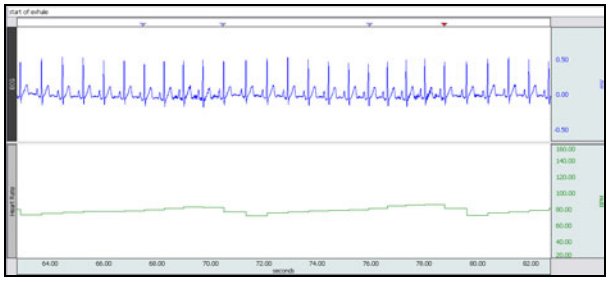


Fig. 5.12 Example Deep Breathing data

The data description is the same as outlined in Step 6 with the following exception:

- The ECG data may exhibit some baseline drift during deep breathing which is normal and unless excessive, does not necessitate **Redo**.

Click **Redo** and repeat Steps 12 – 15 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

After exercise

- **Review** recording steps.

16. **Subject** exercises to elevate heart rate.
    - If electrode leads were unclipped, clip them back on.
    - Following exercise, **Subject** sits down and relaxes.
17. **Record** for 60 seconds.
18. Click **Suspend**.
19. Verify recording resembles the example data.
    - If similar, click **Continue** to proceed to optional recording section, or click **Done** if finished.

Recording continues…

Subject should perform an exercise to elevate his/her heart rate fairly rapidly, such as running up stairs, push-ups, or jumping-jacks.

Note You may remove the electrode cable pinch connectors so that **Subject** can move about freely, but **do not remove the electrodes**.

If you do remove the cable pinch connectors, you must reattach them following the precise color placement in Fig. 5.6 prior to clicking **Record**.

When seated, **Subject's** arms must be relaxed and at sides of body, with arms relaxed and feet supported.

In order to capture the heart rate variation, it is important that you resume recording as quickly as possible after **Subject** has performed the exercise. However, it is also important that you do not click **Record** while **Subject** is exercising or you will capture motion artifact.

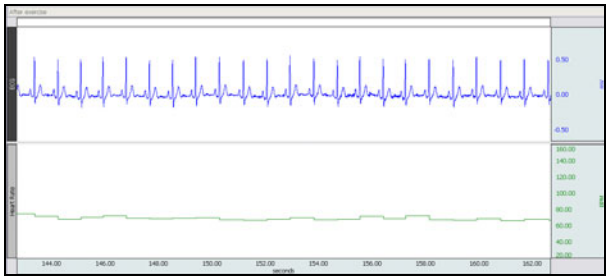


Fig. 5.13 Example After Exercise data

- If necessary, click **Redo**.

The data description is the same as outlined in Step 6, with the following exception:

- The ECG data may exhibit some baseline drift which is normal and unless excessive, does not necessitate **Redo**.

Click **Redo** and repeat Steps 16 – 19 if necessary. Note that once **Redo** is clicked, the most recent recording will be erased.

OPTIONAL ACTIVE LEARNING PORTION

With this lesson you may record additional data segments by clicking **Continue** following the last recording segment. 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 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 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.

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

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

- Repeat Setup Steps 6 – 9, and then proceed to Calibration.

21. 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

In this section, you will examine ECG components of cardiac cycles and measure amplitudes (mV) and durations (msecs) of the ECG components.

Note: Interpreting ECGs is a skill that requires practice to distinguish between normal variation and those arising from medical conditions. Do not be alarmed if your ECG is different than the normal values and references in the Introduction.

FAST TRACK Data Analysis

1. Enter the **Review Saved Data** mode.

- Note Channel Number (CH) designation:

CH 1 **ECG** (Lead II)
CH 40 **Heart Rate**

- Note measurement box settings:

Channel *Measurement*
CH 40 **Value**
CH 1 **Delta T**
CH 1 **P-P**
CH 1 **BPM**

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.

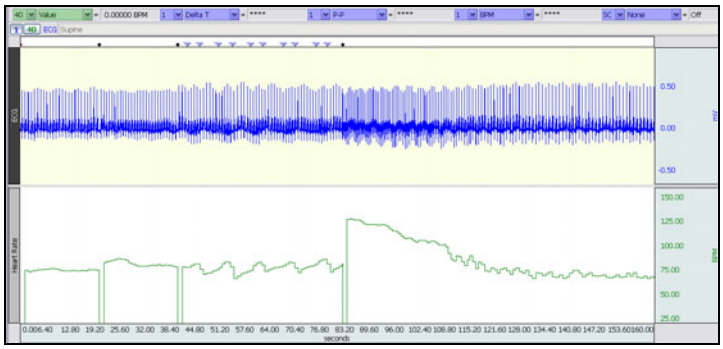


Fig. 5.14 Example data

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:

Value: Displays the amplitude value at the point selected by the I-beam cursor. If an area is selected, displays the value of the endpoint based on the direction the cursor was dragged.

- CH 40 heart rate data is only updated at the end of an R-R interval so it remains constant within an R-R interval; therefore, the Value (BPM) measurement will be accurate from any selected point in the R-R interval.
- Single point Values will be shown when placing the Arrow cursor over the data while holding down the left mouse button.

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

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

BPM: *Use only if CH 40 was not recorded.* 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.

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

Textual notes (such as identifying components of the ECG wave) can be inserted into the graph by using the **Annotation** tool. This tool will place a small editable text box anywhere in the waveform.

2. Set up your display window for optimal viewing of three complete cardiac cycles from the initial "**Supine**" segment.

NOTE: For accurate BPM data go past the first two cardiac cycles.

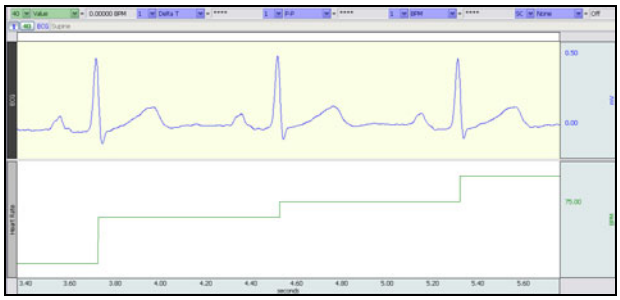


Fig. 5.15 Zoom in on "Supine" data

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

Useful tools for changing view:

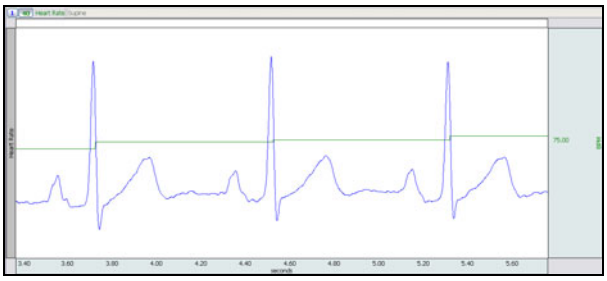
Display menu: Autoscale Horizontal, Autoscale Waveforms, Zoom Back, Zoom Forward

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

Cursor Tools: Zoom Tool

Buttons: Overlap, Split, Adjust Baseline (Up, Down,) Show Grid, Hide Grid, -, +

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



The Heart Rate channel is updated at the end of each R-R interval, so it will initially appear "out of sync," or delayed by one interval. (See Fig. 5.17 for illustration.)

Fig. 5.16 Overlap sample: Heart Rate and ECG after supine Subject is seated

Adjust Baseline allows you to position the waveform up or down in small increments so that the baseline (isoelectric line) can be exactly zero. After **Adjust Baseline** is pressed, **Up** and **Down** buttons are generated. Simply click these to move the waveform up or down. This is not needed to get accurate amplitude measurements, but may be desired before making a printout, or when using grids.

3. For measuring heart rate, use the cursor to select any data point within an R-R interval.

A

Note that the CH 40 Value measurement displays the BPM for the interval preceding the current R-R interval.

If CH 40 Heart Rate data was not recorded, use CH 1 BPM measurement to determine the heart rate; select from R wave peak to R wave peak as precisely as possible.

Follow the examples shown above to complete all the measurements required for the Data Report

4. Take measurements within two other R-R intervals in the current segment.

A

5. Repeat measurements on the other segments as required for the Data Report.

A

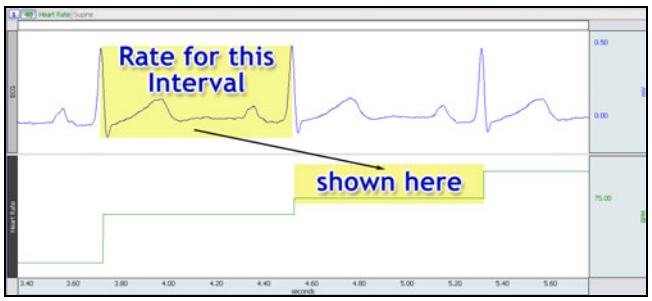


Fig. 5.17 Data point selection for Heart Rate data correlated to ECG data

Data Analysis continues…

6. Hide CH 40.
7. **Zoom** in on a single cardiac cycle from "**Supine**" segment.
8. Measure Ventricular Systole and Diastole.

   B

The remaining measurements use ECG data only. To hide Heart Rate data display and focus on ECG data, Alt + click (Windows) or Option + click (Mac) the "40" channel number box.

For Ventricular Systole and Diastole measurements, the T wave reference point for the selected area is 1/3 of the way down the descending portion of the T wave; if necessary, see Fig. 5.2 and Table 5.1 in the Introduction PDF for selected area details.

9. Repeat measurements for "**After exercise**" segment.

   B

Measurement data starts at the append event marker labeled "**After exercise**."

10. **Zoom** in on a single cardiac cycle from "**Supine**" segment.
11. Use the I-Beam cursor to select segments and measure the durations and wave amplitudes required for the Data Report. Use P-P measurement to obtain amplitudes.

    C

Select the components of the ECG as specified in the Introduction and gather wave amplitude data for 3 cycles using the P-P measurement. If necessary, see Fig. 5.2 and Table 5.1 in the Introduction for selected area details.

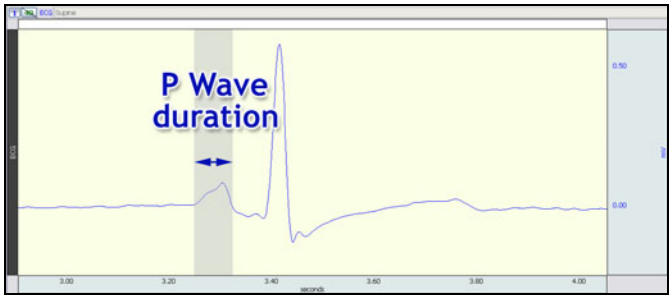


Fig. 5.18 Measuring P wave duration (Delta T) and amplitude (P-P)

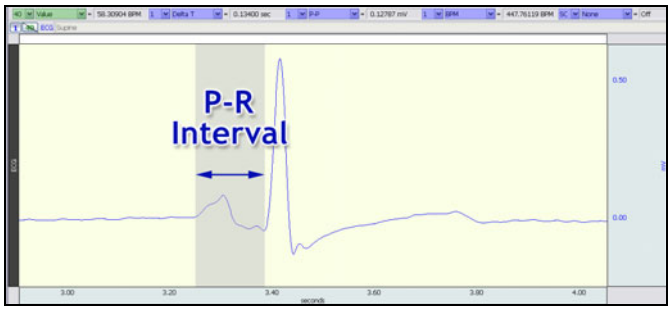


Fig. 5.19 Selection of P-R Interval

12. **Zoom** in on a single cardiac cycle from "**After exercise**" segment.
13. Repeat duration and amplitude (P-P) measurements using "**After exercise**" data as required for the Data Report.

    C

Follow the examples shown above to complete all the measurements required for your Data Report.

Data Analysis continues…

14. **OPTIONAL:** Using the **Annotation** tool, insert text boxes identifying the ECG components in the selected area. Copy and paste this graph to the Data Report at the end of Section C.

Use the **Annotation** Tool to insert text boxes into the graph identifying the ECG components in the selected portion, and then drag them to their correct locations within the ECG waveform.

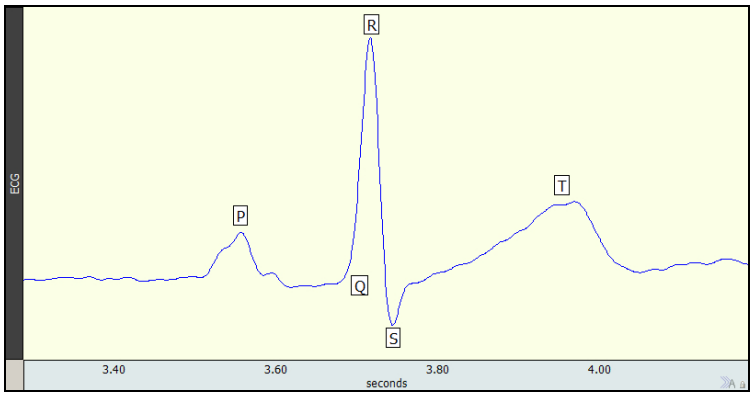


Fig 5.20 Example of ECG Component Annotations

- Use the **Copy Graph** button to copy the selected area.
- Use the contextual menu in the Journal to paste the graph into the Data Report.

15. Answer the questions at the end of the Data Report.
16. **Save** or **Print** the data file.
17. **Quit** the program.

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 5

Complete the Lesson 5 Data Report that follows.

ELECTROCARDIOGRAPHY I

- *ECG I*

DATA REPORT

Student's Name: _____
Lab Section: _____
Date: _____

I. Data and Calculations

Subject Profile

Name:_____ Height:_____

Age:_____ Gender: Male / Female Weight:_____

A. Heart Rate

Complete the following tables with the lesson data indicated, and calculate the Mean as appropriate;

Table 5.2

Recording: Condition	Cardiac Cycle 40 Value 1	2	3	Mean (calculate)
Supine				
Seated				
Start of inhale				
Start of exhale				
After exercise				

- If CH 40 was not recorded, use 1 BPM.

B. Ventricular Systole and Diastole

Table 5.3

Condition	Duration (ms) 1 Delta T	
	Ventricular Systole	Ventricular Diastole
Supine		
After exercise		

C. Components of the ECG

Table 5.4

Condition: Supine Recording (measurements taken from 3 cardiac cycles)										
ECG Component	Normative Values Based on resting heart rate 75 BPM		Duration (ms) 1 Delta T				Amplitude (mV) 1 P-P			
			1	2	3	Mean (calc)	1	2	3	Mean (calc)
Waves	Dur. (sec)	Amp. (mV)								
P	.07 - .18	< .20								
QRS Complex	.06 - .12	.10 – 1.5								
T	.10 - .25	< .5								
Intervals	Duration (seconds)									
P-R	.12 - .20									
Q-T	.32 - .36									
R-R	.80									
Segments	Duration (seconds)									
P-R	.02 - .10									
S-T	< .20									
T-P	0 - .40									

Table 5.5

Condition: After Exercise Recording (measurements taken from 1 cardiac cycle)				
ECG Component	**Normative Values** Based on resting heart rate 75 BPM		**Duration (ms)** 1 Delta T	**Amplitude (mV)** 1 P-P
Waves	Dur. (sec)	Amp. (mV)		
P	.07 - .18	< .20		
QRS Complex	.06 - .12	.10 – 1.5		
T	.10 - .25	< .5		
Intervals	Duration (seconds)			
P-R	.12 - .20			
Q-T	.32 - .36			
R-R	.80			
Segments	Duration (seconds)			
P-R	.02 - .10			
S-T	< .20			
T-P	0 - .40			

Note Interpreting ECGs is a skill that requires practice to distinguish between normal variation and those arising from medical conditions. Do not be alarmed if your ECG does not match the "Normative Values."

II. Questions

D. Using data from table 5.2:

1) Explain the changes in heart rate between conditions. Describe the physiological mechanisms causing these changes.

2) Are there differences in the cardiac cycle with the respiratory cycle ("Start of inhale-exhale" data)?

E. Using data from table 5.3:

1) What changes occurred in the duration of systole and diastole between resting and post-exercise?

F. Using data from tables 5.4 and 5.5:

1) Compared to the resting state, do the durations of the ECG intervals and segments decrease during exercise? Explain

2) Compare your ECG data to the normative values. Explain any differences.

3) Compare ECG data with other groups in your laboratory. Does the data differ? Explain why this may not be unusual. _____

_____

G. In order to beat, the heart needs three types of cells. Describe the cells and their function.

1) _____
2) _____
3) _____

H. List in proper sequence, starting with the normal pacemaker, elements of the cardiac conduction system.

1) _____
2) _____
3) _____
4) _____
5) _____
6) _____
7) _____
8) _____

I. Describe three cardiac effects of increased sympathetic activity, and of increased parasympathetic activity.

Sympathetic _____

_____

_____

Parasympathetic _____

_____

_____

J. In the normal cardiac cycle, the atria contract before the ventricles. Where is this fact represented in the ECG?

_____

_____

K. What is meant by “AV delay” and what purpose does the delay serve?

_____

_____

L. What is the isoelectric line of the ECG?

_____

_____

M. Which components of the ECG are normally measured along the isoelectric line?

_____

_____

III. OPTIONAL Active Learning Portion

A. ***Hypothesis***

B. ***Materials***

C. ***Method***

D. ***Set Up***

E. ***Experimental Results***

End of Lesson 5 Data Report