I. INTRODUCTION

The main function of the heart is to pump blood through two circuits:

1. **Pulmonary circuit**: through the lungs to oxygenate the blood and remove carbon dioxide; and
2. **Systemic circuit**: to deliver oxygen and nutrients to tissues and remove carbon dioxide.

Because the heart moves blood through two separate circuits, it is sometimes described as a dual pump.

In order to beat, the heart needs three types of cells:

1. Rhythm generators, which produce an electrical signal (SA node or normal pacemaker);
2. Conductors to spread the pacemaker signal; and
3. Contractile cells (myocardium) to mechanically pump blood.

The Electrical and Mechanical Sequence of a Heartbeat

The heart has specialized **pacemaker** cells that start the electrical sequence of **depolarization** and **repolarization**. This property of cardiac tissue is called inherent rhythmicity or automaticity. The electrical signal is generated by the **sinoatrial node (SA node)** and spreads to the ventricular muscle via particular conducting pathways: **nodal pathways** and **atrial fibers**, the **atrioventricular node (AV node)**, the **bundle of His**, the right and left **bundle branches**, and **Purkinje fibers** (Fig. 5.1).

When the electrical signal of a depolarization reaches the contractile cells, they contract—a mechanical event called **systole**. When the repolarization signal reaches the myocardial cells, they relax—a mechanical event called **diastole**. Thus, the electrical signals cause the mechanical pumping action of the heart; mechanical events always follow the electrical events (Fig. 5.2).

The **SA node** is the normal pacemaker of the heart, initiating each electrical and mechanical cycle. When the SA node depolarizes, the electrical stimulus spreads through atrial muscle causing the muscle to contract. Thus, the SA node depolarization is followed by atrial contraction.

The SA node impulse also spreads to the **atrioventricular node (AV node)** via the **nodal fibers**. (The wave of depolarization does not spread to the ventricles right away because there is nonconducting tissue separating the atria and ventricles.) The electrical signal is delayed in the AV node for approximately 0.20 seconds when the atria contract, and then the signal is relayed to the **ventricles** via the **bundle of His**, right and left **bundle branches**, and **Purkinje fibers**. The Purkinje fibers relay the electrical impulse directly to ventricular muscle, stimulating the ventricles to **contract** (ventricular **systole**). During ventricular systole, ventricles begin to repolarize and then enter a period of **diastole** (Fig. 5.2).

Although the heart generates its own beat, the heart rate (beats per minute or BPM) and strength of contraction of the heart are modified by the **sympathetic** and **parasympathetic** divisions of the autonomic nervous system.
Table 5.1 Components of the ECG & Typical Lead II Values

<table>
<thead>
<tr>
<th>ECG COMPONENT</th>
<th>Measurement area...</th>
<th>Represent...</th>
<th>Duration (seconds)</th>
<th>Amplitude (millivolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waves</td>
<td>begin and end on isoelectric line (baseline); normally upright in standard limb leads</td>
<td>depolarization of the right and left atria.</td>
<td>0.07 - 0.18</td>
<td>&lt; 0.25</td>
</tr>
<tr>
<td>QRS complex</td>
<td>begin and end on isoelectric line (baseline) from start of Q wave to end of S wave</td>
<td>depolarization of the right and left ventricles. Atrial repolarization is also part of this segment, but the electrical signal for atrial repolarization is masked by the larger QRS complex (see Fig. 5.2)</td>
<td>0.06 - 0.12</td>
<td>0.10 - 1.50</td>
</tr>
<tr>
<td>T</td>
<td>begin and end on isoelectric line (baseline)</td>
<td>repolarization of the right and left ventricles.</td>
<td>0.10 - 0.25</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>Intervals</td>
<td>from start of P wave to start of QRS complex</td>
<td>time from the onset of atrial depolarization to the onset of ventricular depolarization.</td>
<td>0.12-0.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>from start of QRS complex to end of T wave</td>
<td>time from onset of ventricular depolarization to the end of ventricular repolarization. It represents the refractory period of the ventricles.</td>
<td>0.32-0.36</td>
<td></td>
</tr>
<tr>
<td>R-R</td>
<td>from peak of R wave to peak of succeeding R wave</td>
<td>time between two successive ventricular depolarizations.</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>S-T</td>
<td>between end of S wave and start of T wave</td>
<td>period of time representing the early part of ventricular repolarization during which ventricles are more or less uniformly excited.</td>
<td>&lt; 0.20</td>
<td></td>
</tr>
<tr>
<td>Segments</td>
<td>from end of P wave to start of QRS complex</td>
<td>time of impulse conduction from the AV node to the ventricular myocardium.</td>
<td>0.02 - 0.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>from end of T wave to start of successive P wave</td>
<td>time from the end of ventricular repolarization to the onset of atrial depolarization.</td>
<td>0.0 - 0.40</td>
<td></td>
</tr>
</tbody>
</table>

* Notes: Tabled values represent results from a typical Lead II setup (wrist and ankle electrode placement) with Subject heart rate ~75 BPM. Values are influenced by heart rate and placement; values for torso placement would be different.

Leads

The particular arrangement of two electrodes (one positive, one negative) with respect to a third electrode (the ground) is called a lead. The electrode positions for the different leads have been standardized. For this lesson, you will record from Lead II, which has a positive electrode on the left ankle, a negative electrode on the right wrist, and the ground electrode on the right ankle. Typical Lead II values are shown in Table 5.1.

The dominant ECG component in any normal standard lead record is the QRS complex. Usually, in a Lead II record the Q and S waves are small and negative and the R wave is large and positive as shown in Fig. 5.2. However, it is important to note many factors, normal and abnormal, determine the duration, form, rate, and rhythm of the QRS complex.

- Normal factors include body size (BSA) and distribution of body fat, heart size (ventricular mass,) position of the heart in the chest relative to lead locations, metabolic rate, and others.

For example, in a person who has a high diaphragm, the apex of the heart may be shifted slightly upward and to the person’s left. This change in the position of the heart alters the “electrical picture” of ventricular depolarization seen by the Lead II electrodes, resulting in decreased positivity of the R wave and increased negativity of the S wave. In other words, the positive amplitude of the R wave decreases and the negative amplitude of the S wave increases.

Similar changes in the Lead II QRS complex may be observed in a person, an athlete for example, who has no cardiac disease but does have a larger than normal left ventricular mass. In fact the decrease in R wave positivity coupled with the increase in S wave negativity may be so extreme as to give rise to the mistaken impression that the R wave has become inverted, when in reality the inverted spike is an enlarged S wave preceded by a much smaller but still positive R wave. When the amplitudes of Lead II Q, R, and S waves are all negative, the result is an abnormal inverted QRS complex.

- Abnormal factors include hyper- and hypothyroidism, ventricular hypertrophy (observed for example, in chronic valvular insufficiency,) morbid obesity, essential hypertension and many other pathologic states. A more detailed discussion of QRS changes in response to normal and abnormal factors requires an introduction to cardiac vectors, for which the reader is referred to Lesson 6.
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.

Detailed Explanation of Setup Steps

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.

Setup continues...
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.

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](image)

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.

END OF CALIBRATION
Seated

- Review recording steps.

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

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.

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

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.

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.

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...
* 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.

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.

If choosing the *Record from another Subject* option:
* Repeat Setup Steps 6 – 9, and then proceed to Calibration.

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.
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](image)

*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.

![Fig. 5.16 Overlap sample: Heart Rate and ECG after supine Subject is seated](image)

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.

**Note:** 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.

![Fig. 5.17 Data point selection for Heart Rate data correlated to ECG data](image)

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.

![Fig 5.20 Example of ECG Component Annotations]

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.

- 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.

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**

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

16. Save or Print the data file.

17. Quit the program.

**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

<table>
<thead>
<tr>
<th>Recording: Condition</th>
<th>Cardiac Cycle 1</th>
<th>Cardiac Cycle 2</th>
<th>Cardiac Cycle 3</th>
<th>Mean (calculate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start of inhale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start of exhale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* If CH 40 was not recorded, use ________ BPM.

B. Ventricular Systole and Diastole

Table 5.3

<table>
<thead>
<tr>
<th>Condition</th>
<th>Ventricular Systole</th>
<th>Ventricular Diastole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After exercise</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. Components of the ECG

Table 5.4

Condition: Supine Recording (measurements taken from 3 cardiac cycles)

<table>
<thead>
<tr>
<th>ECG Component</th>
<th>Normative Values Based on resting heart rate 75 BPM</th>
<th>Duration (ms)</th>
<th>Amplitude (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 Mean (calc)</td>
<td>1 2 3 Mean (calc)</td>
<td></td>
</tr>
<tr>
<td>Waves</td>
<td>Dur. (sec) Amp. (mV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>.07 - .18 &lt; .20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QRS Complex</td>
<td>.06 - .12 .10 - 1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>.10 - .25 &lt; .5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervals</td>
<td>Duration (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-R</td>
<td>.12 - .20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-T</td>
<td>.32 - .36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-R</td>
<td>.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Segments</td>
<td>Duration (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-R</td>
<td>.02 - .10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-T</td>
<td>&lt; .20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-P</td>
<td>0 - .40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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
Table 5.5

<table>
<thead>
<tr>
<th>ECG Component</th>
<th>Normative Values</th>
<th>Duration (ms)</th>
<th>Amplitude (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Based on resting heart rate 75 BPM</td>
<td>1</td>
<td>Delta T</td>
</tr>
<tr>
<td>Waves</td>
<td>Dur. (sec)</td>
<td>Apmr. (mV)</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>.07 - .18</td>
<td>&lt; .20</td>
<td></td>
</tr>
<tr>
<td>QRS Complex</td>
<td>.06 - .12</td>
<td>.10 - 1.5</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>.10 - .25</td>
<td>&lt; .5</td>
<td></td>
</tr>
<tr>
<td>Intervals</td>
<td>Duration (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-R</td>
<td>12 - 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q-T</td>
<td>32 - 36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-R</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Segments</td>
<td>Duration (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-R</td>
<td>.02 - .10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-T</td>
<td>&lt; .20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-P</td>
<td>0 - .40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

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

   B

9. Repeat measurements for "After exercise" segment.

   B

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

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.

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

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)](image1)

![Fig. 5.19 Selection of P-R Interval](image2)

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

**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](image)

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 Beats Per Minute 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.

Data Analysis 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](image)

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](image)
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.

Fig. 5.9 Example Supine data

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

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.

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:
     o Verify electrodes are making good contact with the skin and that the leads are not pulling on the electrodes.
     o 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.
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

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

8. Start the BIOPAC Student Lab program.
9. Choose lesson "L05 - Electrocardiography (ECG) 1" and click **OK**.
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**.

**END OF SETUP**

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**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.

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)**

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

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.
Effects of the Resting Respiratory Cycle on Heart Rate

Temporary minor increases and decreases in heart rate associated with the resting respiratory cycle reflect heart rate adjustments made by systemic arterial and systemic venous pressure receptor (baroreceptor) reflexes in response to the cycling of intrathoracic pressure (Fig. 5.4). When inspiratory muscles contract, pressure within the thorax (intrathoracic pressure) decreases, allowing thoracic veins to slightly expand. This causes a momentary drop in venous pressure, venous return, cardiac output, and systemic arterial blood pressure. The carotid sinus reflex normally decreases heart rate in response to a rise in carotid arterial blood pressure. However, the momentary drop in systemic arterial blood pressure during inspiration reduces the frequency of carotid baroreceptor firing, causing a momentary increase in heart rate.

When inspiratory muscles relax, resting expiration passively occurs. During early resting expiration, intrathoracic pressure increases causing compression of thoracic veins, momentarily increasing venous pressure and venous return. In response, systemic venous baroreceptors reflexively increase heart rate. However, the slight increase in heart rate is temporary because it increases cardiac output and systemic arterial blood pressure, which increases carotid baroreceptor firing causing heart rate to decrease.

The average resting heart rate for adults is between 60-80 beats/min. (Average 70 bpm for males and 75 bpm for females.) Slower heart rates are typically found in individuals who regularly exercise. Athletes are able to pump enough blood to meet the demands of the body with resting heart rates as low as 50 beats/min. Athletes tend to develop larger hearts, especially the muscle in the left ventricle—a condition known as "left ventricular hypertrophy." Because athletes (usually) have larger and more efficient hearts, their ECGs may exhibit differences other than average resting heart rate. For instance, low heart rate and hypertrophy exhibited in sedentary individuals can be an indication of failing hearts but these changes are "normal" for well-trained athletes.

Because ECGs are widely used, basic elements have been standardized to simplify reading ECGs. ECGs have standardized grids of lighter, smaller squares and, superimposed on the first grid, a second grid of darker and larger squares (Fig. 5.4). The smaller grid always has time units of 0.04 seconds on the x-axis and the darker vertical lines are spaced 0.2 seconds apart. The horizontal lines represent amplitude in mV. The lighter horizontal lines are 0.1 mV apart and the darker grid lines represent 0.5 mV. In this lesson, you will record the ECG under four conditions.
The sympathetic division increases automaticity and excitability of the SA node, thereby increasing heart rate. It also increases conductivity of electrical impulses through the atrioventricular conduction system and increases the force of atrioventricular contraction. Sympathetic influence increases during inhalation.

The parasympathetic division decreases automaticity and excitability of the SA node, thereby decreasing heart rate. It also decreases conductivity of electrical impulses through the atrioventricular conduction system and decreases the force of atrioventricular contraction. Parasympathetic influence increases during exhalation.

**The Electrocardiogram (ECG)**

Just as the electrical activity of the pacemaker is communicated to the cardiac muscle, "echoes" of the depolarization and repolarization of the heart are sent through the rest of the body. By placing a pair of very sensitive receivers (electrodes) on other parts of the body, the echoes of the heart's electrical activity can be detected. The record of the electrical signal is called an electrocardiogram (ECG). You can infer the heart's mechanical activity from the ECG. Electrical activity varies through the ECG cycle as shown below (Fig. 5.2):

![Fig. 5.2 Components of the ECG & Electrical and mechanical events of the cardiac cycle](image)

Because the ECG reflects the electrical activity, it is a useful “picture” of heart activity. If there are interruptions of the electrical signal generation or transmission, the ECG changes. These changes can be useful in diagnosing changes within the heart. During exercise, however, the position of the heart itself changes, so you cannot standardize or quantify the voltage changes.

**Components of the ECG**

The electrical events of the heart (ECG) are usually recorded as a pattern of a baseline (isoelectric line,) broken by a P wave, a QRS complex, and a T wave. In addition to the wave components of the ECG, there are intervals and segments (Fig. 5.2).

- The **isoelectric line** is a point of departure of the electrical activity of depolarizations and repolarizations of the cardiac cycles and indicates periods when the ECG electrodes did not detect electrical activity.
- An **interval** is a time measurement that includes waves and/or complexes.
- A **segment** is a time measurement that does not include waves and/or complexes.