Expected Learning Outcomes
At the end of this lab, you will be able to
• use an ECG sensor to collect data on cardiac electrical activity;
• interpret and explain the wave patterns of the ECG;
• determine heart rate based on intervals of time between peaks of the ECG trace;
• explain why the ECG is a useful clinical tool; and
• apply knowledge of heart anatomy and physiology to clinical symptoms and treatments for heart disease.
Next to listening to the heart sounds with a stethoscope, the most common clinical method of evaluating heart function is the electrocardiogram (ECG or EKG). The depolarization and repolarization of the atrial and ventricular myocardium generate electrical currents that are conducted through the fluid in the chest cavity. Electrodes placed on the skin detect the electrical activity and after the signals have been amplified, they can be displayed on a computer screen.

Three major events are seen in the ECG: the P wave, QRS complex, and T wave. The P wave reflects depolarization of the atria. The QRS complex represents depolarization of the ventricles. It is the largest wave of the ECG because the ventricles constitute the largest muscle mass in the heart and generate the greatest electrical current. The atria repolarize during the QRS complex but the effect is largely masked by depolarization of the ventricles. The T wave represents ventricular repolarization.

The electrical events slightly precede the mechanical events of the heart; there is a slight delay between the electrical stimulation and the contraction of the sheets of cardiomyocytes. For example, ventricular systole (contraction) begins shortly after the QRS complex. Ventricular systole, then, occurs in the ST segment.

The electrocardiogram is useful because it provides a non-invasive, if indirect, snapshot of heart function. The horizontal axis represents time. Heart rate can be determined by measuring the time between successive R peaks. Myocardial infarctions (heart attacks) produce changes in the ECG such as an elevated ST segment. Thus, the ECG provides a valuable tool for rapid preliminary diagnosis of a variety of cardiac conditions.

In this activity, you will use the ECG sensor to make a graphical recording of your heart’s electrical events. From this recording, you will determine the time interval associated with each of the previously mentioned ECG waveforms.
Check Your Understanding: Answer the following questions based on your reading of the introduction.

1. What is happening in the heart to produce the P, QRS, and T waves?
2. Why is the ECG a valuable clinical tool?

Activity 1: Collecting ECG Data

Getting Started

1. The equipment for today’s experiment is listed below.
   - √ Computer
   - √ Biopac MP35 Acquisition unit
   - √ BIOPAC electrode lead set
   - √ Disposable paste-on electrodes
   - √ Yoga mat

2. Use the checklist below to ensure that the basic set-up is working:
   - Check to make sure the electrode lead set is plugged into Channel 2.
   - Turn the computer on. For Mac laptops, press the on silver "ON" button located above the computer keyboard. The computer must finish booting up before turning on the Biopac unit (blue box).
   - Check that the Biopac unit is plugged into the electrical outlet.
   - Check that the Biopac unit is connected to the computer via a black USB cable.
   - Make sure the Biopac unit is turned ON. The Power switch is on the back panel on the right. Check that the AC adapter for the unit is plugged into the back. Wait until the "Busy" light stops flashing before launching software.

3. The subject should remove all jewelry from wrists and ankles.

4. Clean and scrub the regions on the right forearm, and medial right and left ankle for electrode attachment using an alcohol pad (see Figure 10.3) for electrode placement). Let the areas dry after cleaning with the alcohol pad. Place the electrode on the anterior surface of the RIGHT forearm superior to the wrist. Place the second and third electrode on the MEDIAL surface of the lower leg, just superior to the medial malleolus (see Figure 10.3)

5. Each of the pinch connectors needs to be attached to a specific electrode. Each lead cable is a different color. Be sure that, when you attach the pinch connector to each electrode, the metal side of the pinch connector faces down. Attach the WHITE lead to the electrode on the RIGHT FOREARM. Attach the BLACK lead to the electrode on the RIGHT LEG. Attach the RED lead to the electrode on the LEFT LEG. Position the lead cables so that they are not pulling on the electrodes.
**Calibration**

Calibration allows the software to determine the high and low points of your subject’s trace.

1. Launch the Biopac student lab program. The icon is located on the dock at the bottom of the screen (see figure 10.4). Select lesson L05-ECG-1 from the menu. Click on OK.

2. Type in a file name for your experiment. Use a name that distinguishes both your lab group and the exercise you are performing, like “Barbara’s ECG”, not just “ECG”. Click on “OK”.

3. Have the subject lie down and make sure he/she is relaxed. Do not laugh, cough, sneeze, or have any other shifts in body position during calibration.

4. Make sure the electrodes are securely adhered to the subject’s skin.

5. Click on the Calibrate button in the upper left corner of the screen. If an error message occurs, click “Ignore”.

6. Wait for the calibration procedure to stop. At the end of 8 seconds, there should be a recognizable ECG waveform with no large baseline drifts. If your data resembles Figure 10.5, proceed to the data recording section. If your data shows any large drifts or does not resemble figure 6 you must redo the calibration. Click on REDO CALIBRATION, then follow the above directions again.
Now that the computer is calibrated, you can collect your data. During all of the recordings do not talk, laugh, or have any other activity that may alter the ECG recording.

1. Have the subject sit in a relaxed position; the arms should rest palms up on the bench in front of him/her.

2. When everything is positioned properly, click RECORD.

3. Record for 20 seconds.

4. Click SUSPEND.

5. Review the data to ensure that it resembles Figure 10.6. If it does, proceed to the next section. If it does not, click REDO and rerecord the data.

6. When you have obtained an acceptable recording, click DONE. A window will appear asking if you are sure you are done recording. Click YES.

7. A window will appear asking what you would like to do now. Select ANALYZE CURRENT DATA FILE. Click on OK.
Analyzing the Data

1. All of the data you collected will initially be displayed on a single screen no matter how long you recorded. The longer you record, the more squished together your pulses will appear and it can be difficult to place the cursor accurately when measuring your ECG.

2. Adjusting your image: Use the zoom tool to widen your pulses. To do this, click on the zoom tool icon in the lower right hand corner of the screen. The zoom tool looks like a magnifying lens (see Figure 10.7).

![Figure 10.7 Editing and Selection Tools.](image)

Click anywhere on your trace to enlarge your trace. The peaks will get higher and wider and some of the trace may be off screen. To adjust your trace so that the peaks and valleys are visible, pull down the Display menu and select Autoscale Waveforms. This automatically adjusts the Y-axis so that the highest and lowest points are on screen. If your peaks are still too squished together, click on the trace again to zoom in further. Readjust the Y-axis by selecting Autoscale Waveforms again.

(Note the Autoscale Horizontal function in the Display menu. This readjusts the X-axis so all the data you collected is once again displayed on the screen.)

Now enlarge a specific area of your trace. To do this, position the zoom tool at the point that you want to start your enlargement and click and drag the zoom tool to draw a box around a section that contains five successive peaks. Be sure to include the lowest point before the first peak and the lowest point after the last peak. All five peaks should be displayed together now. To undo the zoom, pull down the Display menu and select Zoom Back. There is also a Zoom Forward function to redo a zoom.

3. Set the first two measurement boxes at the top of the screen so the following are displayed:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Measurement Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH2</td>
<td>Delta T (ΔT)</td>
</tr>
<tr>
<td>CH2</td>
<td>BPM (Beats Per Minute)</td>
</tr>
</tbody>
</table>

Figure 10.8 Channel Settings

- Delta T (ΔT) is the time measured along the X-axis by the selected region
- BPM (beats per minute) is heart rate calculated based on the Delta T selected and is valid only if the selected region is one complete cardiac cycle.
4. Highlight the area you want to measure: Once you have your trace of five peaks adjusted so that it can be easily viewed, use the **I-Beam** tool to highlight areas of the trace you want to measure. The **I-Beam icon** is located in the bottom right corner of the screen (see Figure 10.7). You will be determining the time intervals of the following segments:

- **R–R Interval (time from the peak of one R wave to the peak of the next R wave: corresponds to one full cardiac cycle):** Using the I-Beam cursor, select the area between two successive R waves (R–R segment; see Fig. 10.9). To do this, click on the **I-Beam icon**, then position the I-Beam at the peak of the R wave where you want to begin your measurement; click and drag the I-Beam until the I-Beam is positioned at the peak of the next R wave; release the mouse. The area between the two R waves should be highlighted. Record the ΔT and the BPM from this reading (look at the two measurement boxes at the top of the screen) for Cardiac Cycle 1 in Table 10.1. Take R–R measurements for two other cardiac cycles in this display and record the same data in Table 1. Calculate the mean of these 3 values by adding them together and dividing by 3.

- **P–R Interval (time from the beginning of the P wave to the start of the QRS complex):** Again using the I-Beam cursor, select the area between the beginning of one P wave and the beginning of the subsequent QRS complex (see Figure 10.9). Record the ΔT from this reading in Table 10.2.

- **QRS Interval (time from Q deflection to S deflection):** Using the I-Beam cursor, select the area between the beginning of the Q wave and the end of the S wave (see Figure 10.9). Record the ΔT from this reading in Table 10.2.

- **Q–T Interval (time from Q deflection to the end of the T wave):** Select the area between the beginning of the Q wave and the end of the T wave (see figure 10.9). Record the ΔT from this reading in Table 10.2.

- **R–T Interval (time from the peak of the R wave to the end of the T wave: corresponds to ventricular systole):** Select the area between the peak of one R wave and the end of the subsequent T wave (see Figure 10.9). Record the ΔT from this reading in Table 10.3.

- **T–R Interval (time from the end of the T wave to the subsequent R wave: corresponds to ventricular diastole):** Select the area between the end of one T wave and peak of the subsequent R wave (see Figure 10.9). Record the ΔT from this reading in Table 10.3.
**Recording the Data**

Table 10.1

<table>
<thead>
<tr>
<th>Measurement</th>
<th>From Channel</th>
<th>Cardiac Cycle</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔT (Delta Time) (R-R Interval)</td>
<td>CH 2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>BPM (Beats Per Minute)</td>
<td>CH 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10.2

<table>
<thead>
<tr>
<th>Measurement</th>
<th>CH 2 ΔT</th>
<th>Standard Resting ECG Interval Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>P–R Interval</td>
<td></td>
<td>0.12 to 0.20 s</td>
</tr>
<tr>
<td>QRS Interval</td>
<td></td>
<td>less than 0.10 s</td>
</tr>
<tr>
<td>Q–T Interval</td>
<td></td>
<td>0.30 to 0.40 s</td>
</tr>
</tbody>
</table>
Table 10.3

<table>
<thead>
<tr>
<th>Ventricular Readings</th>
<th>CH 2 ΔT</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ R - T \text{ Interval} ]</td>
<td></td>
</tr>
<tr>
<td>(corresponds to Ventricular Systole)</td>
<td></td>
</tr>
<tr>
<td>[ T - R \text{ Interval} ]</td>
<td></td>
</tr>
<tr>
<td>(corresponds to Ventricular Diastole)</td>
<td></td>
</tr>
</tbody>
</table>

**Check Your Understanding:** Answer the following questions.

1. What property of heart muscle must be altered in order for an ECG to detect a problem? Explain.
2. Why can't an ECG be used to diagnose all diseases or defects of the heart?
3. Name and describe a cardiovascular problem that could be diagnosed by a cardiologist using an electrocardiogram recording.
4. What mechanical event is occurring in the heart during the Q–T portion of the ECG? What is occurring during the T–Q portion? Which portion is longer? Which do you suppose would be shorter or longer during exercise? Why?

Portions of this lab were adopted from University of Pittsburgh’s Science in Motion program for science education. <www.upb.pitt.edu/interior3Default.aspx?menu_id=42&id=7499>

**Activity 2: Film “The Hidden Epidemic—Heart Disease in America”**

We will watch a NOVA video that first aired in 2007 that interviews patients, doctors, and researchers about heart disease. It explores the history of the incidence of the disease and contributing factors, including lifestyle.

Be prepared to answer the following questions:

What lifestyle factors contribute to heart disease?

What can individuals do to lessen their risk of developing heart disease?

What is the role of smoking in heart disease? Diet?

What medical procedures have been developed in the past several decades to treat heart disease? Explain the procedures using precise anatomical and physiological vocabulary.

What specific new information did you learn from this film?