Lesson 3 ECG 1
Electrocardiography: Components of the ECG

Lesson Revision 8.07.2007

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Lesson 3 ELECTROCARDIOGRAPHY

I. SCIENTIFIC PRINCIPLES

The four-chambered human heart receives blood from veins and pumps it into arteries. The receiving chambers are the right atrium and the left atrium, and the pumping chambers are the right ventricle and the left ventricle (Fig. 3.1). Blood flows into and out of the heart in the following sequence:

veins → atrium → ventricle → artery

Blood passing through the left side of the heart is kept separate from blood passing through the right side of the heart. Thus, the human heart is actually a double pump, right and left. The right heart receives blood from the systemic veins and pumps the blood into pulmonary arteries going to the lungs. The left heart receives blood coming from the lungs by way of the pulmonary veins and pumps the blood to the rest of the body.

Most of the heart wall is made up of cardiac muscle tissue, called the myocardium (myo – muscle, cardia – heart). Regular, cyclic contractions of the atrial myocardium followed by the ventricular myocardium are called heartbeats, or cardiac cycles. Repetitive cardiac cycles cause blood to circulate through the heart and the blood vessels. The frequency of the heartbeats, expressed as beats per minute (BPM), is called heart rate.

The human heartbeat is myogenic (myo – muscle, gene – origin); that is, the signal for the heart to beat comes from within the heart itself and not from an external signal, such as a nerve impulse or a hormone. Although the heart is supplied with motor nerves that can change heart rate, the extrinsic nerves do not initiate the heartbeat.

If the heart’s extrinsic nerves were cut, the heart would continue to beat rhythmically, but nervous control of the rate would be lost. Thus, the heart possesses the unique ability to initiate its own beat without any stimulation from the rest of the body. This property of cardiac muscle is called inherent rhythmicity or automaticity.

During one heartbeat, the atrial muscles contract, and then the ventricular muscles contract while the atrial muscles relax. Then, the ventricular muscles relax as the heart prepares itself for the next beat. This coordinated sequence of events, and the presence of four one-way valves (Fig. 3.2) in the heart, ensures an orderly flow of blood into and out of the heart.

The control and coordination of cardiac muscles during the heartbeat depend on a specialized system of conductive tissue within the heart. Before contraction of the atria and ventricles can occur, an electric current must first pass to and through the myocardial fibers. A specialized conduction system of the heart is responsible for generating these electric currents and conveying them in an orderly sequence to all parts of the heart. The conduction system, called the pacemaker system, consists of the following areas of specialized conducting tissue (Fig. 3.1): the sinoatrial (SA) node, internodal and interatrial pathways, the atrioventricular (AV) node, the AV bundle, right and left bundle branches, and the Purkinje fiber network.

The SA node is located in the wall of the right atrium. The SA node is commonly called the pacemaker because the electric signal that initiates each heartbeat originates from this node.

The SA-node signal is transmitted through both atria along the internodal and interatrial pathways, stimulating atrial muscle to contract. The impulse also spreads to the AV node, located near the junction between the right atrium and right ventricle. After a short delay, which allows the atria time to finish contraction before excitation of the ventricles, the AV node relays the electric impulse toward the ventricles.

After passing through the AV node, the impulse is carried to the ventricles through the AV bundle and its two main branches. The right bundle branch carries the impulse to the right ventricle; the left bundle branch carries the impulse to the left ventricle. Each bundle branch further subdivides into numerous small conducting fibers called Purkinje fibers, which relay the electric impulse directly to ventricular muscle, stimulating the ventricles to contract.
In summary, the contraction of cardiac muscle is associated with an electric impulse initiated at the SA node, which sweeps over the conduction path of the heart, preceding contraction of cardiac muscle. In each normal heartbeat, the electrical events follow a sequence: 1) generation of an electrical signal (impulse) by the SA node; 2) transmission of the impulse to atrial muscle initiating contraction; 3) stimulation of the AV node and generation of an electrical signal; 4) transmission of the impulse by the AV bundle, bundle branches, and Purkinje fibers to ventricular muscle, initiating contraction.

The electric current associated with the cardiac cycle may be detected at the surface of the body, amplified, and recorded as a time record of the electrical events occurring during each cardiac cycle. Thus, heart rate can be accurately determined, and abnormalities of rhythm and conduction can be identified. The electrical and mechanical device that records the electrical activity of each cardiac cycle is called an electrocardiograph, and the record made by the electrocardiograph is called an electrocardiogram (ECG). The study of electrocardiograph applications and the interpretation of ECGs is called electrocardiography.

The electric current spreading through the heart during the cardiac cycle can be detected by placing a positive electrode and a negative electrode on selected areas of the skin surface and recording the electric current changes occurring between the electrodes as the heart beats. The particular arrangement of two surface electrodes, one positive and the other negative, with respect to a third surface electrode, the ground electrode, is called a lead. There are 15 leads that can be recorded. One of the most commonly recorded leads by family physicians is a bipolar limb lead, called Lead II (Fig. 3.3). The negative electrode is placed on the right arm (at the wrist), the positive electrode is placed on the left leg (at the ankle), and the ground electrode is placed on the right ankle.

The electrocardiograph records electrical activity of the heart on a grid containing 1 mm squares. The horizontal lines represent amplitude in fractions of millivolts (mV), and the vertical lines represent time in fractions of seconds. The standard recording speed is 25 mm/second, and the sensitivity of the recorder is adjusted so that a 1 mV input results in a recorded wave amplitude of 10 mm. Thus, 1 mm of amplitude (vertical) is 0.1 mV, and 1 mm of time (horizontal) is 1/25 seconds, or 0.04 seconds.

Fig. 3.3 is a normal ECG as recorded from Lead II, associated with a single cardiac cycle. The heart’s electrical events are usually recorded on the ECG as a pattern of a baseline broken by a P wave, a QRS complex, and a T wave:

- The baseline (isoelectric line) is a straight line on the ECG. It is the point of departure for the electrical activity of depolarizations and repolarizations of the cardiac cycle.
- The P wave results from atrial depolarization.
- The QRS complex is a result of ventricular depolarization and indicates the start of ventricular contraction. The electrical signal for atrial repolarization is masked by the larger QRS complex.
- The T wave results from ventricular repolarization and signals the beginning of ventricular relaxation.

In addition to the wave components of the ECG, there are periods of time called intervals and segments. An interval is part of the ECG containing at least one wave and a straight line. For example, the PR interval includes the P wave and the connecting line before the QRS complex. The PR interval represents the time it takes for the impulse sent from the SA node to travel to the ventricles. A segment refers to a period of time from the end of one wave to the beginning of the next wave. For example, the PR segment represents the time of AV nodal delay and transmission to the ventricles.

Values within normal ranges for the duration and voltage of the different phases of the ECG complex as seen in Lead II are indicated in Table 3.1.
Table 3.1 Normal Lead II ECG values (wrist and ankle electrodes)*

<table>
<thead>
<tr>
<th>Phase</th>
<th>Duration (seconds)</th>
<th>Amplitude (millivolts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Wave</td>
<td>0.06 – 0.11</td>
<td>&lt;0.25</td>
</tr>
<tr>
<td>PR Interval</td>
<td>0.12 – 0.20</td>
<td></td>
</tr>
<tr>
<td>PR Segment</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>QRS Complex</td>
<td>&lt;0.12</td>
<td>0.8 – 1.2</td>
</tr>
<tr>
<td>ST Segment</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>QT Interval</td>
<td>0.36 – 0.44</td>
<td></td>
</tr>
<tr>
<td>T Wave</td>
<td>0.16</td>
<td>&lt;0.5</td>
</tr>
</tbody>
</table>

* Tabled values represent results from a typical Lead II setup (wrist and ankle electrode placement); values for torso placement would be different.

Normal sinus rhythm (NSR) is the normal, regular rhythm of the heart, originating in the SA node and characterized by a heart rate of 60 to 100 beats per minute. Sinus arrhythmia is an irregularity of the heart rate in which there is a cyclic increase and decrease in the rate of a sinus rhythm. Typically, heart rate increases during inspiration and decreases during expiration. This occurs because breathing alters blood pressure, which triggers changes to the sympathetic and parasympathetic nervous outflow to the heart. Sinus arrhythmia is considered to be present when the difference between the longest and shortest RR interval is greater than 0.16 seconds. Usually, sinus arrhythmia is of no clinical significance (i.e. without overt symptoms or effects). However, marked sinus arrhythmia can cause heart palpitations (a pounding sensation), dizziness, and fainting.

In this lesson, you will record the ECG under four conditions: lying down, after sitting, breathing deeply, and after exercise.

II. EXPERIMENTAL OBJECTIVES

1) To become familiar with the electrocardiograph as a primary tool for evaluating electrical events within the heart.
2) To observe rate and rhythm changes in the ECG associated with body position and breathing.

III. MATERIALS

- Computer system (running Windows XP or Mac OS X)
- Biopac Science Lab system (MP40 and software)
- Electrode lead set (40EL lead set)
- Disposable vinyl electrodes (EL503), three electrodes per subject
- Cot or lab pillow
IV. EXPERIMENTAL METHODS

A. Set Up

**EQUIPMENT**

**SUBJECT**

![Fig. 3.4](image1.png)

![Fig. 3.5 Lead II connections](image2.png)

**FAST TRACK**

1. Turn the computer **ON**.
2. Set the MP40 dial to **OFF**.
3. **Plug the equipment in** as follows:
   - Electrode leads (40EL) \( \rightarrow \) MP40
4. **Attach three electrodes** to the **Subject** as shown in Fig. 3.5.
5. Connect the electrode **leads** (40EL) to the electrodes, matching lead color to electrode position, as shown in Fig. 3.5.

**IMPORTANT**

Clip each electrode lead color to its specified electrode position.

6. **Start** the Biopac Science Lab software.
7. Choose lesson **L03-ECG-1** and click **OK**.
8. Type in a unique **file name**.
9. Click **OK**.

**Details**

Attach three electrodes to the Subject in a Lead II configuration, as shown in Fig. 3.5.

- 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 response, place electrodes on the skin at least five minutes before starting the Check section.

No two people can have the same file name, so use a unique identifier, such as the Subject’s nickname or student ID#.

This ends the Set Up procedure.
B. Check

**FAST TRACK**

**MP40 Check**

1. Set the MP40 dial to \( \text{ECG/EOG} \).
2. Press and hold the \( \text{Check} \) pad on the MP40.
3. Click \( \text{Check MP40} \) when the light is flashing.
4. Wait for the MP40 check to stop.
5. Let go of the \( \text{Check} \) pad.
6. Click \( \text{Continue} \).

**Signal Check**

7. Click \( \text{Check Signal} \).
8. Wait for the Signal Check to stop.
9. Review the data.
   - If correct, go to the Record section.
   - If incorrect, click \( \text{Redo Signal Check} \).

---

**Details**

- Set the dial to "ECG/EOG".
- Press and hold the "Check" pad. Continue to hold until prompted to let go. When the light starts to flash, click "Check MP40".
- Continue to hold the pad down until prompted to let go.
- The MP40 check procedure will last five seconds.
- The light should stop flashing when you let go of the \( \text{Check} \) pad.
- When the light stops flashing, click \( \text{Continue} \).

Subject should be supine, relaxed, and still during the Signal Check. The electrocardiograph is very sensitive to small changes in voltage caused by contraction of skeletal muscles, and the Subject’s arms and legs need to be relaxed so that the muscle (EMG) signal does not corrupt the ECG signal.

The eight-second Signal Check recording should resemble Fig. 3.6.

If the Signal Check did not show R-wave peaks, click \( \text{Redo Signal Check} \).
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C. Record

**FAST TRACK**

1. Prepare for the recording and have the **Subject** lie down and relax.

**Details**

Watch the Help menu videos to prepare for the recording. You will record the Subject in four conditions: lying down, after sitting, breathing deeply, and after exercise. The Subject will perform tasks in the intervals between recordings.

In order to work efficiently, read this entire section so you will know what to do for each recording segment.

The Subject should remain in a supine position and continue to relax while you review the lesson.

Stop each recording segment as soon as possible so you don’t use an excessive amount of time (time is memory).

**Tips for obtaining optimal data:**

a) The Subject should not talk or laugh during any of the recording segments.

b) The Subject should be in a relaxed state for each recording segment and in the position noted for each segment.

c) When sitting up, the Subject’s arms should be supported on an armrest (if available).

d) For Steps 6 and 7: Click **Resume** as soon as possible after the Subject sits up in order to capture the heart rate variation, but not while the Subject is in the process of sitting up or there will be excessive motion artifact.

e) The Subject should be as still as possible during the recording segment. The electrocardiograph is very sensitive to small changes in voltage caused by contraction of skeletal muscles, and the Subject’s arms and legs need to be relaxed so that the muscle (EMG) signal does not corrupt the ECG signal.

**SEGMENT 1 — Lying Down**

2. Click **Record**.

3. Record for 20 seconds.

4. Click **Suspend**.

5. Review the data.

   - If **correct**, go to **Step 6**.

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

Subject should be supine, relaxed, and still (seconds 0-20).

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

Your data should resemble Fig. 3.7.

![Fig. 3.7 Lying down](image-url)
If incorrect, click **Redo**.

The data is incorrect if:

- **a)** The **Suspend** button was pressed prematurely.
- **b)** An electrode peeled up, causing a large baseline drift, spike, or loss of signal.
- **c)** The Subject has too much muscle (EMG) artifact.

If the data is incorrect, click **Redo** and repeat Steps 2-5; the last data segment you recorded will be erased.

**SEGMENT 2 — After Sitting Up**

6. Have the **Subject** quickly get up and sit in a chair, with arms relaxed.

7. Click **Resume** as soon as possible once the **Subject** sits and relaxes.

8. After 20 seconds, click **Suspend**.

9. Review the data.

   - **If correct**, go to **Step 10**.

   - **If incorrect**, click **Redo**.

   Subject should sit with arms relaxed, preferably in a chair with armrests.

   In order to capture the heart rate variation, it is important that you resume recording as quickly as possible after the Subject sits. However, it is also important that you do not click **Resume** while the Subject is in the process of sitting or you will capture motion artifact.

   When you click **Resume**, the recording will continue and an append marker labeled **After sitting up** will be automatically inserted.

   Subject is seated and relaxed (seconds 20-40). When you click **Suspend**, the recording will halt, giving you time to review the data and prepare for the next recording segment.

   Your data should resemble Fig. 3.8.

   ![Fig. 3.8 After sitting up](image)

   **Fig. 3.8 After sitting up**

   The data would be incorrect for the reasons listed in Step 5.

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

**SEGMENT 3 — Seated, Deep Breathing**

10. Click **Resume**.

   When you click **Resume**, the recording will continue and an append marker labeled **Deep breathing** will be automatically inserted.

   **Recording continues…**
11. Record for 20 seconds and have Subject take five deep breaths during recording.
   Insert event markers (F9 or Esc) at each corresponding inhale and exhale.
   \(\n\text{∇ Inhale (five times)}\)
   \(\n\text{∇ Exhale (five times)}\)

12. Click Suspend.

13. Review the data.
   - If correct, go to Step 14.
   - If incorrect, click Redo.

**SEGMENT 4 — After Exercise**

14. Have the Subject perform an exercise to elevate heart rate.

   Subject is seated (seconds 40-60).
   After the recording begins, the Subject should start a series of slow, prolonged breaths, continuing for five cycles.
   It is important to breathe with long, slow, deep breaths in order to minimize the EMG artifact.
   To insert a marker, press F9 (Windows) or Esc (Mac). Insert event markers at the beginning of each inhale and at each corresponding exhale. Label the markers Inhale and Exhale, accordingly.
   When you click Suspend, the recording will halt, giving you time to prepare for the next recording segment.
   Your data should resemble Fig. 3.9.

   ![Fig. 3.9 Deep breathing](image)

   **Note** The Deep breathing recording may have some baseline drift (as shown in Fig. 3.9). Baseline drift is fairly normal, and unless it is excessive, it does not necessitate redoing the recording.
   If incorrect, click Redo and repeat Steps 10-14; the last data segment you recorded will be erased.

15. Click Resume.

   Recording continues…
16. Record for 60 seconds.

Subject is seated in a relaxed state, recovering from exercise (seconds 60-120).

When you click **Suspend**, the recording should halt.

Your data should resemble Fig. 3.10.

<table>
<thead>
<tr>
<th>Resume</th>
<th>Redo</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Zone</td>
<td>2 Zone</td>
<td>2 Zone</td>
</tr>
</tbody>
</table>

When you click **Suspend**, the recording should halt.

If **correct**, go to Step 19.

When you click **Suspend**, the recording should halt.

If incorrect; click **Redo**.

The data would be incorrect for the reasons listed in Step 5.

The **After exercise** recording may have some baseline drift (as shown in Fig. 3.10). Baseline drift is fairly normal, and unless it is excessive, it does not necessitate redoing the recording.

If incorrect, click **Redo** and repeat Steps 14-18. The last data segment you recorded will be erased.

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

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

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

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

Unclip the electrode lead connectors and peel off the electrodes. Throw out the electrodes.

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

20. Click **Done**.

21. Click **Yes**.

22. Choose an option and click **OK**.

23. Remove the electrodes.

---

**END OF RECORDING**

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V. **ANALYZE**

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

**Note:** Interpreting an ECG 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 examples shown or from the tables and figures in Section I (Scientific Principles).

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. 3.11). 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.

**FAST TRACK**

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

   **Note** Channel Number (CH) designations:
   - CH40  ECG
   - CH1   Rate

   **Note** Measurements will be taken on the ECG channel. To see the average heart rate, select an area and measure Mean on CH1, Rate (Fig. 3.13).

   To hide CH1:
   - **Windows:** Ctrl-click channel box
   - **Mac:** Option-click channel box

   Analysis continues…

**Details**

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

The data window should come up the same as Fig. 3.12.
2. Set up the measurement boxes as follows:

<table>
<thead>
<tr>
<th>Channel</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH40</td>
<td>Delta T</td>
</tr>
<tr>
<td>CH40</td>
<td>BPM</td>
</tr>
<tr>
<td>CH40</td>
<td>Delta</td>
</tr>
<tr>
<td>CH40</td>
<td>Max</td>
</tr>
</tbody>
</table>

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.

The following is a brief definition of specific measurements:

- **Delta T**: displays the amount of time in the selected segment (the difference in time between the endpoints of the selected area).
- **BPM** (beats per minute): calculates the difference in time between the end and beginning of the selected area (same as Delta T), and divides this value into 60 seconds/minute.
- **Delta**: computes the difference in amplitude between the last point and the first point of the selected area.
- **Max**: finds the maximum amplitude value within the selected area (including the endpoints).

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

3. Set up your display window for optimal viewing of four successive beats from Segment 1.

The following tools help you adjust the data window:

- Autoscale Horizontal
- Autoscale Waveforms
- Zoom
- Zoom Previous/Back
- Show Grids
- Hide Grids
- Adjust Baseline button: Allows you to move the waveform up or down in small increments so the baseline can be exactly zero. This is not needed to obtain accurate amplitude measurements, but may be desired before making a printout, or when using grids.

Once the Adjust Baseline button is pressed, two more buttons, Up and Down, will be displayed. Simply click these to move the waveform up or down.

Analysis continues...
4. Using the I-Beam tool, select the area between two successive R waves. 

Try to select from R-wave peak to R-wave peak as precisely as possible. Fig. 3.15 shows an example of the selected area.

5. Take measurements at two other intervals in the current waveform display.

Be sure to stay in the first recorded segment when you select the cardiac cycle.

6. Zoom in on a single cardiac cycle from Segment 1.

Gather data for three cycles. You may paste the measurements into the Journal by using the Edit > Journal > Paste measurement option.

7. Using the I-Beam cursor and measurement box values (and referring to Fig. 3.3 as necessary), record the following amplitudes and durations for three cycles.

<table>
<thead>
<tr>
<th>Durations</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>QT interval</td>
<td></td>
</tr>
<tr>
<td>PR interval</td>
<td>ST segment</td>
<td></td>
</tr>
<tr>
<td>QRS interval</td>
<td>T wave</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Amplitudes</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P wave</td>
<td>T wave</td>
<td></td>
</tr>
<tr>
<td>QRS complex</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time Interval</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>QT interval (ventricular systole)</td>
<td>End of T wave to subsequent R wave (ventricular diastole)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3.16 shows a sample setup for measuring P-wave amplitude. Note that the Delta measurement shows the amplitude difference between endpoints in the selected area.

8. Repeat measurements as required for the Data Report.

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

9. Save or print the data file.

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

10. Exit the program.

11. Set the MP40 dial to Off.

END OF LESSON 3

Complete the Lesson 3 Data Report that follows.

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The Data Report starts on the next page.
Lesson 3  ELECTROCARDIOGRAPHY 1  
Components of the ECG

DATA REPORT

Student’s Name: ________________________________
Lab Section: ________________________________
Date: ________________________________________

I. Data and Calculations

Subject Profile
Name______________________________________ Age________
Gender: Male / Female
Height__________ Weight________

BPM Results
A. Complete Table 3.2 with the lesson data indicated, and calculate the Mean and Range as appropriate.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cardiac Cycle</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supine</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After Sitting</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seated–Deep Inhal</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seated–Full Exhale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After Exercise–Start</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After Exercise–End</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ventricular Results
B. Complete Table 3.3 with the lesson data indicated, and calculate the Mean as appropriate.

Note: QT Interval corresponds to ventricular systole, End of T Wave to Subsequent R Wave corresponds to ventricular diastole.

<table>
<thead>
<tr>
<th>Ventricular Readings</th>
<th>Supine, Normal Breathing Cycles</th>
<th>After Exercise Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>QT Interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of T Wave to Subsequent R Wave</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

C. Complete Table 3.4 with the lesson data indicated, and calculate the Mean as appropriate.

<table>
<thead>
<tr>
<th>ECG Component</th>
<th>Cycle Duration [Delta T]</th>
<th>Cycle Amplitude (mV) [Delta]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>P Wave</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR Interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR Segment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QRS Complex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QT Interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST Segment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T Wave</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

II. Data Summary and Questions

D. Heart Rate

Review BPM results (Table 3.2) and describe the changes in heart rate between conditions.

E. Respiratory Cycle

Review BPM results (Table 3.2). Define sinus arrhythmia and describe how the respiratory cycle impacts the heart rate.

Review ventricular results (Table 3.3) and describe changes in the duration of systole and diastole between resting and post-exercise.

F. ECG Components

Review Component Results (Table 3.4)

1. Is there always one P wave for every QRS complex? Yes No

2. Describe the P-wave and T-wave shapes:

3. Do the wave durations and amplitudes for all subjects fall within the normal ranges listed in Table 3.1? Yes No

4. Do the ST segments mainly measure between –0.1 mV and 0.1 mV? Yes No

5. Is there baseline drift in the recording? Yes No

6. Is there baseline noise in the recording? Yes No
VI. ACTIVE LEARNING LAB

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

For this lesson, you might examine how gender, duration of exercise, and changing body position influence the ECG and/or time to return to baseline.

Design Your Experiment

Use a separate sheet to detail your experiment design, and be sure to address these main points:

A. Hypothesis

Describe the scientific principle to be tested or verified.

B. Materials

List the materials will you use to complete your investigation.

C. Method

Describe the experimental procedure—be sure to number each step to make it easy to follow during recording.

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

Run Your Experiment

D. Set Up

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

E. Recording

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

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

Analyze Your Experiment

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