

# Week 5: Electrocardiography (ECG) II

BIOE 320 Systems Physiology Laboratory

## Objectives

1. To become familiar with the ECG 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 the body position and breathing
4. To observe the effects of changing ECG sampling rate on the ECG recordings

## Background

The heart is the physiological engine of the circulatory system, receiving blood from veins and pumping it into arteries. The contractions of myocardium (heart tissue) are a result of electrical signals that originate in the sinoatrial (SA) node of the heart. The SA node acts as a pacemaker for the rest of the heart, keeping a constant rhythm. Based on changing physiological demands, the frequency of impulses can be sped up or slowed down by extrinsic motor nerves via sympathetic and parasympathetic pathways, respectively.

## Electrical Pathways

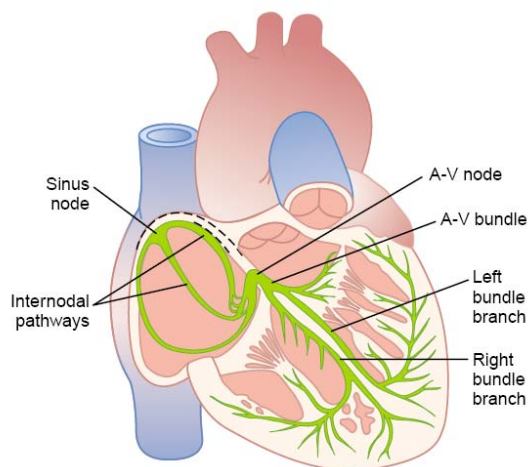


Figure 1: Schematic of the cardiac conduction system

Electrical impulses (Fig. 1) proceed from the SA node, causing atrial muscles to contract by producing an action potential (depolarization). The signal is then conducted to the atrioventricular (AV) node, which lies between the right atrium and ventricle. After a short delay to allow blood to flow out of the atria and into the ventricles, the AV node relays the electrical signal to the bundle of His where the signal splits between the right and left bundle branches. These branches continue to subdivide into Purkinje fibers, which pass on the action potential to ventricular muscle, stimulating the ventricles to contract. After depolarization takes place, subsequent repolarization occurs in which cardiac cells return to their resting state and the cardiac muscles relax.

## Electrocardiogram

The electric currents that travel through the heart can be picked up on the surface of the body in the form of electrical potential. Plotted against time, these readings are known as an electrocardiogram (ECG, seen in Fig. 3).

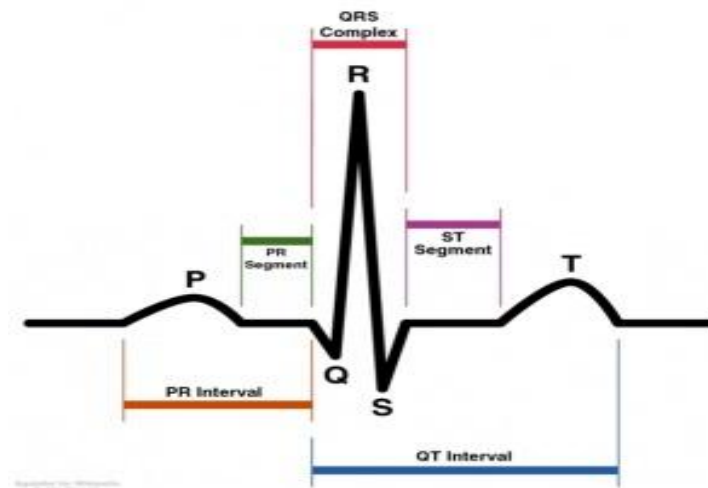


Figure 2: Schematic of an electrocardiogram

There are many different ways to place the electrodes to measure an ECG signal. In the lab today, we will use standard bipolar leads, in which 2 electrodes (positive and negative) are located on different sides of the heart and are measured against a common ground (third electrode).

The baseline of the ECG is known as the isoelectric line. The first peak, called the P wave, correlates to depolarization of the atrial muscle. The QRS system represents both the depolarization of the ventricular muscle as well as repolarization of the atrial muscle. Finally, the T wave correlates to the repolarization of the ventricles.

The PR interval is measured from the beginning of the P wave to the beginning of the QRS complex. Physiologically, it represents the time interval between atrial and ventricular depolarization. An abnormally long PR interval suggests conduction problems between the SA node and AV node. The QT interval is measured from the Q wave to the end of the T wave and is also known as ventricular systole, or period of ventricular contraction. Ventricular diastole is the period from the end of the T wave to the peak of

the P wave. Finally, the period of atrial contraction, or atrial systole, is measured from the peak of the P wave to the Q wave.

## Setting Up

1. Turn on the MP3X acquisition unit by flipping the switch found on the back panel.
2. Place electrodes and leads on the subject as follows (Fig. 3):
  - Positive (red): inside of left ankle, just above the ankle bone
  - Negative (white): inside of the right wrist
  - Ground (black): right ankle bone

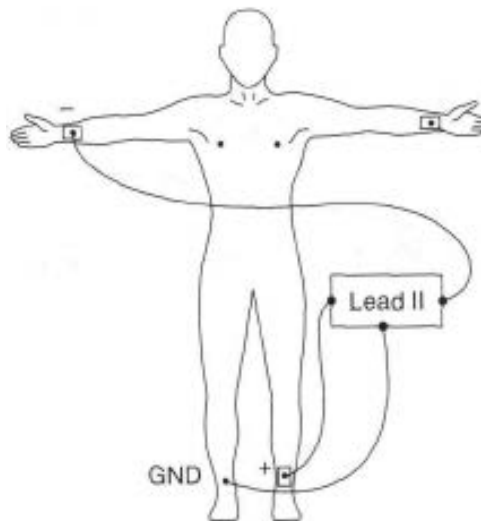


Figure 3: Schematic of electrode lead placement

3. Plug the electrode cord, SS2L, into channel 2 and connect to the electrodes.
4. Open Biopac Pro v3.7 (**not the student lessons**)
5. Go under the MP3X pull-down menu and select Set-up Acquisition (Fig. 4).

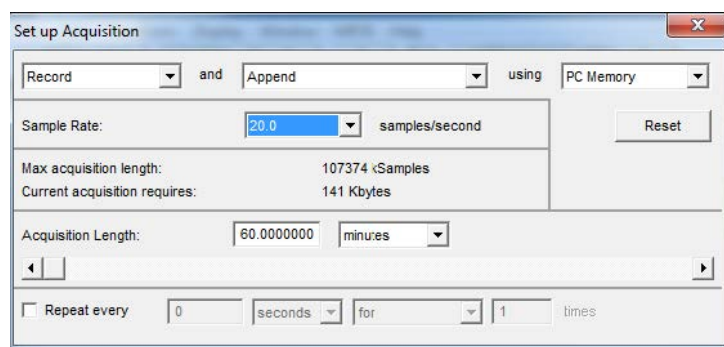


Figure 4: Set-up acquisition window

6. Set the sampling rate to 20/sec. Click reset and close the box.
7. Go under the MP3X pull-down menu and select Set-up Channels (Fig. 5).

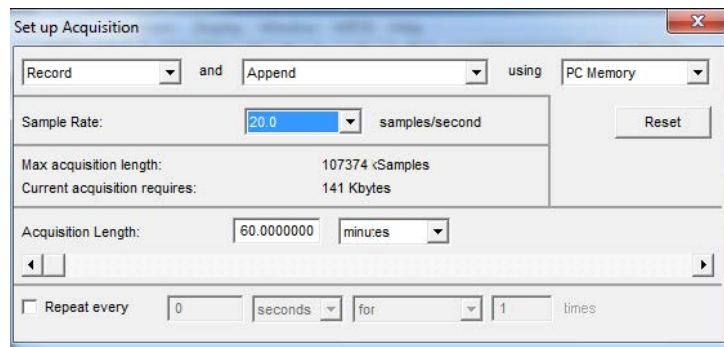


Figure 5: Set-up channels

8. Under the presets drop-down arrow, select ECG 0.05 Hz - 150 Hz for both channels 1 and 3.
9. Check all 3 boxes for channel 2. Deselect all boxes for channels 1 and 3.
10. Take a sample 30 sec ECG recording by pressing Start.

### Changing Sampling Rate

1. Go under the MP3X pull-down menu and select Set-Up Acquisition (Fig. 4).
2. Set the sampling rate to 200/sec.
3. Take another 30 sec ECG recording by pressing Start.
4. Close BIOPAC Pro Software. Do NOT remove electrodes or leads from the subject.
5. What are the differences between the recordings at 20 Hz and 200 Hz?
6. What criteria should be used to establish an appropriate sampling rate?

## Experiments

### Setting Up

1. Plug the electrode cord into channel 1 and connect the electrodes.
2. Launch the BIOPAC software by clicking on the BSL Lessons 3.7.6 icon and select L05-ECG-1 as shown in Fig. 6.

### Calibration



**Info:** The calibration procedure establishes the hardware's internal parameters (such as gain, offset, and scaling) and is critical for optimum performance. Pay close attention to the calibration procedure.

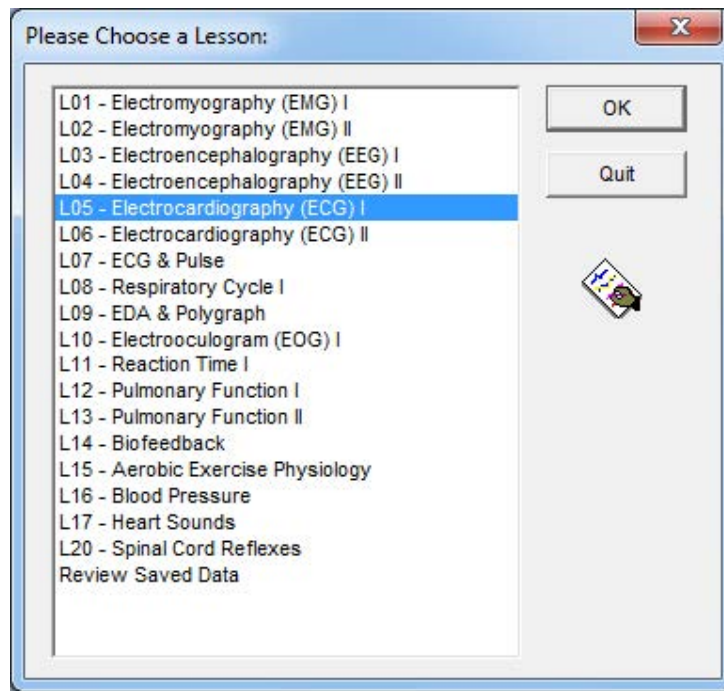


Figure 6: Selecting BIOPAC lesson L05-ECG-I

1. Check that electrodes are still adhered to the skin, If they are being pulled up, you will not get a good ECG signal. The subject must be relaxed and as still as possible during the calibration procedure. The ECG is very sensitive to small changes in voltage caused by contraction of skeletal muscles, so the subject's arms and legs need to be relaxed so that the muscle (EMG) signal does not corrupt the ECG signal.
2. Click on Calibrate. The calibration procedure will begin and then stop automatically after 8 seconds. At the end of the calibration recording, the screen should resemble Fig. 7 below. There should be a regular, periodic ECG waveform with a relatively flat baseline. Some tips for obtaining optimal data:
  - The subject should not talk or laugh during any of the recording segments.
  - The subject should be in a relaxed state for each recording segment and in the position noted for each segment.
  - When the subject is asked to sit up, they should do so in a chair, with arms relaxed.
3. If the data recording shows any jitter or large baseline drifts, you should redo the calibration by clicking on the Redo Calibration button.

### Segment 1: Supine (Laying Down)

1. Prepare for the recording by having the subject lie down and relax with their eyes closed.
2. Click on Record, and record data for 20 seconds, then click on Suspend at the 20 second mark. Proceed unless:
  - The suspend button was pressed prematurely.

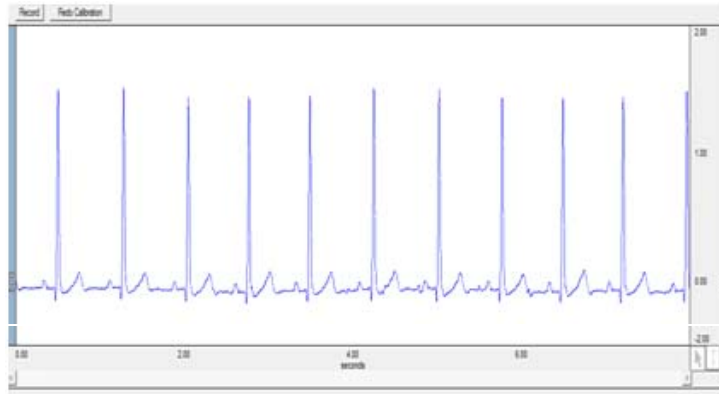


Figure 7: Example calibration

- An electrode peeled up, causing a large baseline drift, spike, or loss of signal.
- The subject has too much muscle (EMG) artifact.

## Segment 2: Sitting Up

1. Starting from the supine position, have the subject sit up quickly. Click on Resume and record for another 20 seconds. The recording will continue from the point where it last stopped and a marker labeled "sitting up" will automatically come up when Resume is pressed.



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

2. Click on Suspend at the end of the 20 second recording segment (at the 40 second mark total). Proceed unless you see any of the conditions described in Segment 1.

## Segment 3: Deep Breaths

1. Click on Resume. The recording will continue from the point where it last stopped, and a marker labeled "5 deep breaths" will automatically come up when Resume is pressed.
2. Record for 20 seconds and have the subject take in 5 deep breaths during recording. The 5 deep breathing cycles should be deeper and slower than normal breathing at rest and should follow one another.
3. During this time, the person operating the software should insert a marker at the beginning of an inhale and insert another marker at the corresponding exhale. The recorder should label these markers "inhale" and "exhale" (note: the hotkey for a marker is F9).
4. At the end of the 20 second recording segment, click on Suspend. Note that deep breathing may produce a baseline drift. This is normal and does not necessitate redoing the recording.

## **Segment 4: Light Exercise**

1. Disconnect the electrode leads (do not remove the electrodes) and have the subject move to a safe area and perform an exercise that will elevate their heart rate fairly rapidly (e.g. push-ups, jumping jacks).
2. Immediately after the exercise, have the subject assume a sitting position and re-connect the electrode leads:
  - Positive (red): inside of left ankle, just above the ankle bone
  - Negative (white): inside of the right wrist
  - Ground (black): right ankle bone
3. After the subject is stationary, click on Resume. The recording will continue from the point where it last stopped, and a marker labeled "after exercise" will automatically come up when you click Resume.
4. Record the post-exercise ECG for 60 seconds, then click on Suspend (120 second mark total). Again, the baseline may drift, but this is fairly normal unless it is excessive.
5. Click on Done. A pop-up window with six options will appear, select "Analyze Data From Current Subject."
6. Remove the electrode cable pinch connectors and peel off the electrodes. Throw out the electrodes. The electrodes may leave a slight ring on the skin for a few hours, which is quite normal.

## **Data Analysis**

### **Segment 1**

1. Determine the time and beats per minute of three cardiac cycles and record in Table 1 of the handout. Calculate the means.
2. Complete Table 2 for the different components of the ECG for Cardiac Cycle 1.
3. Is there always one P wave for every QRS complex? If not, what would this signify?
4. Compare and contrast the shape (duration and amplitude) of the P and T waves. Give the mechanical and electrical reasons for the differences.

### **Segment 2**

1. Complete Table 3.
2. Explain the observed heart rate variations in sitting up vs. supine positioning. Describe the physiological mechanisms causing these differences.

### **Segment 3**

1. Complete Table 4.
2. Are there differences in the cardiac cycle with the respiratory cycle (inspiration vs. expiration)? If so, what is the physiological basis for these differences?

#### Segment 4

1. Complete Tables 5 and 6.
2. What changes occurred in the duration of systole and diastole between resting and immediately after exercise? What could account for these changes?



**Warning:** The data that you will need for your post-lab is located on (find a good location).