Heart’s Conduction System and the ECG

The heart is an organ that is autorhythmic, meaning it generates its own rhythmic action potentials for contraction of myocardial cells (cardiac muscle cells). The rhythmic beating of the heart is controlled by a small group of cells in the wall of the right atrium, collectively called the sinoatrial node (SA node). Because the SA node controls heart rate, it is called the heart’s pacemaker. Action potentials generated in the SA node of the right atrium spread to the myocardial cells of the left atrium, resulting in the simultaneous contraction of both the left and right atria. Action potentials then travel to the base of the right atrium to specialized cells of the atrioventricular node (AV node) where transmission of the action potentials is delayed briefly to allow ventricular filling (of ventricular diastole). From the AV node the action potentials spread down the interventricular septum through the Bundle of His, before finally radiating through left and right ventricle walls via the Purkinje fibers, whereupon both left and right ventricles contract simultaneously. The electrocardiogram (ECG or EKG) is a device that can measure the transmission of the electrical impulse (action potentials) of the heart throughout its conduction cycle. The ECG can help detect any arrhythmia (abnormal heart rate) within the heart. In this lab you will use an ECG to examine the cardiac conduction system.

The Cardiac Cycle and Heart Sounds

A single cardiac cycle is the sequence of events that occurs when the heart “beats”. The cardiac cycle is composed of two separate phases. In Phase 1, the diastole phase, both the left and right heart ventricles are relaxed and the heart fills with blood. In Phase 2, the systole phase, both the left and right ventricles contract (simultaneously) and pump blood to the arteries (either the pulmonary arteries or the aorta). One cardiac cycle is completed when the heart fills with blood and the blood is pumped out of the heart.

The cycle of contraction and relaxation of the heart can be determined by auscultation or the use of a stethoscope to listen for sounds within the chest above the heart. While the muscle contraction itself cannot be heard certain other events that occur, such as the closing of heart valves, do produce sounds. As the ventricles contract simultaneously, the pressure of the blood in the chambers increases until it pushes the atrioventricular valve shut. This happens rather suddenly and produces the first heart sound “lub” or S1. As the intraventricular pressure continues to increase it opens the semilunar valves and pushes blood into the aorta and pulmonary artery. At the end of ventricular contraction, the increased pressure within the arteries close the semilunar valves producing the second heart sound “dub” or S2. In this lab you will use a stethoscope to listen to the lub-dub sounds of your heart and/or your partner’s heart.

Blood Pressure

A sphygmomanometer or a blood pressure cuff is a device used to measure blood pressure. Blood pressure (BP) is the force of blood pumped by the heart against the arterial walls. In humans the blood is pumped through two separate circuits in the heart: the pulmonary circuit and the systemic circuit. The right ventricle of the heart pumps deoxygenated blood through the pulmonary circuit to the lungs where CO2 waste is released and O2 is taken up by the blood. Oxygenated blood returns to the heart on the left side and is pumped out from the left ventricle into the aorta and to the systemic circuit where O2 is supplied to the rest of the body. Oxygenated blood travels through the arteries away from the heart towards body tissues while deoxygenated blood travels through veins towards the heart away from body tissues.

Blood pressure is measured in millimeters of mercury (mmHg), and is recorded as two separate values: systolic blood pressure and diastolic blood pressure. The systolic BP occurs when the ventricles contract and eject blood into arteries; and the diastolic BP occurs when the ventricles relax and fill with blood from the atria. The average blood pressure of healthy young adults (about 20 yrs old) is 120 / 80 mmHg. The first value (120) represents systolic and the second value (80) represents the diastolic BP. In this lab you will use a sphygmomanometer placed over the brachial artery of the arm to measure blood pressure.
Part 1: The Electrocardiogram
Today in Lab we will monitor the electrical activity of the heart with electrodes and Vernier equipment to produce a graphical representation of the events i.e. an electrocardiogram (ECG or EKG).

Electrocardiogram Procedure:

1. Prepare the computer for data collection by opening the file in the Experiment 28 folder of *Biology with Computers*. The vertical axis has voltage scaled from 0 – 3 volts. The horizontal axis has time scaled from 0 – 5 seconds. The data rate is set to 50 samples/second.

2. Attach three electrode tabs to your arms, as shown in Figure 1. A single patch should be placed on the inside of the right wrist, on the inside of the right upper forearm (below elbow), and on the inside of the left upper forearm (below elbow).

3. Connect the EKG clips to the electrode tabs as shown in Figure 1. Sit in a reclined position in a chair or lay flat on top of a lab table. The arms should be hanging at the side unsupported. When everything is positioned properly, click to begin data collection.

4. When data has been collected, click the examine button, to analyze the data. As you move the mouse pointer across the screen, the x and y values are displayed in the Examine window that appears. Identify the various EKG waveforms using the figure below and determine the time intervals listed below. Record the time intervals in Table 1.

   - P-R interval: time from the beginning of P wave to the start of the QRS complex.
   - QRS interval: time from Q deflection to S deflection.
   - Q-T interval: time from Q deflection to the end of the T wave.
   - Heart Cycle: time from beginning of the P wave to the end of the T wave.

5. Determine a method for calculating heart rate in beats/min using the EKG data. Using this method, calculate the heart rate and record the heart rate value in Table 1.

6. Do some mild exercise for 5 minutes. After the exercise lie down for 2 minutes and record the EKG. Examine the EKG and record the calculated values in Table 1.
**Table 1**

<table>
<thead>
<tr>
<th>Interval</th>
<th>At rest</th>
<th>After exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>P – R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>QRS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q – T</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Heart Cycle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Heart Rate beats/min**

**Table 2**

<table>
<thead>
<tr>
<th>Standard Resting Electrocardiogram Interval Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>P - R interval</td>
</tr>
<tr>
<td>QRS interval</td>
</tr>
<tr>
<td>Q - T interval</td>
</tr>
</tbody>
</table>

**Part 2: Auscultation of Heart Sounds**

Go to [http://people.fmarion.edu/tbarbeau/physio_cardio_supplements.htm](http://people.fmarion.edu/tbarbeau/physio_cardio_supplements.htm)

**Normal Heart Sounds**

- **Use a stethoscope to listen to the lub-dub sound of your or your partner’s heart.** The first sound (the “lub”) is referred to as the $S_1$, and is the sound of the tricuspid and bicuspid (mitral) valves closing simultaneously. The atrioventricular valves should close firmly to prevent backward (regurgitant) flow of blood from the ventricles back to the atria. The second sound (the “dub”) is referred to as the $S_2$, and is the sound of the pulmonary and aortic semilunar valves closing simultaneously. The semilunar valves shut firmly to prevent regurgitant flow of blood from either the pulmonary trunk or the aorta back into their respective ventricles. Both the “lub” and the “dub” sounds should be crisp, sounding like distinct separate sounds.

**Extra Heart Sounds**

**Heart Murmur**

- **A heart murmur** is an extra or unusual sound associated with the lub-dub. It might include a “whoosh” sound like “lub-whoosh-dub”. Most heart murmurs are harmless and are called **innocent murmurs**, and innocent murmurs are often detected in children who usually outgrow them or experience no problems with them throughout their life.

- **Pathologic murmurs** usually indicate a problem with the heart valves that might cause “regurgitant flow” or backward flow of blood between chambers. One common pathologic murmur is **aortic stenosis**, when the aortic semilunar valve is narrowed and stiffened with age. The aortic valve does not receive blood easily from the left ventricle, thus a loud ejection sound (a click, whoosh, or shudder) is heard in between the $S_1$ and $S_2$. Aortic stenosis can range in severity from mild, moderate, to severe cases.

**Physiological $S_2$ Split**

- **This sound results from a splitting of the $S_2$ (dub) sound during inspiration (breathing in).** It is caused when the closure of the aortic semilunar valve and the closure of the pulmonary semilunar valve are not synchronized. It is physiologically normal to hear a ”splitting” of the $S_2$ tone during inhalation in younger people. Expansion of the thoracic cage when inhaling drops lung pressure and increases return of venous blood to the right atrium of the heart while
simultaneously decreasing pulmonary blood return from the lungs to the left atrium. With the increased blood pressure within the right atrium and ventricle causes the pulmonary semilunar valve to close a fraction of a second later than the aortic semilunar valve, resulting in an audible split of the S₂ sound, with the first part of the split showing aortic valve closure and the second part of the split showing pulmonary valve closure.

If an S₂ split occurs during exhalation (breathing out) rather than on inhalation is called a **Pathological S₂ Split** and could indicate several possible heart problems including cardiomyopathy (enlargement of the ventricles or septum) or aortic stenosis (stiffening of the aorta).

**S₃ Sound**

In rare cases there may be a third heart sound (S₃) also called a ventricular gallop, or informally the "Kentucky gallop" in reference to its rhythm. The S₃ sound that occurs soon after the normal two "lub-dub" heart sounds (S₁ and S₂) and sounds somewhat like "lub-dub-ta" or "lub-dub-dub". S₃ may be normal in people under 40 years of age, some trained athletes, and sometimes in pregnancy but if it re-emerges later in life it may signal cardiac problems like a failing left ventricle as in dilated congestive heart failure (CHF). The sound of S₃ is lower in pitch than the normal S₁ and S₂ sounds, usually faint, and best heard with the bell of the stethoscope.

**S₄ Sound**

The S₄ sound is an extra sound heart immediately before the normal two "lub-dub" heart sounds (S₁ and S₂) and it indicates stenosis or stiffening of the ventricles or the septum. It is also called an atrial gallop or presystolic gallop because it is a sound heard before the S₁. It is best conceptualized as hearing a "split S₁." This produces a rhythm classically compared to the cadence of the word "Tennessee" with the first syllable ("TEN") representing S₄. One can also use the phrase "a-STIFF-wall" to help with the rhythm. An S₄ sound is caused by the atria contracting forcefully in an effort to overcome an abnormally stiff or hypertrophic ventricle. This causes abnormal turbulence in the flow of blood.

**Part 3: Blood Pressure**

The sphygmomanometer is a tool to measure systemic blood pressure in the brachial artery. It attaches around the upper arm and has a pump with a valve, and a pressure gauge. Blood pressure is expressed as 2 numbers: the upper number or systolic blood pressure is the highest blood pressure resulting from contraction of the left ventricle. The lower number or diastolic blood pressure results from relaxation of the left ventricle. Note that while the pressure in the left ventricle may drop to zero, the pressure in systemic arteries is maintained by the elastic recoil of the artery walls.

When the pressure in the blood pressure cuff is increased to greater than the systolic pressure, the brachial artery will be temporarily occluded. As the pressure in the cuff is gradually decreased it will reach a stage where it is just below the systolic pressure. At this time blood will push through the artery in spurts at the end of ventricular contraction. At this time the blood can be heard rushing through the artery by auscultation distal to the blood pressure cuff. Sounds are detected first when pressure in the cuff approximates the systolic blood pressure. As the cuff pressure is reduced sounds of blood being pushed through the constricted artery will be heard until its pressure falls below the diastolic blood pressure. When sounds of blood moving in the artery can no longer be heard, the pressure in the cuff approximates the diastolic blood pressure.

Generally pump the cuff up to about 160 - 200 mm Hg before SLOWLY releasing the pressure. Normal blood pressure is around 120/80 but can vary considerably with individuals. Systolic pressures above 130 and diastolic pressures above 90 are considered signs of hypertension and may indicate need for some intervention to reduce them.
Part 1: ECG

1. The electrocardiogram is a powerful tool used to diagnose certain types of heart disease. Why is it important to look at time intervals of the different waveforms?

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2. What property of heart muscle must be altered in order for an EKG to detect a problem? Explain.

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3. Why can’t an EKG be used to diagnose all diseases or defects of the heart?

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4. Name and describe a cardiovascular problem that could be diagnosed by a cardiologist using an electrocardiogram recording.

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5. Explain the transmission of the electrical impulse within the heart from where it begins in the right atrium to where it ends within the ventricles. In your explanation please explain the terms SA-node, AV-node, Bundle of HIS, and Purkinje fibers.

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Part 2: Heart Sounds (Auscultation)

6. During a normal cardiac cycle what do the following sounds indicate is happening within the heart?
   A) Lub sound (S\(_1\))  
   B) Dub sound (S\(_2\))

7. Which “extra heart sounds” could be considered normal (not harmful) if they occur when inhaling?

8. Describe what is happening within the heart (and its valves) when the lub (S\(_1\)) is split into two distinct sounds?

9. Which extra heart sound is associated with stiffening of the ventricles?

10. Which extra heart sound occurs after the S\(_1\) and S\(_2\) and is considered abnormal if it develops later in life?

Part 3: Blood Pressure

11. What are some reasons for hypertension?

12. What are some dangers associated with chronic hypertension?

13. What can an individual do to reduce their blood pressure?